UNIVERSITY OF ALBERTA

# FERTILIZER DEMAND BY SMALLHOLDER FARMERS IN KENYA.

BY

**ADDA ZERUYA OWINO** ©

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The undersigned certify that they have read, and recommend to the faculty of Graduate Studies and Research for acceptance, a thesis entitled **Fertilizer Demand by Smallholder Farmers in Kenya** submitted by **Adda Zeruya Owino** in partial fulfilment of the requirements for the degree of **Master of Science** in **Agricultural Economics.**

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## ABSTRACT

A better understanding of the factors affecting fertilizer demand helps to formulate relevant policies for increased fertilizer use. Kenya's rising population and demand for food have made the government focus on increased agricultural production through increased fertilizer use in the smallholder sector. This study develops a model for the Kenyan smallholder fertilizer demand derived from maximization of the certainty equivalent of profits. The analysis is based on the data collected from 150 farm holdings. The Tobit estimation technique is used to determine factors that affect both the probability of using fertilizer and the intensity of fertilizer use. Key factors influencing fertilizer demand include education levels, working capital availability, frequency of contact with extension personal, other sources of information, and the price of fertilizer. A fertilizer price subsidy and an attractive credit programme are recommended for increased fertilizer use.

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# CHAPTER 1

# INTRODUCTION

## 1.1 INTRODUCTION

The government of Kenya has identified self-sufficiency in food production as one of the most important goals in its development plans. Kenya has maintained this policy of food self-sufficiency since 1981 (Republic of Kenya, ROK, 1981). This policy not only ensures that the citizens have enough food, but also removes the dependence on imported food.

Kenya's population was 21.4 million according to the 1990 census. The Central Bureau of Statistics projected this population to grow at a rate of 3.3% per annum, rising to 35 million by the year 2000 (National Development Plan (NDP), 1983). These population estimates are suggestive of the present demand for food. In addition, the population growth rate imposes a further strain on the goal of food self-sufficiency. The rising population and the subsequent increased demand for food have been a concern of the Government of Kenya since 1981. Kenya's Sessional Paper Number 4 of 1981 on the National Food Policy clearly stated that Kenya's agricultural development strategy had the main objective of providing basic needs, and reducing poverty through growth in agricultural output. The discussion below stresses the important role that the agricultural sector plays in Kenya.

The agricultural sector accounts for 75% of the labour force, contributes over 30% of the GDP and provides the base for approximately 65% of Kenya's exports in value terms. Agriculture also provides a means of livelihood for 85% of Kenya's population (Ngigi, 1991). The above statistics show that the maintenance of a dynamic agricultural production system is a key to sustaining other sectors of the economy (NDP, 1988). The role of the agricultural sector in achieving the country's goal of food self-sufficiency places further importance on this sector.

Kenya's Sessional Paper Number 4 on National Food Policy identified increased agricultural output as one way of contributing towards fulfilling the goal of food self-sufficiency. Growth in agricultural output can be achieved via increased acreage under crop (horizontal expansion), or the intensification of the land already cultivated. Of the 58 million hectares (143.3 million acres) that make up Kenya's land area, only 20% is of medium to high agricultural potential (Jaetzold and Schmidt, 1982). However, a large portion of the arable land in Kenya has already been put into agricultural production. Hence the opportunities for increasing agricultural production through horizontal expansion are limited. These facts, coupled with the rapid expansion of the population, present a potentially dangerous imbalance between the supply of food and the demand for food. In addition, the lack of possibilities for horizontal expansion implies that increases in total agricultural and food production will have to rely on increasing yields per hectare or acre of land already under cultivation.

In pursuit of national food self-sufficiency through increased yields per hectare/acre, the Ministry of Agriculture and the Kenya Agricultural Research Institute (KARI) have concentrated on the promotion of intensive farming methods. Such methods generally include irrigation, increased fertilizer use, and high yielding crop varieties. Irrigation potential in Kenya is limited and irrigation is extremely expensive (Gerhart, 1974). Hence, two of the methods which are being promoted are the increased use of fertilizers to enhance soil productivity, and the introduction of high yielding crop varieties for improved crop productivity.

Kenya's National Development Plan, for the period 1978 to 1983, recognized the need to increase food production through intensification of land use, and the importance of fertilizer in this process. In this plan the government stated that, to meet the objective of food self-sufficiency, fertilizer use on food crops would have to increase by 20% between 1978 and 1983. Food self-sufficiency has not been achieved to date, and is still one of the major objectives of the most recent National Development Plan for the period 1989-1993. The rest of this study focuses on increased fertilizer use as one way of contributing towards achieving food self-sufficiency. Increased fertilizer use, refers to increased quantities (mass basis) of fertilizer applied, irrespective of the fertilizer types.

## 1.2 FERTILIZER CONSUMPTION IN KENYA

Kenya does not manufacture any fertilizer, hence, all of the fertilizer consumed in Kenya is imported from manufacturing countries. Estimates show that in the 1982/83 cropping season, the national fertilizer consumption was 250,000 metric tonnes, mass basis, (Ruigu and Schluter, 1985). These estimates have not changed much as is illustrated by Figure 1. In fact, the national fertilizer

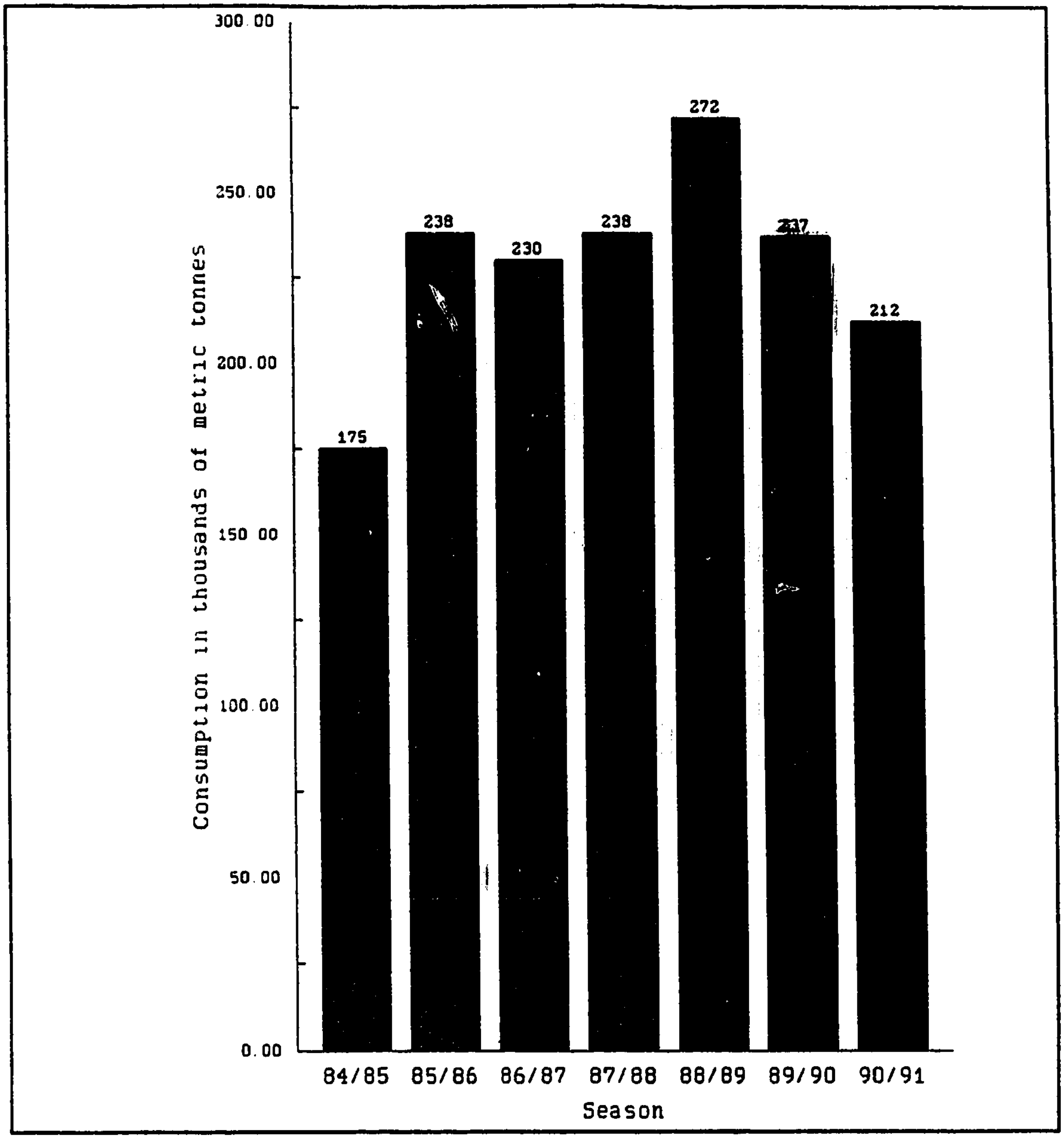


**Figure 1: ESTIMATES OF FERTILIZER CONSUMPTION IN KENYA, 1984/85 TO 1990/91.**

Source: Ministry of Agriculture, Farm Management Division, Annual Report, 1991.

consumption estimates illustrated by Figure 1 compare poorly with the national estimates of recommended levels of fertilizer use. Optimal national levels of fertilizer use, recommended by agricultural research stations, have been estimated to be 650,000 metric tonnes, mass basis. The large gap between the national consumption estimates and the national recommended levels of fertilizer use, suggests that there is room for increased fertilizer use in Kenya. Using 250,000 metric tonnes as the current national fertilizer consumption estimate, increased use of fertilizer to the recommended levels of 650,000 metric tonnes, would mean a 160% increase in fertilizer use. Kenya's National Development Plan for the period 1978 to 1983 showed that fertilizer use needed to increase by 20% to meet the objective of food self sufficiency. The required increase in fertilizer use currently needed to meet the objective of food self sufficiency is expected to be higher than 20%. This is because the population is relatively higher than in 1983. In addition, Figure 1 indicates that fertilizer use has not changed significantly over the last few years. An increase in fertilizer use to the recommended levels continues to be one of the policy goals to achieve food self-sufficiency.

In order to meet the country's objective of food self-sufficiency, projections show that the national fertilizer consumption will have to grow at a rate of 12.2% per annum between 1988 and the year 2000. This projected growth rate in national fertilizer consumption would cause agricultural output to grow at the required rate of 5.3% per annum from 1988 to the year 2000 (ROK, 1986). A world bank study reported that during the period 1974 to 1987, the national fertilizer consumption growth averaged 6.7%, which is only half of the required growth rate to meet the objective of food self-sufficiency (Karuri, 1991). It is evident that there is need to identify feasible ways of increasing national fertilizer use. The smallholder sector in Kenya has been identified as a possible area for promoting the growth of fertilizer consumption. The rest of this sub-section discusses the properties of the smallholder sector and why the smallholder sector is a possible avenue for increased growth in fertilizer consumption.

Several farmer classification schemes exist. The choice of a specific classification scheme is governed by individual study objectives. Kenya's Fourth National Development Plan of 1978/83, uses one such scheme whereby farmers are classified as:

(i) small scale farmers, owning up to 5 acres (1.95 hectares) of land,

(ii) medium scale farmers, owning between 5 and 20 acres (1.95 and 7.83 hectares) of land, and

(iii) large scale farmers, owning 20 acres (7.83 hectares) of land or more.

Other schemes have classified the farmers into two categories: small scale, owning up to 12.5 hectares (31.9 acres) of land, and large scale (estates) owning more than 12.5 hectares of land (World Bank, 1990). Lately, the term "smallholder" is considered more appropriate than "small scale" when dealing with farmer classification according to size. This is so because it is possible to have a small sized farm whose scale of operation is large, making the definition small scale inappropriate. In this study, the term smallholder is used to denote a holding of less than 12.5 hectares (31.9 acres).

The smallholder sector is an important component of agricultural production in Kenya as it consists of 2.7 million farms that accommodate a total of 16 million people. The sector accounts for 66% of the total area under crops and contributes 75% of Kenya's total agricultural output. Further, the sector contributes 55% of the marketed agricultural output, and provides 75% of farm employment. In addition, the sector provides a means of livelihood for the 16 million members of the rural community that comprise 85% of the country's population (Karuri, 1991). However, the per hectare or per acre use of fertilizer in the smallholder sector is very low. Karuri reports World Bank estimates of the fertilizer consumed by the smallholder sector as being only 43% of the total fertilizer consumed in Kenya in 1986.

The low fertilizer consumption by the smallholder sector has been a concern of the government dating as far back as 1963. Ngigi (1991) narrates how the government set up a committee to look into the impeding factors to fertilizer use by smallholder farmers. Ngigi (1991) cites how the committee (Mackenzie et al.) reported that existing distribution channels adequately served the large scale farmers. Ngigi further cites the committee as reporting that fertilizer supply to the smallholder farmers was restricted by poor market penetration and high prices. Ngigi notes that Mackenzie et al. found that farmers had to travel long distances to purchase fertilizer. Mackenzie et al. recommended that farmer cooperatives take up the distribution of fertilizers and the dissemination of information about the benefits of fertilizer use to smallholder farmers. A price subsidy was also recommended.

As a result of the implementation of the recommendations of the Mackenzie report, an increase was realized in the percentage of smallholder farmers using fertilizer. This increase was from 4.25% in 1963 to 15% by 1972. Since the majority of the smallholder farmers (85%) were still not applying fertilizer, another committee, Havelock et al., was set up in 1972 with similar objectives. Lack of competition in the fertilizer market was reported by Havelock et al. to be the main cause of high prices. Following this report, the government took control over fertilizer pricing and import decisions. Subsequently, over time, the share of consumption by the smallholder sector went up from 15% in 1972 to the World Bank estimate of 43% in the year 1986 (Ngigi,1991).

The smallholder farming sector, which is mainly dominated by food crops, accounts for two-thirds of the land under crop. However, this sector only absorbed 43% of the total fertilizer consumed in Kenya in 1986. Hence, there is a potential for increasing the country's food production by increasing the share of fertilizer consumption in this sector. Moreover, the law of diminishing returns implies that increased fertilizer use is expected to have higher marginal returns in the smallholder sector than in the large scale sector. This is because the large scale farming sector has a higher per hectare use of fertilizer. Consequently, the large scale sector has crop yields that are twice as high as those realised in the smallholder sector (Ngigi, 1991).

The smallholder sector accounts for 66% of the land under crop, 75% of total agricultural output, 75% of farm employment and 85% of the country's population. An improvement in this sector's agricultural output through increased fertilizer use is expected to help accomplish the goal of food self-sufficiency. In addition, increased agricultural output from the smallholder sector is expected to increase the sector's contribution to the economy and the living standards of the bulk of the low income population living in the rural areas.

## 1.3 OBJECTIVES AND THESIS ORGANIZATION

The important roles of fertilizer in Kenya's agricultural development and in Kenya's goal of food self-sufficiency have been outlined above. Despite the efforts by the government to increase the level of fertilizer use by the smallholder sector, fertilizer use has not yet reached a level that would enable Kenya to be self-sufficient in food production. Various studies related to fertilizer use in Kenya (e.g Olang, 1980; Chege, 1992; FURP, (ongoing); Mwangi, 1978) have determined optimal levels of fertilizer use according to both the technical and economic criteria. In contrast, few studies have attempted to identify the factors that influence fertilizer use. There is need for research to identify the factors which influence why farmers use or do not use fertilizer, and also the factors which influence the level of fertilizer use. It is the contention of this study that a better understanding of these factors will help explain the current low levels of fertilizer use by smallholder farmers. Such an improved understanding may be useful for policy makers as they formulate strategies to increase food production through more intensive agriculture.

The current study attempts to estimate the factors that affect fertilizer demand by smallholder farmers. The main objectives of this study are:

(i) To develop a model that incorporates all the factors that affect fertilizer demand by smallholder farmers in Kenya.

(ii) To use this model in investigating the factors that affect both the decision to apply fertilizer, and the intensity of fertilizer application.

(iii) To suggest ways, if any, of increasing the current low levels of fertilizer use in the smallholder sector.

This thesis consists of six chapters. The following chapter is a literature review of the studies that have been carried out in relation to the factors that affect the demand for fertilizer. Studies are reviewed both from the developed and the less developed countries. A model for smallholder fertilizer demand is developed in Chapter Three. Chapter Four describes the data collection process and the variables used in this analysis. The estimation procedure and the results obtained are reported in Chapter Five. Finally, the conclusions from the study and suggestions for further study are contained in Chapter Six.

## CHAPTER 2

## LITERATURE REVIEW

### 2.1 INTRODUCTION

The first section of this chapter presents a discussion of the approaches used in the different studies that have been carried out on fertilizer use in Kenya. In addition, the implications of these approaches to the efforts by the Government of Kenya to increase fertilizer use are analyzed. As a result, the need to estimate a demand function in this study is identified. A review of a comparative study of the fertilizer distribution systems in five developing countries also suggests the need for identifying factors that affect fertilizer use. Subsequent sections review literature that contain ideas on base models for input demand estimation. These studies display the existing methods of deriving input demand. From these studies, it is anticipated that ideas on the variables that should be included in fertilizer demand estimations will be identified. Studies reviewed are from both developing and developed countries. It is hypothesized that the effect of factors that affect fertilizer demand will be different for developing and developed countries.

### 2.2 STUDIES IN KENYA AND OTHER DEVELOPING COUNTRIES

Most of the studies in Kenya have focused on investigating the physical relationships between the input of fertilizer and crop yields. From these studies on physical relationships, levels of fertilizer that farmers ought to be using have been derived from the production function. Kenya Agricultural Research Institute

(KARI) has, since its inception, concentrated on agronomic research related to fertilizer use. The purpose of agronomic research by KARI has been mainly to determine the appropriate fertilizer types and application rates, crop spacing, time of planting and recommendations on disease and pest control. In fact, these agronomic experiments date as far back as 1910.

Ngigi (1991) narrated how a working party was set up by the Government of Kenya in 1963 to identify the factors impeding fertilizer use. The working party found that the existing distribution channels only adequately served the large scale farmers. Poor market penetration and high prices restricted fertilizer supply to smallholder farmers. The working party's report, known as the Mackenzie report, recommended that the distribution of fertilizers be taken up by farmers' co-operatives. In addition, the farmers' co-operatives were to disseminate information on fertilizer use to smallholder farmers. The report also recommended a price subsidy which was introduced by the Government of Kenya in 1963. However, by 1972, the increase in fertilizer consumption among the smallholder sector was still not up to the Government's expectations. As a result, another working party (Havelock, et al.) was established in 1972 to look further into factors hindering fertilizer use. Havelock, et al. concluded that one of the factors impeding fertilizer use was lack of competition in the fertilizer market leading to high prices.

Zschernitz (1973) carried out a study to identify the different channels of fertilizer distribution. He reported that the most efficient channel of fertilizer sales was through local fertilizer distributors. He recommended that the profit margin for the wholesalers be increased from 8% to 10%. In addition, he suggested that fertilizer traders be given credit to build fertilizer stores, as storage of fertilizer was a major problem.

During the late 1960's and early 1970's, the Food and Agricultural Organization of the United Nations (FAO) sponsored fertilizer trials in Kenya. These trials concentrated on the use of fertilizer on food crops. In particular, the studies focused on demonstrating to farmers, fertilizer's ability to enhance crop yields. Mwangi (1978) criticized the FAO trials because the studies had ignored the important aspect of risk. He indicated that the studies should have included the costs of fertilizer application, capital, and fertilizer transportation in the analysis from which the recommendations were made (the recommendations had considered only the fertilizer purchase price and crop prices).

Mwangi (1978) illustrated how one could derive demand functions from a crop response function if one assumed the behaviour of the farmers to be profit maximization, perfect knowledge of the production function and factor prices. However, he argued that it was unrealistic to assume that farmers maximized profit without any regard to risk. Mwangi suggested that, by considering all the costs involved in fertilizer use (e.g. application, capital, and transportation costs), one could partly compensate for not accounting for risk in the analysis. Including all costs, however, does not capture the stochastic nature of production and prices. An appropriate production function must be specified when addressing risks in production. The current study specifies such a production function in developing the model for smallholder fertilizer demand. Mwangi further noted that the choice of a relevant fertilizer response function was arbitrary and not based on a theoretical model. Mwangi criticized the recommendations from studies by the agricultural research centres that were solely based on technical optima. He argued that such studies implied fertilizer use was not responsive to economic conditions (e.g. price changes).

In 1990, the Kenya Agricultural Growth Prospects (KAGP) study was conducted, using experimental data to determine the optimal recommendation of fertilizer level at specific locations. The problems of fertilizer use in this study were identified and divided into supply and demand side problems. The supply side problems were identified as lack of foreign exchange coupled with a poor system of allocation of importation quotas to the importers. Lack of fertilizer recommendations that took into account the smallholder farmers' attitude to risk were suggested as the demand side problem. The study addressed the demand side problem by determining the economic criteria of optimal fertilizer use, based on experimental data from specific locations. It is noted that typically-applied economic criteria for optimal fertilizer use do not incorporate risk in production nor the risk associated with prices. The KAGP study identified non-incentive prices and an inefficient fertilizer market structure as the other constraints on fertilizer use.

The most recent research in relation to fertilizer started in 1985, and is still being conducted by the Ministry of Agriculture and KARI. This study aims at recommending the correct levels of fertilizer use for each region based on each region's soil analyses. This project, Fertilizer Use Recommendations Project (FURP), attempts to make research findings more representative of the farmers' conditions by carrying out experiments in the farmers' own production environment. FURP's approach is superior to the approach of agricultural research stations. This is because FURP's recommendations are based on region-specific production functions, while recommendations from the agricultural research stations are based on production functions from each station's experimental data. The response from agricultural stations is hypothesized to be different from the response from the farmer's conditions.

The FURP project was set up all over the country with the following objectives:

(i) To develop better fertilizer recommendations by regularly updating previous recommendations, to cater for changes in farming and economic conditions.

(ii) To obtain reliable and up-to-date data on fertilizer responses for the main food crops in all the major Agro-Ecological Zones in the country.

(iii) To correlate the fertilizer responses to the different soil types and climatic conditions in the country.

Fertilizer recommendations in the project are based on criteria like Maximum Marginal Profits, Fertilizer Use Efficiency, and Value Cost Ratios (FURP, 1982). It has been noted that the inclusion of other costs incurred in fertilizer use, such as transport costs and labour in handling and harvesting, would be a further refinement of FURP's recommendations (Chege, 1992). Chege adds that the choice of an appropriate production function which takes into account the random nature of crop yields would be an improvement.

Many of the studies reviewed above (e.g., Mwangi, 1978; KAGP 1990, FURP, ongoing) have aimed at determining the economic and/or the agronomic optimal levels of fertilizer use. The Government of Kenya has been concerned, since 1963, about the low levels of fertilizer consumption, especially by smallholder farmers. Despite various efforts by the Government of Kenya to enhance the level of fertilizer use, that level is still much below the potential 650,000 metric tonnes if recommended levels of fertilizer were used.

Earlier studies in Kenya (Havelock, et al. 1963 and Mackenzie, et al. 1972) which were cited by Ngigi (1991), looked at the factors hindering fertilizer use. More recent studies have concentrated on deriving the optimal levels of fertilizer use. No known studies in Kenya have made an attempt to explain the nature of farm level fertilizer demand and/or the factors that influence whether the farmers use or do not use fertilizer.

A gap exists in the complete effort to enhance the level of fertilizer use by farmers in Kenya. It is important to understand the nature of farm-level fertilizer demand because a better understanding is expected to lead to a better application of the policy options available for increasing the level of fertilizer use. In other words, a better understanding of what farmers **are** doing, not what they **ought to** be doing, is anticipated to yield more specific and relevant information from which policies may be formulated to increase the level of fertilizer use. It is therefore crucial to determine the factors that influence the farmers' decision to use or not use fertilizer. In addition, it is necessary to determine the factors that make the farmers apply fertilizer at the levels which they do. Effective region-specific policies can be formulated once these factors are determined. The views expressed above agree with the views contained in a comparative study by de Guia in 1972 on the nature of fertilizer distribution systems in five developing countries.

The study by de Guia (1972) aimed at identifying institutional issues that affect the efficiency and the pattern of fertilizer distribution in Chile, Ivory Coast, Mexico, Philippines and United Arab Republic. He aimed at showing how an efficient fertilizer distribution system together with appropriate institutional policies could deal with the major variables hindering the application of recommended levels of fertilizer. de Guia added that numerous variables were involved when trying to convince farmers to adopt fertilizer. In addition, he noted that once modern farming practices were accepted, additional factors had to be considered in sustaining the acceptance. He further noted that fertilizer policies, whether macro or micro oriented, had to take into consideration the many variables that affect fertilizer consumption by the new and old users of fertilizer. Hence the concept of an efficient fertilizer distribution system was not only restricted to the physical availability of fertilizer at the right time and place, but also to three other key variables. These variables were identified as the farmer's education and level of awareness on the benefits associated with fertilizer use, the farmers' access to credit and a favourable input/output price ratio. He noted that these factors were bound to relate to each other differently through the various stages of fertilizer use of any given community.

In identifying how these factors fitted together, de Guia hypothesized that three stages of fertilizer use existed:

**Stage I:** This was referred to as the "fertilizer introduction stage". In this stage, the farmer was expected to have used little or no fertilizer. Farmer awareness and education were the most important variables because the farmer had to be convinced of the potential benefits before considering fertilizer use. Other factors such as fertilizer prices and credit availability were of secondary importance.

**Stage II:** This stage is the stage that was hypothesized to follow the initial use of fertilizer. Stage II was referred to by de Guia as the "reinforcement stage." In this stage, de Guia argued that the farmer had to have easy access to fertilizer both physically and financially. He noted that farmers in this stage purchased fertilizer with little or no stimulus from the extension personnel. The financial ability to get access to fertilizer (either credit or available working capital) were of primary importance.

**Stage III:** This stage was referred to as the "maintenance of proper fertilizer usage". In this stage, farmers were hypothesized to be well informed, to have used fertilizer over long periods and to have understood how the use of fertilizer affected profitability. The farmer's operations and use of fertilizer were expected to be routine. In addition, the volume of fertilizer used was expected to be higher than in the other stages. Any changes on the fertilizer price were expected to be interpreted by the farmers as changes on the profit levels. Hence the price of fertilizer was hypothesized to be the most important variable in this stage.

de Guia studied the use of NPK fertilizer in the five developing countries. He collected data on the national fertilizer requirements, the procurement of these requirements, the fertilizer pricing system and the fertilizer supply movements. He carried out both quantitative and qualitative analyses on the data that he gathered. The findings of de Guia's comparative study did not contradict his hypothesis of three stages of fertilizer use. He noted that because the farming community went through three stages of fertilizer use, the development of the distribution and the marketing of fertilizer was also likely to undergo three stages.

It is apparent from the fertilizer studies in Kenya and the comparative study in the five developing countries that there is need to identify the factors that hinder farmers from using fertilizer. The factors affecting fertilizer use will not only suggest the stage of fertilizer use that the given community is in, but will also make it possible to formulate relevant policies for increasing the levels of fertilizer use. The aim of this study, therefore, is to determine factors that affect fertilizer use by smallholder farmers. This is done via the estimation of fertilizer demand functions for smallholder farmers in Kenya. From these demand functions, factors that influence whether farmers use or do not use fertilizer can be determined. The next sections in this chapter review studies that have used various approaches in estimating input demand functions.

## 2.3 INDIRECT ESTIMATION OF INPUT DEMAND

According to Timmer (1974), there are two ways of estimating fertilizer demand functions: indirectly from a production or a profit function, and, directly, from observed market data on fertilizer consumption, fertilizer prices and/or output prices. Indirect derivation of input demand from production functions yields optimal levels that are not responsive to economic conditions (e.g., prices). Timmer (1974) advocates the need to assume some behaviour pattern for the farmer (e.g., profit maximization or cost minimization), in order to yield optimal levels of fertilizer use that are responsive to economic conditions. Unfortunately, most studies in Kenya have recommended optimal levels of input demand using the production function approach without any assumptions on the behavioral patterns of the farmers. Section 2.3.1 discusses studies that have derived input demands by assuming profit maximization to be the farmer's goal. In particular, input demands functions are derived by maximizing indirect profit functions.

### 2.3.1 Maximization of the Indirect Profit Function.

Lau and Yotopoulos (1972), used data from Indian agriculture to show how the output supply function and factor demand functions for the variable inputs could be derived from an arbitrary profit function. They said that the profit function possessed many desirable properties. Among these is the existence of a one-to-one correspondence between the set of concave production functions and the set of convex profit functions. In other words, almost all concave continuous production functions in current use will produce a well-behaved profit function. Constant returns to scale in the variable factors was ruled out because the authors argued that it would lead to indeterminate output and input levels. In deriving the supply and input demand functions, Lau and Yotopoulos considered a firm with a production function,

$$(1) \quad V = F(X_1, \ldots, X_m; Z_1, \ldots, Z_n)$$

where V is output, $X_i$ represents variable inputs, and $Z_j$ represents fixed inputs of production. The profit function was defined as current revenue, less current total variable costs plus fixed costs, and was written as:

$$(2) \quad \pi = p.F(X_1,\ldots,X_m;Z_1,\ldots,Z_n) - \sum_{i=1}^{m} r_i X_i - b,$$

where p is output price and $r_i$ is the unit price of the *i*th variable, b is the fixed cost and $\pi$ is the profit.

By taking the first order necessary conditions, $\frac{\partial \pi}{\partial X_i} = 0$ and assuming the satisfaction of second order conditions, the marginal productivity conditions for profit maximization were arrived at. These conditions which require that the Value Marginal Product equals Marginal Factor Cost (VMP=MFC), were:

$$(3) \quad p\frac{\partial F(X;Z)}{\partial X_i} = r_i, \qquad i=1,\ldots,m.$$

By defining $c_i=r_i/p$ as the normalized price of the $i$th input, equation (3) was rewritten as:

$$(4) \quad \frac{\partial F}{\partial X_i} = c_i, \qquad i=1,\ldots,m.$$

Similarly, equation (2) was rewritten as equation (5) where $\pi'$ was defined as the normalized profit function given by:

$$(5) \quad \pi' = \frac{\pi}{p} = F(X_1,\ldots,X_m;Z_1,\ldots,Z_n) - \sum_{i=1}^{m} c_i X_i.$$

The set of equations in (4) were simultaneously solved to yield the optimal quantities of variable inputs, $X_i^*$. The resulting $X_i^*$ are functions of the normalized prices of the variable inputs and of the quantities of the fixed inputs:

$$(6) \quad X_i^* = X_i^*(c,Z), \qquad i = 1,\ldots m.$$

The vector of normalized input prices was represented by c, and the vector of fixed factors of production by Z.

By substituting the optimal quantities of variable inputs $X_i^*$ as represented in equation (6), into the profit function (2), the indirect profit function was obtained:

$$(7)\quad \pi^* = p\,[F(X_1^*,\ldots,X_m^*;Z_1,\ldots,Z_n) - \sum_{i=1}^{m} c_i X_i^*].$$

The indirect profit function represents the maximum value of profit given the price of output, p, vectors of input prices, c and the level of fixed factors, Z. Since the set of $X_i$* were a function of normalized prices and fixed inputs, the term within the large parentheses on the right-hand side of equation (7) was a function of normalized prices and fixed inputs as well. The indirect profit function was then rewritten as:

$$(8)\quad \pi^* = p.G(c_1,\ldots,c_m;Z_1,\ldots,Z_n).$$

The normalized indirect profit function, was then given by

$$(9)\quad \pi^{**} = \frac{\pi^*}{p} = G(c_1,\ldots,c_m;\ Z_1,\ldots,Z_n).$$

Using Hotelling's Lemma, the optimal quantities of variable inputs were obtained:

$$(10)\quad X_i^* = \frac{-\partial\pi^{**}(c,Z)}{\partial c_i}.$$

A substitution of $-\frac{\partial\Pi^*(c,Z)}{\partial c_i}$, for $X_i^*$ in the indirect profit function given by equation (7) and rearranging, gave the optimal supply function, $V^*$:

$$(11)\quad V^* = \pi^{**}(c,Z) - \sum_{i=1}^{m} \frac{\partial\pi^{**}(c,Z)}{\partial c_i} c_i,$$

Lau and Yotopoulos (1972) emphasized three advantages of working with the normalized indirect profit function as opposed to the direct production function.

(i) The use of Hotelling's Lemma makes it possible to derive the output supply function, given by equation (11), and the factor demand functions, given by equation (10), directly from an arbitrary normalized indirect profit function. The fact that this can be done without the explicit specification of the corresponding production function provides more flexibility in empirical analysis.

(ii) Assuming that the fixed inputs are traded in competitive markets, duality ensures that the resulting system of output supply and factor demand functions is obtainable from a production function concave in the variable inputs.

(iii) The profit function, the output supply function, and the derived demand functions obtained may be explicitly written as functions of variables that are normally considered independent of the firm's behaviour.

The third advantage implies that the econometric problem of simultaneous equation bias can be avoided by estimating these equations directly.

Lau and Yotopoulos (1972) used the logarithmic form of the normalized indirect profit function derived from a Cobb-Douglas production function. Using cross sectional data from the Indian Ministry of Food and Agriculture, they showed how one could derive output supply and input demand functions from the profit function. They jointly estimated the output supply function and the labour demand function for Indian agriculture.

In another study by Yotopoulos, Lau and Lin (1976), the methodology outlined above was used to analyze data from a cross section of farm households in the Province of Taiwan, Republic of China. Two features which distinguish this study from that of Lau and Yotopoulos are:

(i) The number of variable inputs increased from one (labour), to four (labour, animal labour, mechanical labour, and fertilizer).

(ii) They compared the means of the estimated parameters across different cross-sections. They noted that this test could be interpreted as a test of the stability of the estimated production function parameters.

They derived the demand for each variable factor by applying Hotellings Lemma to the normalized profit function. Yotopoulos, Lau and Lin concluded, among other things, that the hypothesis of profit maximization could not be rejected. In addition, they concluded that while direct production function estimation yielded unreasonable estimates, the normalized indirect profit function and factor demand functions approach gave reasonable estimates for the parameters of the production function. This conclusion agreed with the findings of the earlier study by Lau and Yotopoulos (1972). Yotopoulos, Lau and Lin (1976) added that the use of the normalized profit function should be given more weight in the empirical analysis of production, where data from non-experimental situations are used.

Sidhu and Baanante (1979), in their analysis of fertilizer demand for Mexican wheat varieties, estimated the farm-level demand for fertilizer, labour and irrigation water. Their aim was to come up with recommendations for promoting efficient and expanded use of fertilizer. They noted that only a limited amount of knowledge existed on the possibilities of fertilizer expansion at the farm-level. They felt that this was partly because of the difficulties associated with specifying farm-level input demand functions and partly because of the inadequacies of the "methodological procedures" used to analyze farm level demand. They felt these two facts led to inadequate knowledge of the policy options available and the use of the available policies to increase the levels of fertilizer use.

In their study, a normalized restricted indirect profit function in the logarithmic form, derived from a Cobb-Douglas production function, was used with cross sectional data. The profit function was referred to as a restricted profit function because it was normalized by the price of wheat. They noted that the application of the normalized restricted profit function was a more reasonable approach than the production function. They added that the normalized restricted profit function was a function of predetermined variables and was therefore more suitable for econometric analysis. In addition, they noted that the resulting system of factor demand and output supply functions made the analysis for deriving policy implications simple. They included the average number of years of schooling (for each family member above thirteen years of age) in their analysis of farm level fertilizer demand. Resulting estimates from treating education of the farm family members as a fixed input in production provided support for the hypothesis that education contributed to technical efficiency.

Their conclusion supplemented that of Lau and Yotopoulos (1972), and Yotopoulos, Lau and Lin (1976) in favour of the indirect profit function as a suitable tool for empirical analysis and interpretation of production using farm-level data. In addition they concluded that the education of family members should be treated as a fixed input of production. They also concluded that the impact of a one percent decrease in fertilizer price was not symmetric with a one percent increase in wheat price.

Stefanou and Saxena (1988) developed a methodology using a modified form of the indirect profit function to evaluate how education, representing the stock of human capital, influences short run variable input allocations. They debated whether education served as an endowment that the operator could not significantly change during the production period, or, whether it was like other variable factors of production (i.e., was it a flow or a stock?). They noted that if education was like another variable factor of production, then elasticities of substitution of education for another factor of production could be calculated. Their conclusion was that the level of education was not like other physical fixed factors of production and that the level of education affected the decision making process of production through the degree of inefficiency in input allocation. In addition, they found that education and experience were substitutes and played a significant role in the level of efficiency.

### 2.3.2 Maximization of the Direct Profit Function

Under maximization of the direct profit function, the traditional profit function was maximized instead of the indirect profit function. Abebe, Dahl, and Olson (1989), used the profit maximization model of the competitive firm as a base model in deriving input demand functions. They derived demand functions for the variable inputs from the short-run static profit maximization model of the competitive firm. The demand functions for fixed or durable inputs were derived from the long-run net worth maximization model.

Abebe, et al. considered a firm using several variable inputs and a level of fixed inputs to produce one output, Q, as having the production function:

$$(12)\quad Q = F(X; K).$$

where X is a vector of variable inputs, and K is a vector of fixed inputs. They assumed the production function was strictly concave (implying the law of diminishing returns), and that the marginal products of the variable and fixed inputs were greater than zero. Abebe, Dahl, and Olson also assumed that the output price, P, the vector of variable input prices, W, and the fixed input costs, B, were known with certainty. They expressed the profit function as:

$$(13)\quad \pi = P\ F(X,K) - WX - B, \qquad X > 0.$$

The first order necessary conditions for profit maximization were:

$$(14)\quad P\frac{\partial F(X,K)}{\partial X_i} = W_i \qquad i=1,\ldots,n.$$

These conditions require that the firm hires inputs up to the point where the value of the marginal product from employing one unit of factor equals the factor's own price. Assuming that the second-order conditions held, the first-order, necessary conditions were solved to give a set of short-run variable input demand functions:

$$(15) \quad X_i^* = X_i^* \, (W,P,K) \qquad i=1,\ldots,n.$$

The $X_i^*$ were assumed to be homogeneous of degree zero so that proportional changes in output and input prices did not change the input or demand levels.

In the above model, Abebe, Olson, and Dahl (1989) assumed that the level of fixed input stock could not be changed in the short run. To estimate the demand for fixed inputs, they modified the model to allow the decision-making process to extend beyond the short run. They argued that the stock of fixed inputs could be varied in the long run. Abebe, Olson and Dahl noted that the unconstrained profit maximization model implied that capital funds required for production purposes were unlimited. They noted that this assumption was unrealistic and some farmers had to borrow from commercial banks and credit institutions to finance the purchase of production inputs. Thus, they recommended that credit constraints be placed on the optimization model. In estimating the demand for durable inputs, their study included interest rates paid by farmers to represent the cost and ease with which credit could be obtained.

Abebe, Olson and Dahl suggested that derived input demand functions had several other limitations. They noted other constraints that could arise from the profit maximization model were:

(i) The model assumed that producers immediately adjusted the quantity of input demanded in response to changes in relative prices, unhindered by market information, and/or supply lags.

(ii) The model assumed that output and input prices were known and given at the time of planning production. They noted, however, that agricultural production decisions were based on expected, not actual product prices, and that the expected product price should have been used instead of actual product prices.

A further limitation was that the derived input demand functions were static. Constraints on the production function (e.g., technology, or inputs fixed in the short run) were assumed unknown and constant during the production period. They noted that some studies had included a proxy for technology to overcome this. Another problem identified by Abebe, Olson and Dahl was that derived input demand functions did not include explanatory variables other than input and product prices. They noted that other studies had included the "other relevant variables" to correct the shortcomings of the theoretical models. It is noted that what Abebe, Olson and Dahl term as "other relevant variables" are not shortcomings of theoretical models, but are actually parts of the theoretical models, which can enter the estimating equations as fixed or variable inputs.

Timmer (1974) also concluded that the most appealing approach to fertilizer demand estimation was via the application of profit maximization conditions. He asserted the necessity of assuming some sort of maximizing behaviour by the farmer. He further argued that profit-maximization without regards to risk, uncertainty, knowledge and other constraints was a poor characterization of the behaviour of all farmers anywhere in the world. He noted that omitting risk and uncertainty caused the marginal revenue/marginal cost ratio, which should be equal to one where profits are maximized, to exceed one. The marginal revenue/marginal cost ratio exceeds one, because the presence of risk causes an increase in the value representing marginal cost. The size of the increase in the value representing marginal cost depends on how risk-averse a farmer is. Timmer suggested that the marginal revenue/marginal cost ratio could be expected to be higher for developing countries than developed countries because farmers there were likely to be more risk-averse. The lack of crop insurance in the developing countries has been noted as one factor that makes the farmers more risk averse.

Timmer (1974) applied a model that incorporated a "working capital constraint" in the profit maximization framework. He noted that the availability or lack of working capital to farmers could dictate production strategies. Timmer noted that the limited access to working capital could hinder the ability of farmers to finance production costs. Following is a review of his model:

If output is taken as an exponential function of fertilizer applications $q=f^{\beta}$ , with other inputs held constant, the unconstrained profit maximization can be expressed as:

(16) $\max_{f} \quad \pi = pf^{\beta} - fp_f - b$

where $b$ is the fixed cost, $f$ is the quantity of fertilizer, $\beta$ is the output elasticity of fertilizer, $p_f$ is the price of fertilizer and $p$ is the output price.

The first order condition of this profit function becomes:

(17) $\frac{\partial \pi}{\partial f} = p\frac{\partial f^{\beta}}{\partial f} - p_f = 0.$

Timmer solved for this first order condition to give:

(18) $f_0 = (\frac{1}{\beta})^{\frac{1}{\beta-1}} (\frac{p_f}{p})^{\frac{1}{\beta-1}}$ ,

where $f_0$ is the optimal level of fertilizer application.

When a working capital constraint K was introduced, the simple profit maximizing calculus changed. From the response function as above, $q = f^{\beta}$ , the constrained profit maximization expression was formed as follows:

(19) $\max_{f} \quad \pi = pq - p_f f$

subject to

$K - p_f f = 0.$

$K$ in equation (19) represents the maximum amount of capital funds available for fertilizer purchase. The Lagrangean function of the constrained profit maximization problem is then expressed as:

$$(20)\quad \mathcal{L} = pq - p_f f + \lambda(K - p_f f),$$

where $\mathcal{L}$ is the Lagrangean function, $\lambda$ is the Lagrange multiplier and the other variables are as previously defined. Note that, $K - p_f f = 0$ when the working capital is a binding constraint.

Solving for the first order conditions now yields a new expression for the optimal level of fertilizer use under a working capital constraint:

$$(21)\quad f_0 = [(\frac{\lambda}{\beta})^{\frac{1}{\beta-1}} + (\frac{1}{\beta})^{\frac{1}{\beta-1}}]\,(\frac{p_f}{p})^{\frac{1}{\beta-1}}.$$

Timmer concluded that the only impact a capital constraint had on fertilizer purchases was a shift on the intercept term in the demand function for fertilizer. Thus capital constraints, according to Timmer, affect the level of fertilizer use, but not the extent to which farmers react to prices. He also noted that when liquid capital was not available, credit-worthiness of the farmer and/or current interest rates should be included in fertilizer demand functions. He explained that in the absence of credit, farmers had to maintain cash reserves for use in the purchase of production inputs, or completely forfeit certain production processes (e.g. the purchase of fertilizer). Timmer further explained that credit allowed producers to remove the working capital constraint, thus allowing for greater consumption and greater use of inputs.

In another study, Hotelling (1929) investigated the effect of the distance between two firms on each firm's profit. Hotelling used the profit maximization set up to model the fact that transportation to and from the purchasing point was part of the cost of a commodity to the consumer. He further showed that a consumer would purchase from one firm and not the other, if the cost of transportation to that firm, plus the price of the commodity to be purchased, did not exceed the cost of transportation to the other firm, plus the commodity's price as given by the other firm. The fundamental ideas embodied in this model can be extended to the farmer, whose objective is to maximize profits, and who has to travel away from the homestead to purchase fertilizer. In this study, it is hypothesized that, the further away the fertilizer selling point is, the higher the incurred costs of travel to purchase fertilizer will be. The third chapter of this thesis develops a detailed proposal of the extension of this model as it relates to the current study.

## 2.4 DIRECT ESTIMATION OF INPUT DEMAND

Timmer (1974) felt that the indirect estimation of fertilizer demand functions from the underlying production or profit function did not completely explain the factors affecting the demand for fertilizer. He viewed the approach of direct estimation as overcoming some shortcomings of indirect estimation. He further noted that direct estimation methods captured some of the dynamic elements associated with fertilizer demand (such as price changes between periods) better than static models. The static models are one-period models that do not take into account the fact that prices change over time.

Under the direct estimation approach, input demand functions are derived from observed market data. Timmer (1974) discussed the use of distributed lag models developed by Nerlove. The distributed lag model is expressed as follows:

$$(22) \quad F_t^* = \alpha_0 + \alpha_1 P_{ft} + \epsilon_t ,$$

where $F_t^*$ is the logarithm of desired fertilizer consumption or demand in the long run at time t, $P_{ft}$ is the logarithm of fertilizer price relative to the price of output at time t and $\epsilon_t$ is a random disturbance term.

Timmer imposed zero degree homogeneity on the demand function as required by economic theory. Imposing this condition implies that proportional changes in fertilizer and output prices do not change the level of input demand. Hence a one percent increase in the price of output should increase fertilizer demand by the same magnitude that a one percent decrease in the price of fertilizer will. Timmer suggested that existing evidence to support the validity of imposing the zero degree of homogeneity was for developed countries and queried whether the implications of the zero degree of homogeneity condition would hold for developing countries.

Timmer also reviewed a Nerlovian model that considers that actual fertilizer use adjusts through proportional changes and not instantaneously:

(23) $F_t - F_{t-1} = \gamma(F_t^* - F_{t-1})$ ,

where $F_t^*$ is the desired fertilizer consumption in the long run, time t, $\gamma$ is the adjustment coefficient ($0< \gamma <1$) and $F_t$ is the actual fertilizer consumption at time t.

Timmer noted that this model was useful for time series data as it incorporated an adjustment coefficient. In addition, he reasoned that this model performed well because the lagged dependant variable captured the effect of excluded but otherwise relevant independent variables. Nonetheless, the application of the above equation in developing countries was not expected to be easy primarily because of inadequate price statistics at the farm-level.

It is important to note that all of the studies of direct estimation of fertilizer demand reviewed use time series data. The purpose of the current study is to determine the factors that affect the farm-level demand for fertilizer using a cross-section of smallholder farmers in Kenya. The models reviewed under direct estimation are therefore inappropriate as base models for this study.

## 2.5 MAXIMIZATION OF THE EXPECTED PROFIT FUNCTION

The levels of profit were assumed to be certain in the studies that were reviewed in the sub-sections 2.3.1 and 2.3.2. Hence, the optimal levels of input demand were derived from the profit function with confidence. In the presence of risk and uncertainty, however, profit is no longer certain. Thus the profit function can no longer yield, with certainty, results regarding input demand and output supply.

Risk is considered in this study because changes in input use have uncertain impacts on the variability of yields and, consequently, on the variability of profit. Under risky conditions, input demand may be analyzed by considering expected profits. Important too is the farmer's risk attitude, since it affects how the farmers' optimal choice of inputs changes in the presence of risk. Following is a review of literature that address production risk as it may relate to this study.

Alain de Janvry (1972), while studying optimal levels of fertilizer use under risk in Argentina, described the economic return from fertilizer as stochastic, since it depended on non-controllable climatic events. de Janvry used the constrained profit maximization approach to determine optimal levels of fertilizer use. He noted that it was critical to estimate precisely, the level of risk that farmers assume when they invest in fertilizers, particularly in developing countries. High input prices in developing countries make the input-output price ratio unfavourable. Consequently, narrower profit margins are realized for farmers in developing countries. In addition, de Janvry noted that farmers in developing countries did not have the financial resources nor the crop insurance, to enable them to bear losses in bad years. He added that failure by farmers who were in the early stages of adopting fertilizer, to assess the risk they faced in using certain levels of fertilization could result in huge losses. The huge losses could cause a serious setback in the spread of fertilizer use and other technological changes.

In analyzing optimal levels of fertilizer use, de Janvry used a production function that considered:

(i) The stochastic nature of the weather. This was done by obtaining the probability of rainfall events.

(ii) The organic matter content of each farm. This is because the lower the level of soil fertility, the higher the response to fertilizer is expected to be.

(iii) The cultural practices on the farm. This is because these practices varied from farm to farm.

In addition, he incorporated the probability that farmers were going to cover at least the cost of using fertilizer under risky conditions. This he did by deriving the internal rates of return from investing in various levels of fertilizer. de Janvry obtained a frequency distribution and a cumulative distribution function of these internal rates of return. He used these functions to determine the probability that farmers could at least cover the cost of using fertilizer. He gave the example of a producer who wanted to be $(100-\alpha)$ percent sure not to lose money in investing in fertilizer. Such a producer could be considered as having an objective function of maximizing expected profits once the goal that the probability that the internal rate of return is greater than or equal to zero, equals $(100-\alpha)$ was satisfied $(Prob(IRR\geq 0)=(100-\alpha))$. Further, the expected profit function of such a producer would be derived from a production function that takes into account the variability of the weather.

de Janvry (1972) noted the need to constrain expected profits and added that unconstrained maximization of expected profits was a criterion that could not be used. This is because the variance of profits could be high, leading to a higher probability that losses occur. Imposing a restriction to the solution to satisfy for example, $Prob\ (IRR \geq 0) = .95$ , means that fertilizer use is forbidden when costs of its use may not be covered in one out of 20 years. The constraint would also determine the subset of the space over which maximization of expected profits could be performed while meeting the risk aversion requirements. He concluded that the lack of careful assessment of risk could lead to incorrect interpretation of available data.

Roumasset (1975) conducted a study of risk in rice production by Philippine farmers. He identified that the goal of rice farmers was primarily subsistence, followed by profit maximization. Roumasset suggested a framework that satisfied these goals as minimizing the probability, $\alpha$, that some objective function, typically profits, falls below a specified disaster level $d^*$:

(23) $\text{Min}\ \alpha = \Pr\ (\pi < d^*)$,

where $\pi$ is the level of profit, $\alpha$ is the probability being minimized and $d^*$ is the exogenously determined disaster level.

Alternatively, the problem could be specified as one of maximizing profits, with the restriction that the probability of the profit level falling below the disaster level, does not exceed a given probability limit:

(25) Max $\pi$

subject to $P_r(\pi<d^*)\leq\alpha^*$,

where $\alpha^*$ is the probability limit. Roumasset investigated the optimal levels of fertilization under risky conditions. He used the approach of expected profit maximization to analyze optimal levels of fertilizer use.

Lambert (1990) used data for cotton production in Arizona to evaluate risk associated with fertilizer use. He estimated a production function as specified by Just and Pope (1979) and addressed the role of uncertainty in determining optimal input use. He used the single crop production function:

(26) $Y = f(X_n, X_w) + h^{1/2}(X_n, X_w)\epsilon$,

where $Y$ is per acre yield, $X_n$ and $X_w$ are inputs of nitrogen and water, and $\epsilon \sim N(0,1)$. Following Just and Pope (1979), the production function was broken down into deterministic and stochastic elements respectively as:

(27) $E(Y)= f(X_n, X_w)$

(28) $\sigma^2_Y= h(X_n, X_w)$.

The expected yield, $E(Y)$, is given by equation (27) and is the deterministic component. The variance of yield ($\sigma^2_Y$) given by equation (28), is the stochastic component.

Lambert considered a case of random output prices, $p$, and known costs, $r_n$ and $r_w$ and expressed profit per-acre as:

(29) $\pi = pY - r_nX_n - r_wX_w - VC - b$,

where $VC$ represents variable costs other than for water and nitrogen and $b$ is the level of fixed costs. Expected profit, $E(\pi)$ was expressed as:

(30) $E(\pi) = E(pY - r_nX_n - r_wX_w - VC - b).$

Since $E(Y) = f(X_n, X_w)$), expected profit was re-expressed as:

(31) $E(\pi) = p^*f(X_n, X_w) + \sigma_{pY} - r_nX_n - r_wX_w - VC - b,$

where $p^*$ represents expected price, and $\sigma_{py}$ represents the covariance term. The covariance term, $\sigma_{pY}$, was equal to zero because the distributions of price and quantity were assumed independent.

The variance of profit, $\pi$, when both $p$ and $Y$ were assumed random and independent was:

$$(32)\quad Var(\pi) = Y^{*2}\sigma^2_p + p^{*2}\sigma^2_Y$$

$$= [f(X_n, X_w)]^2\sigma^2_p + p^{*2}[h(X_n, X_w)].$$

Given a risk-free and a risky environment, the certainty equivalent is the return in the risk-free environment that yields a utility level equal to the expected utility from the risky option. In profit terms, it is the profit level under certainty that yields the same utility level as the expected utility from profit under uncertainty. Robison and Barry approximated the certainty equivalent of per-acre profit to be:

$$(33)\quad CE = E(\pi) - \frac{\lambda}{2}\ Var(\pi),$$

where $\lambda$ is the value of Pratt-Arrow absolute risk aversion function. The Pratt-Arrow absolute risk aversion function measures the shape of an individual's utility function. It depicts a functional correlation between the level of risk aversion and the level of an individual's indicator for utility (e.g., wealth or profit level). The level of the individual's wealth/profit is the object of the individual's utility function.

Lambert (1990) obtained optimal input decisions from maximization of the certainty equivalent of per-acre profit (CE) by solving:

$$(34)\quad \max_{X_n,\, X_w} CE = p^{*}f(X_n,X_w) - r_nX_n - r_wX_w - VC$$
$$-\frac{\lambda}{2}[[f(X_n,\, X_w)]^2\sigma_p^2 + p^{*2}h(X_n,X_w)]$$

subject to specified upper and lower input ranges.

The first order conditions of this problem were:

$$(35)\quad \frac{\partial CE}{\partial X_i} = p^{*}\frac{\partial f}{\partial X_i} - r_i - \frac{\lambda}{2}a_i = 0, \qquad i=n,\ w.$$

where

$$(36)\quad a_i = p^{*2}\frac{\partial h}{\partial X_i} + 2\sigma_p^2\frac{\partial f(X_n,X_w)}{\partial X_i} \qquad i=n,\ w.$$

From the first order conditions in equation (35), interior solutions yielding optimal input levels were derived.

These first order conditions in equation (35) differ from the first order conditions under certainty. The first order conditions under certainty are equivalent to risk neutrality when $\lambda = 0$. The more risk-averse an individual is, the larger the value for $\lambda$ will be. The first order conditions in equation (35) imply that under uncertainty, input use increases up to the point where marginal value product equals input cost, $r_i$, and the risk term. An interaction of various moments of the price and yield distributions weighted by the individual profit maximizer's attitude to risk gives the risk term.

Abebe, et al. (1989), Lau and Yotopoulos (1972) are relevant to this study in terms of estimation of fertilizer use. Aspects of studies by Lambert (1990), Hotelling (1929), Timmer (1974) and de Janvry (1972) are used in the formulation of a model for the smallholder farmers in Kenya.

# CHAPTER 3

# THEORETICAL FRAMEWORK

## 3.1 INTRODUCTION

The objective of formulating a model in this study is to analyze farm-level fertilizer demand by smallholder farmers in Kenya. The focus of this chapter is on the choice of an econometric model that satisfies, as best as possible, the desirable properties of econometric models in explaining the micro level factors that affect the fertilizer demand by smallholder farmers in Kenya. Koutsoyianis (1973:29-30), outlined the desirable properties of econometric models as:

(i) Theoretical plausibility: The model should be compatible with and postulate economic theory.

(ii) Explanatory ability: The model should explain the observations of the real world and be consistent with the observed behaviour of the economic variables whose relationship it determines.

(iii) Unbiased, consistent and efficient estimates: The estimates of the coefficients should have these properties in approximating the true parameters of the structural model.

(iv) Forecasting ability: The model should produce satisfactory predictions of future values for the economic variables whose relationship are determined by the model.

(v) Simplicity: The model should represent economic relationships parsimoniously.

The next section of this chapter discusses existing methods for deriving factor demands. This is done to select one model that is most reasonable in terms of theoretical consistency and explanatory ability, to be employed as a base model for this study. The model for smallholder fertilizer demand in Kenya is formulated in the subsequent section of the chapter. Ideas from the studies reviewed in Chapter Two are included in the model formulation. A derivation of the fertilizer demand function for the smallholder farmer in Kenya is found in the last section of this chapter.

## 3.2 FACTOR DEMAND MODELS

Factor demand functions are derived from the underlying demand structure for the output of the production process. The approaches employed in determining optimal factor demand levels can be broadly categorized into two groups, according to the assumptions concerning the objectives of the decision maker:

(i) Profit maximization, and

(ii) Cost minimization.

Further assumptions may be imposed regarding whether the decision maker is certain or uncertain about price and/or yields.

### 3.2.1 PROFIT MAXIMIZATION UNDER CERTAINTY

The following sub-section reviews different approaches to deriving factor demands based on profit maximization under certainty. Unconstrained profit maximization, constrained profit maximization, and differentiation of the indirect profit function with respect to input prices are the three approaches considered.

#### 3.2.1.1 Unconstrained Profit Maximization

In this approach the production function is appropriately substituted into the profit function, resulting in an unconstrained profit function. The following steps are employed in this approach. Let the profit function $\pi$ , be given by:

$$(1)\quad \pi = py - c$$
$$= py - \sum r_i x_i - b$$

where $p$ is the price of output, $y$ is the production function, $c$ is the total cost, $r_i$ is the price of the *ith* variable input, $x_i$ is the quantity of the *ith* variable, and $b$ is the fixed cost. The farmers problem is set up as:

$$(2)\quad \underset{x_i}{Max} \quad \pi = py - \sum r_i x_i - b$$

subject to $y=f(x_i; z)$,

z is the vector of fixed inputs and b is fixed costs.

Substituting the production function for $y$ in the profit equation yields:

$$(3)\quad \pi = p.f(x_i; z) - \sum r_i x_i - b$$

Maximization of profit over the inputs $x_i$ can then be done by setting the first derivatives of the above equation equal to zero:

$$(4) \quad \frac{\partial \pi}{\partial x_i} = 0 \qquad i=1,\ldots,n$$

Solving for $X_i$ yields the optimal quantities of $X_i$, $X_i^* = X_i^*(r_i, p, Z)$ under the production constraint defined by $y$.

### 3.2.1.2 Constrained Profit Maximization

Constrained profit maximization is yet another strategy. In this approach the profit function is subject to equality or inequality constraints. The decision maker may be limited by the level of liquid cash available for input purchase or the level of inputs available for use in maximizing profits. In such a case, the farmer must maximize profit subject to the constraint. These are constraints other than of the production function constraint.

Timmer (1974) criticized the use of profit maximization models that are subject only to the production function. In his study of fertilizer demand in developing countries, Timmer noted that it was unrealistic to use profit maximization models that were subject only to the product function constraint, since these did not represent the farmers' true situation. He suggested that constraints other than the production function should be included when deriving factor demands. In particular, he suggested the inclusion of liquid capital constraints. He argued that lack of liquid capital constraints implied that cash or liquid capital was not limited to the farmer.

The problem is outlined as one of maximizing profits (with the production function substituted into the profit function), subject to an equality or an inequality constraint. A Lagrangean function, integrating the particular constraint, is formed. Setting the first derivatives equal to zero and simultaneously solving them for $X_i$ in the equality constraint case, yields optimal levels of factor demand. These are the levels of input demand needed to maximize profits, given the equality constraint. For the inequality constrained problems, solving for the Kuhn-Tucker conditions yields optimal factor demand levels, given the constraint.

#### 3.2.1.3 Indirect Profit Function

If the specific production function is unknown and the only available data are on the level of profits and factor and output prices, factor demand functions can be derived from the indirect profit function.

Following is an outline of how factor demand functions are derived from the indirect profit function. Optimal quantities of each of the input, $X_i^* = X_i^*(r_i, p)$, obtained from the solution of first order conditions of profit maximization, are substituted into the direct profit function. The resulting indirect profit function is the maximal profit that the firm can obtain and is given by:

(5) $\pi^* = p.f(X_i^*; Z) - \sum r_i X_i^* - b.$

Since the set of $X_i^*$ are a function of the input prices, $r_i$, and output price, $p$, $(X_i^* = X_i^*(r_i p))$, the indirect profit function can also be expressed as a function of $r_i$ and $p$:

(6) $\pi^* = g(r_i, p, Z)$

Hotelling's Lemma can then be applied by taking the derivative of the indirect profit function with respect to the input prices (Beattie and Taylor, 1985). Hotelling's Lemma yields the set of factor demand functions.

(7) $X_i^* = -\frac{\partial \pi^*}{\partial r_i} \qquad i=1,...,n$

There are several advantages associated with the use of the indirect profit function over the use of the direct profit function (Lau and Yotopoulos, 1972)

(i) The indirect profit function provides a great deal of flexibility in empirical analysis because output supply and factor demand functions can be derived without the explicit specification of the corresponding production function.

(ii) The indirect profit function assures that the obtained output supply and factor demand functions can be derived from profit maximization of a firm with a concave production function in the variable inputs.

(iii) The resulting output supply and input demand functions may be explicitly written as functions of exogenous variables that would be considered as being independent of the firm's behaviour.

### 3.2.2 PROFIT MAXIMIZATION UNDER UNCERTAINTY

Under uncertainty, there is need for the specification of a production function that takes into account the uncertain nature of production and subsequently, profits. According to Just and Pope (1979), the ideal production function in the presence of risk should be of the form:

(8) $y=f(x;Z)+h(x;Z).\epsilon$

where x is a vector of variable inputs, and Z is a vector of fixed inputs. This stochastic production function can be broken down into deterministic and stochastic elements:

(9) $E(y)=f(x;Z)$ , and

(10) $\sigma^2(Y)=h^2(x;Z)$ , respectively.

At this point it is noted that only production risk will be considered in this study. Input price risk is not considered simply because it is assumed that the input price is known to the farmer with certainty at the time of purchase. Output price risk exists but is not considered. It is nevertheless acknowledged that output price risk may be very important when there is production risk. This is because output price risk may magnify the effect of production risk on optimal input decisions. However, the modelling of both production risk and output price risk becomes complex and is beyond the scope of this study. Only production risk that is affected directly by changes in input use, is incorporated in the modelling.

Under the assumptions of known input prices and known output prices expected profit $E(\pi)$ , can be expressed as:

(11) $E(\pi)=E(py-\sum rx-b).$

Since $E(Y)=f(x; Z)$ and $E(p)=p$, the expected profit can be further expressed as:

$$(12) \quad E(\pi) = p\, f(x;Z) - \sum rx - b.$$

The variance of profit under the same assumptions will be:

$$(13) \quad \sigma^2(\pi) = p^2 h^2(x;Z)$$

The certainty equivalent of profit is the profit level under certainty that yields the same utility level as the expected utility from profit under uncertainty. Robison and Barry (1987) assumed concave utility functions and normally distributed profits to approximate the certainty equivalent of per-acre profit as:

$$(14) \quad CE_\pi = E(\pi) - \frac{\lambda}{2}\sigma^2(\pi)$$

where $\lambda$ is the Pratt-Arrow absolute risk aversion coefficient.

In order to derive optimal input levels under uncertainty, the problem is set up as one of maximizing the certainty equivalent as shown below:

$$(15) \quad \underset{x_i}{Max} \quad CE = pf(x;Z) - \sum rx - b - \frac{\lambda}{2}p^2h^2(x;Z) \qquad i=1,\ldots,n.$$

Differentiating the certainty equivalent with respect to the inputs, and setting the first derivatives equal to zero yields:

$$(16) \quad \frac{\partial CE}{\partial x_i} = p\frac{\partial f(x;Z)}{\partial x_i} - r_i - \frac{\lambda}{2}p^2\frac{\partial h^2(x;Z)}{\partial x_i} = 0 \qquad i=1,\ldots,n$$

The optimal input decisions under risk, obtained by solving the above set of first order conditions are:

$$(17) \quad X_i^* = X_i^*[r_i, p, \lambda, Z, \partial Var(\pi)],$$

where $\partial Var(\pi)$ is $p^2 \frac{\partial h^2(x; Z)}{\partial x_i}$. These first order conditions differ from the optimal decisions under certainty which were shown in section 3.1.1.1 to be $X_i^* = X_i^*(r_i, p, Z)$. A conclusion that can be drawn from this is that the optimal input levels satisfying the first order conditions under risk aversion will be less (greater) than the optimal input levels satisfying the first order conditions under certainty if the input is risk increasing (decreasing).

Under uncertainty, constraints other than the production function can be incorporated into the certainty equivalent of profits. A constrained certainty equivalent of profit can be set up in the same manner that the constrained profit under certainty was set up (i.e., a Lagrangean function incorporating the constraint can be formed). Taking the partial derivatives with respect to the inputs and simultaneously solving the partial derivatives yields optimal factor demands given the particular constraint.

### 3.2.3 COST MINIMIZATION UNDER CERTAINTY

An alternative to examining the optimization problem from the profit side is to examine the firm's cost. In this approach, the problem is set up as one of cost minimization subject to a given level of output in the following manner:

$$(18) \quad \min_{X_i} \quad \sum r_i X_i + b$$

subject to $Y^o - f(X_i;\ z) = 0$,

where $Y^o$ is a specified level of output and the other variables are as defined previously.

The Lagrangean function for this constrained cost minimization problem is denoted as:

(19) $\mathcal{L} = \sum r_i X_i + b + \lambda [Y^0 - f(X_i; z)]$

Setting the first order conditions equal to zero and solving for the set of $X_i$ results in conditional factor demands. These factor demands, $X_i^c = f(r_i, Z, Y^0)$, are conditional on a given level of output, and are often referred to as *conditional factor demands*. Similarly, for inequality constraints, optimal factor demands are obtained by solving the Kuhn-Tucker conditions.

It is important to note that a dual exists for the cost function. In the same way that Hotelling's Lemma was applied to the indirect profit function to yield optimal factor demands, Shepherd's Lemma can be applied to the indirect cost function to yield conditional factor demands. It is also possible to subject the cost minimization problem to constraints other than the production function constraint. The existence of a certainty equivalent of cost minimization under uncertainty is beyond the scope of this study and is not explored further.

## 3.3 JUSTIFICATION OF THE CHOICE OF A BASE MODEL

The choice of a base model in this study is to enable the modelling of fertilizer demand by the smallholder farmers in Kenya. The smallholder Kenyan farmer is faced with non-controllable climatic factors. For example, in 1992, the year that this study was carried out, there was a prevailing period of drought. An obvious implication for the data collected for this study is that the levels of fertilizer purchased were likely to be lower than other normal years. It seems more appropriate to specify the farmers' goal of profit maximization to be that of expected utility of profit maximixation rather than that of profit maximization under certainty. In addition, the farmers' goal is hypothesized to be constrained by the availability of cash for the purchase of inputs. The cash availability for the purchase of inputs, herein referred to as the working capital, is dependent on each homestead's total annual income less the amount spent on other items. The other items include expenses on food, education, clothing and leisure. Note that the expenditure on other items is expected to be a function of the number of members in each homestead. Hence, in the absence of credit, the amount of working capital available (after expenditure on the other items has been deducted) determines how much fertilizer the smallholder farmer can purchase.

The model chosen as a base model for this study should therefore be able to accommodate a constraint. The farmer is hypothesized to be restricted by the transportation costs incurred in purchasing fertilizer. This is because of the distances between the farms and the fertilizer selling points. The lack of ownership of transportation vehicles makes this restriction even more severe. Following is a critical discussion of the appropriateness of each model as a framework that allows for the modelling of the farmer's true situation.

Despite the advantages of the indirect profit function, there is one major criticism. When a constraint is imposed on the profit function, Hotelling's Lemma no longer holds. This implies that the use of the indirect profit function to derive factor demands may not apply in the presence of a constraint, such as the working capital constraint in this study. Further, the lack of data on the levels of profit realized by the farmers in this study rules out the use of the indirect profit function.

The cost minimization approach is also not appropriate as a base model in this study. This is because the collected data on input costs and output levels are inadequate, and do not allow for the use of the cost minimization approach. In addition, the cost function yields factor demands that are independent of product prices. For the above reasons, the cost minimization approach and its counterpart, the indirect cost function, are not suitable for this study.

Because of the stochastic nature of production in Kenya, it is appropriate to model the farmer's situation as one of uncertainty. This is consistent with the view held by de Janvry (1972) that failure by farmers to assess the risk they face in using fertilizer could lead to huge losses in bad years and abstinence from further fertilizer use.

As mentioned above, the farmer's problem is hypothesized to be restricted by a working capital constraint. The farmer's problem is therefore one of constrained optimization; a fact that excludes the use of the approaches constrained only by the production function. A constrained optimization problem is consistent with previous literature (Timmer 1974; Mwangi, 1978) that argued that the unconstrained profit maximization approach is uncharacteristic of the farmer's real situation.

Due to the limitations of the other models outlined above, the certainty equivalent of profit is chosen as an appropriate base model for this study.

## 3.4 MODEL DEVELOPMENT

Following Lambert (1990) and Just and Pope (1979), assume that the production function of the farmer under uncertainty is given by:

$$(20) \quad Y = f(X_i, X_F; Z_j) + s^{1/2}(X_i, X_F; Z_j).\epsilon$$

where $X_i$ are quantities of other variable inputs, (i=1,...,n), $X_F$ is the quantity of fertilizer, $Z_j$ are levels of fixed inputs, (j=1,...,m) and $\epsilon \sim N(0,1)$.

The expected output E(Y), given that $E[s^{1/2}(X_i, X_F; Z_j).\epsilon] = 0$ can be expressed as:

$$(21) \quad E(Y) = f(X_i, X_F; Z_j).$$

Equation (21) forms the deterministic component of the production function. The expression for the variance of output (the stochastic component) is:

$$(22) \quad \sigma^2(Y) = E[Y - E(Y)]^2$$

$$= E[f(X_i, X_F; Z_j) + s^{1/2}(X_i, X_F; Z_j).\epsilon - f(X_i, X_F; Z_j)]^2$$

which implies that:

$$(23) \quad \sigma^2(Y) = s(X_i, X_F; Z_j).$$

The farmer's profit function is then expressed as:

$$(24) \quad \pi = p[f(X_i, X_F; Z_j) + s^{1/2}(X_i, X_F; Z_j)] - \sum_{i=1}^{n} r_i X_i - R.X_F - b,$$

where $p$ is the price of output, $R$ is the total cost per unit of fertilizer, $r_i$ is the cost of purchasing a unit of variable input $i$ and $b$ is the level of fixed cost.

The total cost of purchasing a unit of fertilizer $R$, can be further broken down into two components: $R = r_F + h_F$, where $r_F$ is the price of fertilizer per unit, and $h_F$ is the total cost of transporting one unit of fertilizer. The variable $h_F$ includes the human cost of transportation to and from the selling point, and the cost of transporting the fertilizer brought to the farm. Note that $h_F$ is a function of $d_F$, the farmer's distance from the fertilizer selling point. The greater the farmers' distance from the fertilizer selling point, the higher the total cost of transporting one unit of fertilizer. Clearly, if the farmer buys no fertilizer $X_f = 0$ then the cost of transporting one unit of fertilizer will be zero; $h_f = 0$. The total cost of transporting one unit of fertilizer $h_F$, is a function of the distance $d_F$. Given the above framework, the profit function can be stated algebraically as:

$$(25) \quad \pi = p[f(X_i,X_F;Z_j) + s^{1/2}(X_i,X_F;Z_j)] - \sum r_i X_i - [r_F + h_F(d_F)]X_F - b.$$

Under risky conditions, output is not certain, which implies uncertain profit levels. The farmer is forced to base input decisions on expected profit rather than actual profit.

At this point, it is noted that, for simplicity, only production risk is addressed in this model. Output price risk is not considered for various reasons (section 3.2.2), while input price risk is ignored because it is assumed the farmer knows the input cost with certainty at the time of purchase. Given this frame of reference, expected profit, $E(\pi)$, is given by:

$$(26) \quad E(\pi) = E[p(f(X_i, X_F; Z_j) + s^{1/2}(X_i,X_F;Z_j).\epsilon - \sum r_i X_i - [r_F + h_F(d_F)]X_F - b] ,$$

which reduces to equation (27)

(27) $E(\pi) = p.f(X_i,X_F; Z_j) - \sum r_i X_i - [r_F+h_F(d_F)].X_F - b.$

Similarly, variance of profit can be derived as:

$$(28) \quad Var(\pi) = E[\pi - E(\pi)]^2$$

$$= E[[p.f(X_i, X_F; Z_j + s^{1/2}(X_i,X_F;Z_j).\epsilon - \sum r_i X_i - [r_F+h_F(d_F)]X_F - b]$$

$$-[p.f(X_i,X_F;Z_j) - \sum r_i X_i - [r_F+h_F(d_F)].X_F - b]^2$$

$$= E[p.s^{1/2}(X_i, X_F; Z_j).\epsilon]^2$$

Given that $E[s^{1/2}(X_i,X_F; Z_j).\epsilon]^2 = s(X_i,X_F; Z_j)$ and that $E(p)=p$, the variance of profit becomes:

$$(29) \quad Var(\pi) = p^2.s(X_i,X_F; Z_j).$$

When the farmer is indifferent between a risk-free alternative and a risky alternative, the difference between the expected return on the risky alternative and the return on the risk-free alternative is known as the risk premium. Robison and Barry (1987) defined certainty equivalent of the risky environment's expected return as the level of profits in a risk free environment that gives a level of utility equal to that obtained from a risky environment's expected return. In terms of profit, the certainty equivalent of the expected profits can be defined as the level of profit that gives a level of utility equal to the expected utility of profits under uncertainty.

Robison and Barry (1987) assumed concave utility functions and normally distributed profits to further approximate the certainty equivalent of profit as:

$$(30)\quad CE_\pi = E(\pi) - \frac{\lambda}{2} Var(\pi),$$

where $\lambda$ is the Pratt-Arrow absolute risk aversion coefficient. The farmer can then maximize the certainty equivalent of profit, in the same way as profit would be maximized.

Given this background, the farmer's problem can be stated as the constrained maximization of the certainty equivalent of profit $CE_{(\pi)}$.

$$(31)\quad \underset{X_i, X_F}{Max} \quad CE_\pi = [p.f(X_i, X_F, Z_j) - \sum r_i X_i - [r_F + h_F(d_F)]X_F] - \frac{\lambda}{2}[p^2 s(X_i, X_F; Z_j)]$$

subject to the working capital constraint

$$O^0 + \sum_{i=1}^{n} r_i X_i + [r_F + h_F(d_F)]X_F \leq K^0 \ .$$

$K^0$ is the total annual income of the household from all sources, and $O^0$ is the annual expenditure on other items (e.g., education and food).

The resulting Lagrangean function is:

$$(32)\quad \mathcal{L} = p.f(X_i, X_F; Z_j) - \sum r_i X_i - (r_F + h_F(d_F))X_F + \frac{\lambda}{2} p^2 s(X_i, X_F; Z_j)$$
$$+ \mu[K^0 - O^0 - \sum r_i X_i - (r_F + h_F(d_F))X_F]$$

The Langrangean function is differentiated with respect to $X_i$, $X_F$, and the Lagrange multiplier, $\mu$ . In the presence of an inequality constraint, such as the working capital constraint above, the first order conditions derived from the

Lagrangean function are known as Kuhn-Tucker conditions. The first of these three Kuhn-Tucker conditions is outlined as:

$$(33) \quad \frac{\partial \mathcal{L}}{\partial X_i} = p.\frac{\partial f(X_i, X_F; Z_j)}{\partial X_i} - (1+\mu)r_i - \frac{\lambda}{2}p^2\frac{\partial s(X_i, X_F; Z_j)}{\partial X_i} \leq 0$$

$$X_i \geq 0 \qquad\qquad X_i\frac{\partial \mathcal{L}}{\partial X_i} = 0.$$

Equation (33) requires that the marginal gross profit from the use of a unit of input *i* be no greater than its price, $r_i$ weighted by $(1+\mu)$ plus a risk term, $\frac{\lambda}{2}p^2 \frac{\partial\ s(X_i, X_F; Zj)}{\partial X_i}$ . The condition also requires $X_i$ to be greater than or equal to zero. If $X_i$ is greater than zero (i.e., an interior solution), then the marginal gross profit from the use of a unit of input must be equal to the input's price plus the risk term. Further, if the solution is not an interior one, then $X_i$ must be equal to zero. It is also possible, mathematically, to have an interior solution and have $X_i$ equal to zero.

The second Kuhn-Tucker condition is given by:

$$(34) \quad \frac{\partial \mathcal{L}}{\partial X_F} = p.\frac{\partial F(X_i, X_F, Z_i)}{\partial X_F} - (r_F + h_F(d_F)) - \frac{\lambda}{2}p^2\frac{\partial s(X_i, X_F; Z_j)}{\partial X_F} - \mu\,[r_F + h_F(d_F)] \leq 0$$

$$X_F \geq 0 \qquad\qquad X_F\frac{\partial \mathcal{L}}{\partial X_F} = 0$$

which can be rewritten as:

$$(35) \quad \frac{\partial \mathcal{L}}{\partial X_F} = p.\frac{\partial F(X_i, X_F, Z_i)}{\partial X_F} - (1+\mu)[r_F + h_F(d_F)] - \frac{\lambda}{2}p^2\frac{\partial s(X_i, X_F; Z_j)}{\partial X_F} \leq 0$$

$$X_F \geq 0 \qquad\qquad X_F\frac{\partial \mathcal{L}}{\partial X_F} = 0$$

This is the most important Kuhn-Tucker condition in this analysis. It requires that the marginal gross profit from the use of a unit of fertilizer be no greater than the sum of (i) the price of fertilizer $r_F$ plus the added cost of transportation $h_F(d_F)$, weighted by $(1+\mu)$, and (ii) the risk term, $\frac{\lambda}{2}p^2\frac{\partial s(X_i,X_F;Z_j)}{\partial X_F}$. If a change in fertilizer use changes the variance of output, i.e $\frac{\partial s(X_i,X_F;X_j)}{\partial X_F}\neq 0$, then the size of the risk term depends on the size of the farmer's risk aversion coefficient $\lambda$. The larger the effect of changes in fertilizer use on the variance of output and the more risk-averse a farmer is, the greater the influence on "total" marginal cost of fertilizer, where total marginal cost is the marginal cost of fertilizer plus the sum of the cost of transportation and the risk term.

Equation (35) also requires that, if $X_F$ is greater than zero, then the partial of the Lagrangean function with respect to $X_F$ must be equal to zero. If the solution is not an interior solution, $\frac{\partial \mathcal{L}}{\partial X_F} \neq 0$, then $X_F$ must equal zero.

The final Kuhn-Tucker condition is the partial derivative of the Lagrangean with respect to the Lagrangean multiplier.

$$(36) \quad \frac{\partial \mathcal{L}}{\partial \mu} = K^0 - O^0 - \sum r_i X_i - (r_F + h_F(d_F))X_F \geq 0 \qquad \mu \geq 0 \qquad \mu\frac{\partial \mathcal{L}}{\partial \mu} = 0$$

It restates the working capital constraint and requires the firm to stay within the capacity of the working capital limitation. If the working capital is not fully utilized, (i.e. $\frac{\partial \mathcal{L}}{\partial \mu} > 0$ ), then the shadow price of working capital $\mu$ (which has been restricted to be greater than or equal to zero) must be zero. Alternatively, if the working capital has a positive shadow price in the solution, $\mu > 0$, then working capital is inevitably fully utilized, $\frac{\partial \mathcal{L}}{\partial \mu} = 0$ (Chiang, 1984).

Optimal values of $\mu$, $X_i$ and $X_F$ that satisfy the three conditions above can then be solved for and expressed as presented in the equations below[1]:

$$(37) \quad X_i^* = X_i^*[r_i, r_F, d_F, p, Z_j, K^0, O^0, \lambda, \partial Var(\pi)]$$

$$(38) \quad X_F^* = X_F^*[r_i, r_F, d_F, p, Z_j, K^0, O^0, \lambda, \partial Var(\pi)]$$

$$(39) \quad \mu^* = \mu^*[r_i, r_F, d_F, p, Z_j, K^0, O^0, \lambda, \partial Var(\pi)]$$

The farm level fertilizer demand for smallholder farmers under production uncertainty and a working capital constraint can thus be specified as a function of fertilizer price, $r_F$, a vector of other input prices, $r_i$, and the price of output, $p$. In addition, this demand is a function of the distance from the fertilizer selling point, $d_F$, the total annual income, $K^0$, the annual expenditure on other items, $O^0$ and a vector of fixed inputs, $Z$. The other influencing factors on farm level demand for fertilizer is the farmer's risk attitude reflected by the risk-aversion coefficient $\lambda$ and the variables representing the vector of marginal risk, $\partial Var(\pi)$.

The objective of formulating a model for fertilizer demand for the smallholder farmer in Kenya is thus satisfied by the resulting equation from the developed model:

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[1] Note that $\lambda$ and $\partial\, Var(\pi)$ in these equations represent the risk terms as they appear in equations (34) and (35).

$$(40) \quad X_F = f[r_i, r_F, p, d_F, K^0, O^0, Z_j, \lambda, \partial Var(\pi)].$$

The components of the above equation are described in Chapter Four. In Chapter Five, equation (40) is used to estimate fertilizer demand.

# CHAPTER 4

# THE DATA

## 4.1 INTRODUCTION

The first part of this chapter discusses the data collection procedure. It explains the nature of the questionnaire used and the associated survey methods. The limitations of the survey and the data collected are also discussed. In the second part of the chapter, the derivation of each variable used in the empirical analysis is discussed. A definition of each variable and/or the proxy used for each of these variables is also given. In addition, the expected effect of the variable/proxy on fertilizer demand is explained.

## 4.2 DATA COLLECTION

Data for this research were obtained from a primary data collection procedure, through the administration of a questionnaire A copy of the questionnaire is contained in Appendix 1. The questionnaire was designed to gather data that could be used to analyze farm level fertilizer demand.

### 4.2.1 The Survey

The actual survey, carried out in June 1992, involved the completion of the questionnaire by 150 farmers from Vihiga District, Western Province, Kenya. These farmers were selected from three of the divisions in Vihiga District:

Sabatia, Hamisi, and Vihiga. An attempt was made to get a balanced number of farmers from each of the three divisions. However, because of the lack of a list of all the farmers in this region, farmers had to be chosen at random as the survey team drove through the three divisions. Upon completion of the questionnaire, each farmer was given one kilogram of sugar as a token of appreciation. The surveys were administered over a period of 10 days.

Six enumerators facilitated the completion of the questionnaires. Apart from asking the questions in the local dialect, the enumerators also recorded the responses of the farmers. The enumerators consisted of one graduate from the University of Nairobi, two technical research officers working at Kenya Agricultural Research Institute (KARI) and three technical agricultural extension officers working at the Ministry of Agriculture, Vihiga District Office. During a one-day training session prior to the data collection, the researcher explained to the enumerators the importance of each question in the questionnaire. A primary objective of the training exercise was to increase the level of consistency in questionnaire completion across the enumerators. The enumerators were each paid 100 Kenya Shillings ($ Canadian 4.00) daily.

#### 4.2.2 The Questionnaire

A pretest of the questionnaire was conducted in May 1992 in Nyeri District, Central Province, Kenya. Following the pretest, alterations that involved the wording and ordering of some items in the questionnaire were made. The pretest showed Nyeri District to be a region dominated by smallholder farmers who grew cash crops (i.e., tea and coffee). The dominance of cash crops assured farmers access to fertilizer. This is because there were more fertilizer distribution points per square kilometre in Nyeri than in regions where subsistence crops predominated. Farmers who grow cash crops have automatic access to fertilizer credit because the marketing board for the crop in question issues fertilizer on credit to ensure high quality produce. As a result of the higher demand, more fertilizer distribution outlets exist in areas growing mostly cash crops as compared with areas growing mostly food crops.

In an attempt to suggest ways of increasing the level of food production in Kenya, this research tries to identify the factors that affect fertilizer demand by smallholder farmers in Kenya. In this study, fertilizer demand is measured as quantity of fertilizer applied per-acre, hereafter referred to as the intensity of fertilizer use by smallholder farmers. The focus is on smallholder farmers because, in Kenya, most smallholder farming regions are dominated by food crops. Nyeri District, because it was dominated by cash crops, was found inappropriate for this study. In addition, the district also had a large number of fertilizer distribution outlets.

The questionnaire consisted of six sections. Section one contained general questions on the farmers' personal characteristics, such as age and sex. The enumerators recorded the division and village names in which each farm was located, and also noted the house types on each farm.

Information concerning agronomic practices was solicited in the second section of the questionnaire. Every farmer was asked to list the major crops that she/he grew. This question helped to identify the farmers who grow cash crops (tea, coffee and french beans). The identification of the farmers growing cash crops was necessary to test the hypothesis that farm with access to credit are more likely to use fertilizer.

In the second part of this section, there was a question asking individual farmers to indicate whether each of the crops that she/he grew were sold. For the crops which were sold in the market place the farmer was asked what price she/he received last year. Each farmer was also asked to indicate whether the price expected for each crop this year was higher, lower, or the same as the previous year's price. The crop prices or output prices are important components of fertilizer demand analysis since the demand for any input is derived from the demand for the associated output. This section of the questionnaire also explored the distances the farmers had to travel to market their output.

Individual farmers were also asked about crop residue incorporation into the soil. Each farmer was asked about livestock ownership, the method of feeding the livestock, and if manure was incorporated into the field. Both crop residue and manure incorporation add nutrients to the soil and may be considered as substitutes for chemical fertilizer.

Finally, each respondent was asked about the acreage of land owned, the portion cultivated, and the land leased. These aspects of land use were of interest because it is hypothesized that the more land a farmer cultivates, the more fertilizer the farmer is expected to purchase.

Section three of the questionnaire dealt with the sources of awareness and the benefits of fertilizer use. Each farmer was asked about:

(i) the source of information on fertilizer use,

(ii) the frequency of participation in agricultural extension activities (e.g. on-farm trials and demonstrations, put on by agricultural research stations and district agricultural offices)

(iii) the perceptions of the benefits accrued from fertilizer use,

(iv) the respective methods of fertilizer payment; whether credit, cash or both,

(v) the types, the amount, and the unit price of each fertilizer purchased that year, and,

(vi) the distance travelled to the fertilizer distribution outlet.

It was hypothesized that the further the farmer was from the fertilizer distribution outlet, the less fertilizer the farmer could purchase, *ceteris paribus*. This was because, the further the fertilizer distribution point, the greater the transportation cost for purchase of fertilizer. The questions on the frequency of participation in agricultural activities were designed to evaluate the effectiveness of extension education on the promotion of fertilizer use.

Questions in the fourth section aimed at establishing each farmer's level of education. Each farmer was asked whether she/he had attended school, and the level of schooling attained. Similarly, the respondents were asked to state the number of family members who had post-secondary education.

Section five sought to establish the level of capitalization and wealth in each household. It included questions on the ownership of transportation vehicles, and farming equipment in each homestead. Ownership of a transportation vehicle was considered crucial in determining the ease with which each farmer could purchase and transport fertilizer.

The final section of the questionnaire contained questions on each household's annual income and expenditure patterns. It was hypothesized that the annual disposable income (defined as total annual income less expenditure on food in a household) was an indicator of how much money could be allocated to the purchase of fertilizer.

### 4.2.3 The Survey Limitations

One limitation was in the timing of the survey. Kenya experienced a period of drought in 1992 just before and during the time that the survey was conducted. The amounts of fertilizer purchased in 1992 may therefore not be representative of a normal year. Further, the prevailing political situation that year restricted the actual research and the pretesting to the areas chosen, as they were more peaceful at the time.

A second limitation of the survey was in the design of the questionnaire. The questionnaire did not solicit all the information necessary to analyze farm level fertilizer demand. In particular, data were not gathered on other input prices, the acreage of each crop grown and the quantities of each crop sold.

### 4.2.4 The Data Limitations

In addition to the limitations of the survey noted above, there are a number of limitations of the data gathered. Each farmer did not use all the available kinds of fertilizer. The different kinds of fertilizer were Double Ammonium Phosphate (DAP), Nitrogen Phosphorus Potassium (NPK) composites, Calcium Ammonium Nitrate (CAN), Triple Super Phosphate (TSP) and Urea. Hence, for each farmer, a quantity was not recorded for each type of fertilizer. This meant that sample sizes for each fertilizer's demand estimations were not standard across the fertilizers.

Similarly, a unit price for each fertilizer type was obtained only for the fertilizers used by each farmer. By cross-checking farmers from the same village, it was possible to infer a price for many of the non-users from those who used the particular fertilizer. This step was taken because a unit price exists for each fertilizer type, whether the farmer uses the fertilizer or not.

Following is an overview of how the price inference was performed. If one farmer in the village used a fertilizer type, that unit price was used for all the farmers in that village, even if the remaining farmers purchased none of that fertilizer. For cases where more than one farmer in a village used a fertilizer type, an average of the respective unit prices was employed. In some villages, fertilizer was not applied by any of the farmers and, therefore, a price could not be inferred for any of the farmers from that village. These observations were omitted from the analysis. Table I shows the number of observations for which a price was inferred, and the resulting number of observations with a value for price. Because of the data limitations outlined above, sufficient data for estimation was obtained for only three of the five fertilizers (DAP, CAN, NPK).

**Table I: Breakdown of observations by presence of fertilizer price**

| Fertilizer Type | Number using fertilizer | Number with inferred price | Number with no price | Total number with price |
|---|---|---|---|---|
| DAP | 100 | 41 | 9 | 141 |
| CAN | 62 | 59 | 29 | 121 |
| NPK | 22 | 29 | 89 | 51 |
| UREA | 12 | 0 | 146 | 4 |
| TSP | 1 | 0 | 150 | 0 |

An attempt to derive output prices revealed another limitation of the data. Output price was mentioned earlier to be an important part of this study because fertilizer demand is derived from the demand for the final output. The computation of a common output price was complex because the farmers grew different of crops, whose prices per unit varied. Since maize was a common crop grown by 94.7% of the farmers interviewed, an attempt was made to generate a maize price for each farmer. However, the attempt was unsuccessful since only

33% of the farmers who grew maize sold it. Sixty-seven percent of the farmers who grew maize grew it entirely for subsistence purposes. A further attempt was made to derive a maize price by generating a price for each region. Unfortunately, even within a given region, there were maize price variations of up to 200%. Table II shows the price distributions for some of the different crops

**Table II: Statistics of Crop Prices**

| CROP | Number growing | Number with price | Mean price | Minimum price | Maximum price | Standard deviation |
|---|---|---|---|---|---|---|
| MAIZE | 139 | 41 | 5.07 | 3.30 | 10.50 | 1.998 |
| BEANS | 80 | 29 | 10.12 | 5.00 | 15.00 | 2.374 |
| COFFEE | 34 | 24 | 1.08 | 0.30 | 3.00 | 0.776 |
| TEA | 32 | 22 | 3.00 | 2.00 | 4.00 | 0.308 |
| FRENCH BEANS | 21 | 15 | 6.46 | 5.00 | 7.00 | 0.634 |

grown and the number of observations for which a price was available. Therefore, the price of output was omitted in the empirical estimations.

## 4.3 VARIABLES

The following sub-sections discuss each of the variables used in estimating fertilizer demand. A discussion of the proxy used for each variable, reasons why the variable is included, and the variable's expected effect on fertilizer demand is given.

### 4.2.1 DEPENDENT VARIABLE

Three separate analyses, one for each of the fertilizers DAP, CAN and NPK are performed in this study. In each case, the dependent variable is the quantity of fertilizer, applied per acre by each farmer. It is obtained by dividing the quantity of fertilizer, in kilograms, by the amount of land the fertilizer was applied on. The resulting quantity of fertilizer applied per acre makes it possible to compare fertilizer use across farms of different sizes. QDAPACRE, QCANACRE, and QNPKACRE correspond to the quantity of fertilizer applied per acre for DAP, CAN and NPK, respectively.

### 4.3.2 INDEPENDENT VARIABLES

According to the model formulated in section 3.4 for fertilizer demand by smallholder farmers in Kenya, $X_F = f[r_i, r_F, d_F, p, K^0, O^0, \lambda, \partial Var(\pi)]$, the demand for fertilizer is expected to be a function of the price of output, the price of fertilizer and a vector of other input prices. The distance from the fertilizer selling point and the amount of working capital available also affect fertilizer demand. The effects of risk on production, represented by the risk aversion coefficient of the farmer and a variable representing marginal risk, also influence the demand for fertilizer.

A fixed input is one over which the producer has no control in the short run. Fixed inputs in this analysis include credit accessibility, contact hours of the farmer with sources of agricultural information (e.g. demonstrations and on-farm trials), the level of education of the farmer and the acreage of land owned. Each input, variable or fixed, is discussed separately in the following sections.

#### 4.3.2.1 Price of output

The demand for an input is derived from the underlying demand for the commodity that the input produces. An increase in the output price would induce the farmer to increase production and, in pursuit of this, increase the use of the input.

The output price variable was omitted in this empirical estimation since it was not possible to compute a composite output price from the survey results. This was due to the fact that many of the crops grown were not sold. Even for the few farmers who sold their crop, data limitations on the unit prices of each of the crops, and the amount of each crop sold made it impossible to calculate a composite output price. A detailed discussion of the unsuccessful attempt to derive an output price is contained in sub-section 4.2.4.

#### 4.3.2.2 Price of fertilizer

For farmers who did not purchase fertilizer, a fertilizer price was derived by inferring a price from other farmers, in the same village, who had purchased the fertilizer. A description of this process is contained in section 4.2.4. The unit for fertilizer price is Kenya Shillings per kilogram. DAPP, CANP, and NPKP correspond to the price of DAP, CAN, and NPK respectively. Since fertilizer is a normal input, an increase in the price of fertilizer is expected to result in a decrease in the demand for fertilizer.

#### 4.3.2.3 Other input prices

The typical smallholder farmer in Kenya uses family labour, uses seed from the previous year's crop and does not use pesticides or herbicides. Therefore, it is assumed in this study that the only input for which the farmer pays cash is fertilizer.

#### 4.3.2.4 Distance

The distance of the farmer from the fertilizer selling point is considered important in this analysis. Distance represented by DISTANCE, is modelled in this study as a part of the unit cost of acquiring fertilizer.

A typical smallholder farmer in Kenya owns no motorized transportation. An increase in the distance from the farm to the fertilizer selling point would imply an increase in the transportation cost for the farmer. Thus the distance variable, DISTANCE, is expected to have a negative effect on fertilizer demand.

#### 4.3.2.5 Income

Each household's income was computed as the total annual income from crop sales, off-farm employment (e.g. sale of dairy, or poultry products) and money sent in by other family members working away from the farm. The purpose of collecting the data on annual income was to derive each farmer's working capital constraint. As outlined in section 3.4, the working capital constraint is $K^0 - O^0 - \sum_{i=1}^{n} r_i X_i - [r_F + h_F(d_F)] X_F \geq 0$. Unfortunately, it was not possible to obtain values for all the components of the working capital constraint. The use of disposable income was considered as an alternative.

Disposable income is the total annual household income less the annual food expenditure for the household. Insufficient and unreliable data on annual food expenditure made the calculation of disposable income impossible. An alternative to disposable income as a proxy for working capital was per capita income (PCINC). This variable, expressed in thousands of Kenya Shillings, was calculated by normalizing annual income by the number of family members for each household. PCINC not only allows for the comparison between households with different numbers of family members, but also indicates how much money is available for each family member. It is postulated that higher PCINC indicates more available working capital. The higher the level of working capital, the less binding the working capital constraint, implying the household is more likely to purchase more fertilizer.

A problem presented by the use of PCINC as a proxy for working capital is that individual farmer's preferences for income allocation vary. The make-up of individual households is one factor that determines how income is allocated. This point can be illustrated by the following example of two households with the same income and number of family members and thus the same PCINC. If the first household has more school age children than the second, the first household will most likely allocate more money for education expenses. The differences in allocation preferences, due to the family composition imply that higher levels of PCINC may not necessarily be associated with larger expenditure on fertilizer. The use of PCINC as a proxy for the level of working capital is therefore less than perfect.

#### 4.3.2.6 Education

Higher levels of education are postulated to enhance the understanding of the benefits of fertilizer use, and speed the decision making process. Stefanou and Saxena (1988) and Sidhu and Baanante (1979) found that as the farmer's level of education increases, the processing ability necessary for decision making also increases. Furthermore, they argued that the farmer needs to understand the benefits associated with fertilizer use in order to be motivated to apply fertilizer.

Two dummy variables were calculated to represent the levels of education. The first dummy variable, ED1, takes on a value of one if the farmer has attended primary school and no more, and a value of zero if she/he has not attended primary school. The second dummy variable, ED2, takes a value of one if the farmer has attended secondary school or more, and a value of zero otherwise. For the farmers who have never attended school each of the two dummy variables takes on a value of zero.

The dummy variables representing the level of education are expected to have a positive effect on fertilizer demand. ED2 is expected to have the most influence on fertilizer demand, followed by ED1. Table III contains the descriptions of ED1 and ED2.

#### 4.3.2.7 Credit accessibility

Farmers who grow a cash crop or crops, (tea, coffee, or french beans), have access to fertilizer credit because each cash crop's marketing board issues fertilizer credit in an attempt to maintain high quality produce. It is hypothesized that farmers with access to fertilizer through credit-in-kind use more fertilizer than those without access to credit-in-kind. To be eligible for credit, the farmer must either be a cash crop farmer, or own assets that can be used as collateral.

A dummy variable, CREDIT, to indicate whether the farmer used fertilizer credit, was included in the initial analysis for each fertilizer. This variable was assigned a value of one if the farmer had access to fertilizer through credit-in-kind and zero, if not. A summary of this variable is included in Table III. Farmers who have access to credit-in-kind are expected to demand more fertilizer than the farmers who do not.

#### 4.3.2.8 Level of Contact

This study examined whether the farmer's contact with agricultural activities or agricultural personnel increased her/his level of awareness on the benefits of fertilizer use. Agricultural activities include attending on-farm trials, attending agricultural demonstrations, attending agricultural field days, attending agricultural shows, visiting research centres and reading farmer magazines. Through these agricultural activities, the recommended levels of fertilizer application and the benefits of fertilizer use are displayed. It was expected that the higher the frequency of participation in these agricultural activities, the more the farmer would appreciate the benefits of fertilizer, and the higher the rate of fertilizer use.

Contact with agricultural personnel involves meetings with, or visits by the agricultural officers. The three levels of agricultural officers are the technical assistants, the divisional and the district agricultural officers from the Ministry of Agriculture. Farmers need to meet with these officers because research station findings are disseminated to the farmers through these agricultural officers. It, therefore, follows that the higher the number of contacts with the agricultural officers, the higher the farmers' level of awareness.

The variable CONTACTS, representing the annual level of contact, was calculated by assigning a value of one for every activity or meeting involving the farmer during the year. For example, if the farmer met with the divisional agricultural officer once a week, then the annual value for contacts was assigned a value of 52. If the farmer met the officer only once a year, then a value of one was assigned for that event. This exercise was done for each of the activities/meetings, and a total was obtained for the whole year. Two dummy variables, MEDCONT and HICONT were derived from the variable CONTACTS. Contact frequencies greater than zero but less than 12 per year (once per month), were classified as MEDCONT. Annual contacts greater than 12 were classified under HICONT. It is expected that HICONT will have a larger effect on fertilizer demand than MEDCONT. Table III contains the summary of these three dummy variables.

A shortcoming of this variable may be that every activity/meeting is given equal weight. It is possible that some activities/meetings may have a larger influence on the farmer's fertilizer use decisions than the other activities or meetings.

**Table III: Coding of dummy variables used in the model**

| VARIABLE | VARIABLE DEFINITION | CODING |
|---|---|---|
| CREDIT | Does farmer use credit or not? | YES=1,NO=0 |
| ED1 | Is primary education the highest grade attained? | YES=1,NO=0 |
| ED2 | Is education level attained equal to or higher than secondary education? | YES=1,NO=0 |
| MEDCONT | Is annual contact more than 0 and less than 12? | YES=1,NO=0 |
| HICONT | Is annual contact more than 12? | YES=1,NO=0 |

#### 4.3.2.9 Animal Units

In the rural communities in Kenya the number of livestock that a farmer owns is a sign of wealth. Ninety-six percent of the 150 farmers interviewed owned livestock and each of the farmers had a different combination of livestock. To enable a comparison of the different types of livestock across these farmers, a variable ANIMALS was designed. This variable was calculated on the basis of how much manure each animal type produced, relative to a cow's manure. A cow was given a value of one unit. Goats, sheep and pigs were calculated as half a unit, while chicken were calculated as one hundredth of a unit. A farmer owning 3 cows, 2 sheep, 1 goat and 20 chicken had an animal unit value of 4.7. This variable ANIMALS was calculated for each farmer interviewed.

It is noted that the value of each type of animal may be used as a base for classification in the same way that quantities of manure were used. Going by the value, cows rate higher than goats and sheep as cows are priced higher in the markets. Similarly, goats and sheep would fetch more money in the market than chicken. ANIMALS is used as a sign of wealth and is expected to have a positive effect on fertilizer demand.

#### 4.3.2.10 The effect of Manure

It was hypothesized that the more manure the farmer had the less fertilizer they would wish to buy. Since 94% of the 144 farmers who own livestock incorporated manure in their field, most farmers are assumed to be aware of the positive effects of incorporating manure into the field.

In order to capture the effect of different quantities of manure, it was necessary to consider the method of livestock feeding. In one method of feeding, namely, herding or open grazing, the livestock feed on communal grazing areas and dispose of most of their manure in the fields. The farmer, therefore, cannot gather the manure for application on the farm. In the alternative method of feeding, namely zero grazing, the animals are kept and fed in a cattle shed. All the manure is therefore retained and can be used on the farm. The variable MANURE only represents the animal units owned by farmers who zero graze their animals. MANURE is assigned a value of zero if the farmers method of feeding livestock is open grazing or herding and a value equal to ANIMALS otherwise. It is expected to have a negative impact on fertilizer demand.

#### 4.2.2.11 Risk

The terms representing risk comprise of the farmers risk aversion coefficient, $\lambda$, and the marginal effects on the riskiness of profit, $\partial Var(\pi)$. The analysis of the effect of risk on the farmer's demand for fertilizer is omitted from this study due to data inadequacy. Its effect on fertilizer demand is random and cannot be determined *a priori*, without specific data. This is due to the stochastic effect of fertilizer use on output which leads to stochastic profit variability. Chapter Five gives a brief discussion on the impact of omitting risk in the analysis.

The variables described in this chapter are used in fertilizer demand estimation in chapter Five.

# CHAPTER 5

# MODEL ESTIMATION AND RESULTS

## 5.1 INTRODUCTION

The first part of this chapter discusses the selection of an appropriate estimation technique, given the nature of this study's data. As a result, the Tobit framework is reviewed. A discussion of the expected signs on the coefficients of the variables used for the estimations is followed by a review of the consequences of omitting important variables. Demand functions for the three different fertilizers DAP, CAN and NPK are analyzed using Ordinary Least Squares (OLS) and Tobit analysis. Resulting coefficient and elasticity estimates are reported and discussed in the last part of the chapter.

## 5.2 ESTIMATION TECHNIQUES

The use of appropriate estimation techniques is determined by the nature of the data to be used in estimation. Data for this study are classified as censored data. Censored data typically include the existence of limit values for the dependent variable, where observed values exist for the independent variables. The data may be censored at the upper tail or at the lower tail. An example of upper tail censoring of data is the demand for theatre tickets, which has a limit value equal to the capacity of the theatre. The data for this study is an example of lower tail censoring with a limit of zero. A farmer's actual demand for fertilizer

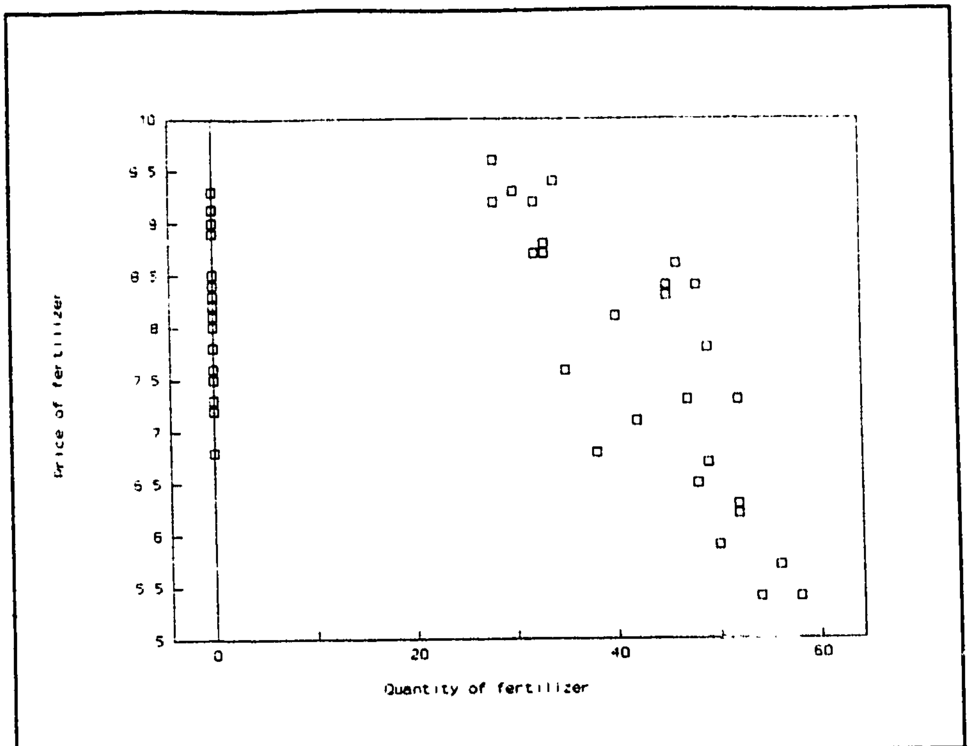


**Figure 2: An illustration of censored data**

may be negative, but since negative values are not observed, this farmer's fertilizer demand is assigned a value of zero. Therefore, zero values may occur for fertilizer demand (the dependent variable), while values exist for each of the independent variables. A graphical illustration of censored data is shown in Figure 2. The distribution of points in this figure shows that trying to fit a linear regression on this kind of data will yield biased estimates because of the presence of the observations with a zero value for the dependent variable. The distribution of points in Figure 2 suggests the need for a separate analysis for the observations with a zero value for the dependent variable, and another separate analysis of the observations with a value greater than zero for the dependent variable.

In general, censored data are analyzed by defining a new variable Y:

If $Y^* \leq c$ $\quad$ $Y = c$

If $Y^* > c$ $\quad$ $Y = Y^*$.

Y is the observed data, c is the cut-off limit (in this case 0) and $Y^*$ is the unobserved or the latent variable.

An OLS model, that assumes a normally distributed error term, is not appropriate for analyzing censored data. OLS estimation yields estimates that are best, linear and unbiased if the dependent variable takes on the full range of values, including those values less than zero. However, in the case of this data, negative values for fertilizer demand are represented by zero. The presence of a large number of observations with a value of zero for fertilizer demand consequently leads to biased and inconsistent estimates.

Omitting the observations with a value of zero for the dependent variable and applying OLS to the non-zero observations also yields biased and inconsistent estimates (Green, 1981). Bias and inconsistency are caused by truncation of the dependent variable and, consequently, the error term. Leaving out the observations with a value of zero for the dependent variable implies that the mean of the remaining observations will be equal to the mean of the observed values greater than zero only, i.e., $E(Y^*) = E(Y^* | Y^* > 0)$. Ideally, the mean of all the values (both zero and greater than zero) is correctly expressed in terms of expectations and probability. The mean of all the values is in fact the product of the expected mean of the zero and the non-zero values, weighted by their probabilities:

(1) $E(Y^*) = E(Y^*|Y^*=0) * prob(Y^*=0) + E(Y^*|Y^*>0) * Prob(Y^*>0)$

Since $E(Y^*|Y^*=0) = 0$, the expected mean of the observed values reduces to

(2) $E(Y^*) = E(Y^*|Y^*>0) * Prob(Y^*>0)$.

Owing to the fact that Y is equal to $Y^*$ if $Y^*$ is greater than zero, the expected mean of the observed values (equation(2)) can be re-expressed as $E(Y|Y>0) * Prob(Y>0)$. An appropriate estimation technique for censored data should be able to determine this value correctly in estimating independent variable coefficients.

Several approaches can be used to produce suitable results for censored data. Examples of such approaches are Tobit, Cragg's Two Step Procedure, and Heckman's Two Step Procedure. The Tobit approach to censored data is used for data analysis in this research and is discussed in the following sub-section.

### 5.2.1 Tobit Estimation

McDonald and Moffitt (1982) expressed the Tobit model as:

$$Y_t = X_t\beta + \mu_t \qquad \text{if } X_t\beta + \mu_t > 0$$

$$Y_t = 0 \qquad \text{if } X_t\beta + \mu_t \leq 0, \qquad t = 1,2,\ldots,N$$

N is the number of observations, $Y_t$ is the dependent variable, $X_t$ is a vector of the independent variables, $\beta$ is a vector of unknown coefficients and $\mu_t$ is the independently distributed error term that is assumed to be normal.

The Tobit technique uses observations at the limit (zero), and above the limit to estimate a regression equation. Tobit coefficients are estimated using the method of maximum likelihood. There is need to interpret the resulting estimates of the Tobit model with care since they are not simply the marginal effects of independent variables on the dependent variable (Kennedy, 1979, Judge et al., 1988). This is because incorporated within the Tobit coefficients are the probabilities of being above or at the limit.

Ideally, the interpretation of the effects of independent variables on the dependent variable based on the Tobit coefficient should be from calculated elasticities. From the elasticities, it is possible to separate the marginal effects of changes in the independent variable on the probability of using fertilizer and on the mean of fertilizer use by those who are already fertilizer users.

To produce the relevant elasticities, McDonald and Moffit (1982) considered the partial derivative representing the Tobit coefficient with respect to the $i^{th}$ independent variable:

$$(3) \quad \frac{\partial E(Y)}{\partial x_i} = \frac{\partial\, (Prob(Y>0) * E(Y|Y>0))}{\partial x_i}$$

where $x_i$ is the $i^{th}$ independent variable. This partial derivative was further broken down into:

$$(4) \quad \frac{\partial E(Y)}{\partial x_i} = Prob(Y>0) * \frac{\partial E(Y|Y>0)}{\partial x_i} + E(Y|Y>0) * \frac{\partial\, Prob(Y>0)}{\partial x_i} .$$

The first half of equation (4), $Prob(Y>0) * \frac{\partial E(Y|Y>0)}{\partial x_i}$, is the change in the dependent variable due to the change in $x_i$ given that Y is greater than zero, weighted by the probability that Y>0. The second half, $E(Y|Y>0) * \frac{\partial\ Prob(Y>0)}{\partial x_i}$, is the change in the probability of Y being greater than zero due to a change in $x_i$, weighted by the mean of Y. These two portions which are of interest for coefficient interpretation are:

(i) The change in the mean of Y due to a change in $x_i$ given that Y>0,

$\frac{\partial E(Y|Y>0)}{\partial x_i}$, and

(ii) The change in the probability of Y>0 due to a change in

$x_i$, $\frac{\partial\ Prob(Y>0)}{\partial x_i}$

In this study, these two components of the Tobit coefficients are referred to as the *intensity of use* and the *probability of use* decisions, respectively. The intensity of use decision refers to the effect of changes in an explanatory variable on the mean of fertilizer use, given that the farmer is using fertilizer. The probability of use decision refers to the effect of changes in an explanatory variable on the probability of using fertilizer.

A notable feature of the Tobit method is that the resulting coefficients imply that a variable which increases the probability of the observations being above the limit value (zero), also increases the mean of the dependent variable. In this study, this feature of the Tobit method is derived from the calculated elasticities. The total elasticity is calculated as:

$$(5)\quad \frac{\partial E(Y)}{\partial x_i} * \frac{\bar{x}_i}{Prob(Y>0) * E(Y|Y>0)} = Prob(Y>0) * \frac{\partial E(Y|Y>0)}{\partial x_i} * \frac{\bar{x}_i}{Prob(Y>0) * E(Y|Y>0}$$

$$+ E(Y|Y>0) * \frac{\partial Prob(Y>0)}{\partial x_i} * \frac{\bar{x}_i}{Prob(Y>0) * E(Y|Y>0)}$$

The elasticities of the probability of use and the intensity of use decisions are derived from the total elasticity. The derived elasticities, which enable the correct interpretation of Tobit results, are as shown below:

$$(6)\quad Prob(Y>0) \;*\; \frac{\partial\, E(Y|Y>0)}{\partial x_i} \;*\; \frac{\bar{x}_i}{Prob(Y>0) \;*\; E(Y|Y>0)}$$

$$(7)\quad E(Y|Y>0) \;*\; \frac{\partial Prob(Y>0)}{\partial x_i} \;*\; \frac{\bar{x}_i}{Prob(Y>0) \;*\; E(Y|Y>0)}$$

Equation (6) yields the elasticity of intensity of use and equation (7) yields the elasticity of the probability of use.

## 5.3 RESULTS

For each of the three fertilizers DAP, CAN and NPK, separate tables are presented. These tables contain estimates of the Tobit method using data on all the observations with values for the independent variables, and estimates from the OLS approach using only the observations with a non-zero value for the dependent variable.

A set of nine variables, characterizing the Kenyan smallholder farmer, is used in the estimations of the demand for each of the fertilizer types. It is expected *a priori* that the signs of the coefficients of the variables will be similar for each fertilizer type. The following sub-section gives a brief discussion on the expected sign of the coefficient for each of the variables[2]. Then the anticipated effect of the omitted variables (risk, other input prices and output price) on the magnitude of each coefficient is also discussed.

### 5.3.1 EXPECTED SIGNS ON THE COEFFICIENTS

Economic theory postulates that for a normal input the quantity demanded of an input will decrease as the price of the input increases. The coefficient of the price of each fertilizer, DAPP, CANP and NPKP, is therefore expected to have a negative sign.

It is postulated that longer distances from the fertilizer selling points to the homesteads are associated with higher costs of fertilizer transportation that reduce fertilizer demand. The variable, DISTANCE, represents the distance between each farm and the fertilizer selling point. The coefficient of DISTANCE is expected to have a negative sign.

The variable PCINC is a proxy for the working capital availability that can be used for the purchase of fertilizer. PCINC is calculated as the total annual income of each homestead, divided by the number of family members. *A priori*,

[2]Chapter Four contains the detailed definitions of each of these variables.

the coefficient of PCINC is expected to have a positive sign because a higher PCINC level suggests a higher purchasing power for goods, fertilizer included.

ED1 and ED2 are education dummy variables representing different levels of education attained by the farmer. ED2 represents a secondary level education while ED1 represents primary level education. The more highly educated farmers are expected to have a better understanding of the benefits associated with fertilizer use and, therefore, are expected to have a higher propensity to use fertilizer. The expected signs of the coefficients of both variables are thus positive. In addition, the magnitude of the coefficient of ED2 is expected to be greater than the magnitude of the coefficient on ED1. The farmer with more education is expected to have a higher propensity to use fertilizer.

MEDCONT and HICONT are dummy variables. They represent the influence of different levels of "contact" on fertilizer use, where "contact" is the farmer's personal involvement with extension programmes that promote the advantages of using fertilizer. MEDCONT represents no more than monthly contact, while HICONT represents a frequency of contact greater than once a month. Coefficients of both dummy variables are expected to have positive signs. Further, the size of the coefficient of HICONT is expected to be larger than that of MEDCONT. It is expected that higher levels of contact with extension programmes will increase the awareness of the benefits associated with fertilizer use and consequently result in increased fertilizer use.

Animal units are calculated based on the waste matter/manure production capacity of the animals in each homestead. The variable ANIMALS represents animal units and is included in this analysis to investigate the effect of animals as a sign of wealth on fertilizer demand. Its coefficient is expected to have a positive sign.

MANURE is a variable designed to capture the number of animal units owned and the method of feeding livestock. The amount of manure produced by the animals owned in each homestead can only have an influence on fertilizer demand if the method of feeding the animals ensures that all the manure is retained on the farm. Zero-grazing is a method of feeding livestock whereby the animals are kept and fed in a cattle shed. All the manure is retained on the farm and is applied to the cultivated land[3]. MANURE is assigned a value of 0 if the farmer's method of feeding livestock is open grazing and a value equal to ANIMALS otherwise. The coefficient of MANURE is expected to have a negative sign. This is because the more zero-grazed animal units a farmer has, the more manure she/he will apply on the cultivated land and the less need for chemical fertilizer.

### 5.3.2 IMPACT OF OMITTED VARIABLES

In this study, theory suggest that fertilizer demand, $X_F$, given by:

[3]The incorporation of manure into the farm is automatically assumed because 94% of the farmers who owned livestock incorporated manure into their fields.

$$(8)\quad X_F = \beta_0 + \beta_1 \textit{Fertilizer price} + \beta_2 \textit{DISTANCE} + \beta_3 \textit{PCINC} + \beta_4 \textit{ED1} + \beta_5 \textit{ED2} + \beta_6 \textit{MEDCONT} + \beta_7 \textit{HICONT} + \beta_8 \textit{MANURE} + \beta_9 \textit{ANIMALS} + \beta_{10} \textit{Output price} + \beta_{11} \textit{Seed price} + \beta_{12} \textit{Labour price} + \beta_{13} \textit{Chemical price} + \beta_{14}\lambda + \beta_{15} Var(\pi) + \mu.$$

However, due to insufficient data, output price, seed price, labour price, chemical price, $\lambda$ (the farmers' risk aversion coefficient) and $\partial Var(\pi)$ are omitted from the estimated equations.

The consequence of omitting variables from the estimated equations can be illustrated by analyzing a simple equation involving two variables, with one missing. Let the correct specification be:

$$(9)\quad Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \epsilon$$

For this simple case, the effect of omitting the variable $X_2$ on the coefficient of the included variable $X_1$, depends on the correlation between the omitted variable and the included variable. Applying OLS to the estimation of $b_1$, the coefficient of $X_1$, would be biased:

$$(10)\quad E(b_1) = \beta_1 + (X_1'X_1)^{-1} X_1'X_2 \beta_2$$

where $\beta_1$ and $\beta_2$ are the true coefficients. The direction of the bias, therefore, depends on the correlation between $X_1$ and $X_2$, and the sign of $\beta_2$. So, for example, if $X_1$ is fertilizer price and $X_2$ is output price, one would expect both the correlation between the two variables and $\beta_2$ to be positive. Therefore, $b_1$ would be positively biased.

However, for the fertilizer demand (equation 8) such biases are difficult to assess *a priori*. First, censored data requires the use of a non-linear estimation technique such as Tobit. Even in the simple case of one omitted variable, the complicated impacts of the right hand side variables make assessment of the bias difficult. In addition, this study is further complicated by the possibility of one included variable being correlated with several omitted variables. The overall impact of excluded variables on the coefficient of such a variable is difficult to determine. For example, one of the included variables in the estimated equation was PCINC. PCINC, made up of income from the sale of crops produced, is expected to be positively correlated with the omitted variable, output price. Another source of income is labour. One would expect the omitted variable labour price to be positively correlated with output price. Finally, it is generally believed that as income increases, risk aversion represented by the omitted variable $(\lambda)$ decreases. These three omitted variables would be likely to have varying impacts on the coefficient of the included variable, PCINC. Because of the differences in the nature and extent of correlation, little can be said about the overall direction of bias on the coefficient of PCINC *a priori*.

Finally, omitting $\partial Var(\pi)$ creates another source of bias. Because of this omission, each included variable will represent two effects:

(i) The direct influence on fertilizer demand,

(ii) The indirect influence through the impact that the variable has on the variance of profits.

Again, consider an example. It is expected that an increase in fertilizer price will reduce fertilizer demand. Suppose that the increase in fertilizer price causes an increase in the riskiness of profits as well. An increase in $\partial Var(\pi)$ is expected to reduce fertilizer demand. Hence, the fertilizer price has an indirect effect through $\partial Var(\pi)$. The estimated effect of fertilizer price will confound these two effects.

It is noted that the effect of omitting other input prices (prices of labour, chemicals like herbicides, and seed) is expected to be negligible. This is because the typical smallholder farmer uses no chemicals, purchases no seed and uses family labour. Similarly, the effect of omitting output price is expected to have little impact on the coefficients of the included variables. This is because this area is hypothesized to be dominated by subsistence farmers who do not sell their crop. Finally, it is difficult to say anything about the impact of omitting $\lambda$ and $\partial Var(\pi)$ in the absence of data.

### 5.3.3 RESULTS FOR DAP

DAP fertilizer is applied to promote the root development of the crop and is normally placed in the planting hole at the time of planting. Sixty-five percent of the 150 farmers surveyed used DAP (75% of the farmers using fertilizer). The high percentage of farmers using DAP is suggestive of the level of awareness of the benefits associated with using DAP. Table IV contains results for DAP.

The results presented in Table IV are for the Tobit model using all observations, and the OLS model using observations with non-zero values for DAP quantity. An initial inspection of the coefficients from the OLS model reveals

**Table IV: Results for DAP**

| VARIABLE | TOBIT | OLS (Y>0) |
|---|---|---|
| CONSTANT | 89.336 * (19.65) | 89.975 * (19.85) |
| DAPP | -6.4938 * (1.295) | -4.6238 * (1.298) |
| DISTANCE | -0.2235 (0.3584) | -0.44901 (0.3689) |
| PCINC | 0.14499 (0.3629) | -0.37307 (0.3342) |
| ED1 | 1.5696 (8.624) | 0.58173 (9.006) |
| ED2 | 12.666 (9.138) | 8.5001 (9.317) |
| MEDCONT | 2.6457 (6.799) | -3.7963 (6.859) |
| HICONT | 15.819 * (6.594) | 6.3619 (6.710) |
| MANURE | -2.8062 (1.490) | -1.0915 (1.637) |
| ANIMALS | 2.2392 (1.384) | 1.0492 (1.380) |
| $\sigma$ | 29.243 * (2.181) | |
| Number of Observations | 141 | 98 |
| Degrees of freedom | 131 | 88 |
| Overall significance | 0.20506 | |
| $R^2$ | | 0.1718 |
| Adjusted $R^2$ | | 0.0871 |

Values in parentheses are standard errors.
The sign * indicates coefficients are 2 or more times their standard errors. Since Tobit estimates are calculated using maximum likelihood, the coefficients are asymptotically normal.
Overall significance in the Tobit model refers to the squared correlation between the observed and the expected values.

that MEDCONT and PCINC do not have the expected signs. The signs on all the Tobit model coefficients coincide with *a priori* expectations. Table IV also shows that the coefficient on ED2 is larger than the coefficient on ED1. In addition, HICONT has a larger coefficient than MEDCONT. The magnitudes of both sets of the education and the contact variables for Tobit and OLS are consistent with prior expectations.

Further examination of the OLS coefficients and their associated standard errors reveals that only the price of DAP and the constant are statistically significant. In the Tobit analysis, HICONT as well as DAP price are statistically significant. The results of the Tobit model show that the agricltural extension programmes have the expected impact on DAP use because of the significance of HICONT. Due to the potential bias of the OLS results discussed in section 5.2., only the Tobit results are discussed further.

Table V presents the elasticity values as calculated from the Tobit results for all the variables. A detailed discussion on the implications of the reported elasticities is presented only for the significant variables DAPP and HICONT. The DAP price elasticity implies that a one percent increase in DAP price reduces the probability of using DAP by 1.7617%. A 1% increase in DAP price also reduces the amount of DAP fertilizer presently applied per acre by 1.5051%. The overall effect of a 1% increase in the price of fertilizer is given by the total elasticity as -3.2668%. The total elasticity is the sum of the probability of use elasticity and the intensity of use elasticity.

**Table V: DAP elasticities***

| Variable | Probability of Use | Intensity of Use | Total effect on Use |
|---|---|---|---|
| DAPP | -1.7617 | -1.5051 | -3.2668 |
| DISTANCE | -0.0333 | -0.284 | -0.0617 |
| PCINC | 0.0175 | 0.0150 | 0.0325 |
| ED1 | 0.0145 | 0.0124 | 0.0269 |
| ED2 | 0.0928 | 0.0793 | 0.1721 |
| MEDCONT | 0.0140 | 0.0120 | 0.0260 |
| HICONT | 0.0944 | 0.0807 | 0.1751 |
| MANURE | -0.0578 | -0.0494 | -0.1071 |
| ANIMALS | 0.1368 | 0.1169 | 0.2536 |

*All elasticities are calculated at the sample means of the variables.

Elasticity values in Table V also imply that a 1% increase in the number of farmers with more than a monthly contact would increase the probability of DAP use by 0.094%. In addition, the 1% change in the number of farmers with more than a monthly contact would increase the intensity of DAP application by 0.08%. These results seem reasonable because the activities referred to as 'contacts' disseminate information concerning the appropriate types of fertilizer to use, the levels of fertilizer to apply, method of fertilizer application, and timing of fertilizer application.

Education levels, wealth and the distance from the fertilizer selling point appear not to have a significant impact on DAP demand. It is suspected that the benefits associated with DAP fertilizer are so widely appreciated in this region that the level of education, working capital and the distance from the fertilizer selling point are not important in their contribution to DAP demand.

### 5.3.4 RESULTS FOR CAN

CAN fertilizer is applied to promote the vegetative growth of the crops. It is applied by top dressing the area around the crop once the crop has established it's roots. Approximately 41% of the 150 farmers interviewed used this fertilizer (over 50% of the fertilizer users). These figures indicates that CAN is not as widely used as DAP.

Table VI contains the CAN results of the OLS and the results of the Tobit model using all observations. While all the coefficients of the Tobit model have the expected signs, the coefficients of PCINC, ED1, MEDCONT and HICONT in the OLS model do not have the expected signs.

The coefficient estimates for ED2 are larger than the coefficient estimates for ED1 in both the OLS and Tobit models. Likewise, HICONT coefficient estimates are larger than MEDCONT estimates for both the OLS and the Tobit model. However, because of the bias potential of the OLS results, the subsequent discussions focus on Tobit results.

## Table VI: Results for CAN

| VARIABLE | TOBIT | OLS |
|---|---|---|
| CONSTANT | -21.039<br>(16.26) | 39.345<br>(14.98) |
| CANP | -0.65037<br>(1.378) | -1.8199<br>(1.167) |
| DISTANCE | -0.0470<br>(0.3274) | -0.26020<br>(0.3210) |
| PCINC | 0.82816 *<br>(0.2955) | -0.0895<br>0.2209 |
| ED1 | 10.906<br>(9.258) | -1.3369<br>(10.64) |
| ED2 | 19.933 *<br>(9.400) | 5.7675<br>(10.24) |
| MEDCONT | 5.7307<br>(6.525) | -1.6846<br>(5.909) |
| HICONT | 12.266 *<br>(6.005) | -0.61405<br>(5.483) |
| MANURE | -1.1203<br>(1.226) | -0.50842<br>(1.027) |
| ANIMALS | 1.5834<br>(1.200) | 0.3968<br>(1.024) |
| $\sigma$ | 23.328 *<br>(2.305) | |
| Number of Observations | 122 | 62 |
| Degrees of freedom | 112 | 52 |
| Overall Significance | 0.16823 | |
| $R^2$ | | 0.108 |
| Adjusted $R^2$ | | -0.0459 |

Values in parentheses are standard errors.
The sign * indicates coefficients are 2 or more times their standard errors. Since Tobit estimates are calculated using maximum likelihood, the coefficients are asymptotically normal.
Overall significance is the squared correlation between the observed and expected values.

Results from the Tobit analysis show that PCINC, ED2, and HICONT are statistically significant for the Tobit model. Education, contact and per capita income appear to have the expected influence on CAN demand. On the other hand, only the constant is statistically significant for the OLS model.

The elasticity values calculated for the Tobit model are displayed in Table VII. The implications of the elasticities are only discussed for the variables that are statistically significant (HICONT, ED2 and PCINC).

A 1% increase in the number of farmers with more than secondary school education in this region would have an overall influence on CAN use of 0.422%. The overall elasticity is the sum of the probability of use elasticity (0.265%) and the intensity of use elasticity (0.157%). Hence a 1% increase in the number of farmers with more than secondary school education in this region would not only increase the probability of CAN use by 0.265%, but would also cause an increase in the mean of CAN applied per acre by 0.157%. The elasticities also indicate that a 1% increase in the number of farmers who have more than a monthly contact with extension programmes would have an overall effect of 0.223%. Hence a 1% increase in the number of farmers who have more than a monthly contact with extension programmes would increase the probability of using CAN by 0.14%, and the intensity of CAN application by 0.223%. Because the probability of use elasticity is almost twice the magnitude of the intensity of use elasticity, it appears that extension programmes influence non users more than farmers already using CAN. In addition, it appears that an increase in extension

**Table VII: CAN elasticities***

| Variable | Probability of Use | Intensity of Use | Total Elasticity |
|---|---|---|---|
| CANP | -0.1985 | -0.1174 | -0.3159 |
| DISTANCE | -0.0120 | -0.0071 | -0.0191 |
| PCINC | 0.1788 | 0.1057 | 0.2845 |
| ED1 | 0.1751 | 0.1035 | 0.2786 |
| ED2 | 0.2657 | 0.1571 | 0.4229 |
| MEDCONT | 0.0499 | 0.0295 | 0.0794 |
| HICONT | 0.1402 | 0.0829 | 0.2230 |
| MANURE | -0.0403 | -0.0239 | -0.0642 |
| ANIMALS | 0.1684 | 0.0996 | 0.2680 |

*All elasticities are calculated at the sample means of the variables.

programmes would have a greater impact on CAN use than DAP use because the contact elasticities for CAN are larger than for DAP. This is an acceptable notion as the number of farmers using CAN is lower than the number of farmers using DAP.

If PCINC is a good instrument for working capital, then the PCINC elasticities in Table VII can be interpreted to mean that a 1% increase in per capita income would have an overall effect on CAN use by 0.28%. This total elasticity consists of the probability of use elasticity and the intensity of use elasticity. Hence a 1% increase in per capita income would increase the probability of using CAN by 0.1788% and increase the intensity of the present CAN use by 0.1057%.

The results of the Tobit analysis suggest that the benefits of CAN may not be as widely recognized as those of DAP. Hence the demand for CAN, and the subsequent intensity of use are not only influenced by the higher levels of contacts, but also by higher levels of education and availability of working capital.

### 5.3.5 RESULTS FOR NPK

The composite fertilizer, NPK, is mostly applied on the cash crops, coffee and tea. NPK was used by only 14.7% of the farmers interviewed. The results for NPK are reported in Table VIII.

Table VIII shows that the OLS results are not consistent with *a priori* expectations because only NPKP and DISTANCE have the expected signs. The Tobit results are more consistent as they indicate that MEDCONT, HICONT, ANIMALS, MANURE and NPKP have the expected signs.

An examination of the education and contact for the Tobit and the OLS shows that HICONT has a larger magnitude than MEDCONT only for the Tobit model. In addition, the magnitude of the variable representing the higher education level is only larger than the lower education level in the OLS model. The realized magnitudes are therefore not fully consistent with prior expectations. Because of the bias potential of using OLS in analyzing censored data, the subsequent discussions only apply to the Tobit results.

**Table VIII: Results for NPK**

| VARIABLE | TOBIT | OLS (Y>0) |
|---|---|---|
| CONSTANT | -2.7423<br>(43.13) | 122.00 *<br>(40.58) |
| NPKP | -1.2587<br>(2.868) | -3.2202<br>(2.489) |
| DISTANCE | 0.0897<br>(0.6048) | -0.202<br>(0.4615) |
| PCINC | -1.1461<br>(1.165) | -1.8627<br>(1.668) |
| ED1 | -18.473<br>(21.65) | -17.334<br>(18.27) |
| ED2 | -28.711<br>(23.16) | -10.625<br>(20.26) |
| MEDCONT | 15.286<br>(18.74) | -30.628<br>(18.44) |
| HICONT | 29.340<br>(17.12) | -30.811<br>(16.55) |
| MANURE | -2.0855<br>(3.698) | 0.952<br>(3.341) |
| ANIMALS | 6.4168 *<br>(3.123) | -0.563<br>(2.734) |
| $\sigma$ | 35.231 *<br>(5.953) | |
| Number of Observations | 51 | 22 |
| Degrees of freedom | 41 | 12 |
| Overall significance | 0.12229 | |
| $R^2$ | | 0.477 |
| Adjusted $R^2$ | | 0.0853 |

Values in parentheses are standard errors.
The sign * indicates coefficients are 2 or more times their standard errors.Since Tobit estimates are calculated using maximum likelihood, the coefficients are asymptotically normal.
Overall significance is the squared correlation between the observed and expected values.

The coefficient for the ANIMALS variable is statistically significant in the Tobit analysis. Since ANIMALS represents the level of wealth, it can be inferred from this result that the level of wealth influences NPK use.

The elasticities for all the Tobit coefficients in the NPK analysis are presented in Table IX. This table (Table IX) shows that the total elasticity value for the variable ANIMALS is 0.8616. It is noted that the probability elasticity is twice as high as the intensity of use elasticity. Specifically, a one percent increase in the animal units, not only increases the probability of using NPK by 0.59%, but also increases the intensity of NPK application by 0.267%.

**Table IX: NPK elasticities***

| Variable | Probability of Use | Intensity of Use | Total Elasticity |
|---|---|---|---|
| NPKP | -0.4385 | -0.1970 | -0.6355 |
| DISTANCE | 0.207 | 0.0093 | 0.300 |
| PCINC | -0.2021 | -0.0908 | -0.2929 |
| ED1 | -0.2354 | -0.1057 | -0.3411 |
| ED2 | 0.3354 | -0.1506 | -0.4860 |
| MEDCONT | 0.1136 | 0.0510 | 0.1647 |
| HICONT | 0.3427 | 0.1539 | 0.4966 |
| MANURE | -0.0405 | -0.0182 | -0.0587 |
| ANIMALS | 0.5945 | 0.2670 | 0.8616 |

*All elasticities are calculated at the sample means of the variables.

The Tobit results show that the levels of education, income and distance from the fertilizer selling point are not significant in determining the farmer's probability and intensity of NPK use. These results are not surprising given the fact that NPK fertilizer is mostly obtained through credit. The wrong signs and insignificance of the education, distance and income variables (ED1, ED2, DISTANCE and PCINC) are therefore not unusual. Nevertheless, it is felt that the number of farmers using NPK fertilizer (22), is not representative of the 150 farmers surveyed. The estimates resulting from analyzing this small sample size of NPK users may not be reliable and conclusions drawn from these results must be viewed with caution.

### 5.3.6 SUMMARY OF RESULTS

Before a summary of the results is presented, it is noted that the comparative study by de Guia in 1972 on the fertilizer distribution systems in five developing countries identified the existence of three stages of fertilizer use:

**Stage I:** In this stage, farmers in the given region have used little or no fertilizer. The awareness of the benefits associated with fertilizer use and the level of education are expected to be the most important variables.

**Stage II:** In this stage, farmers have realized the benefits associated with fertilizer use. The level of working capital gains importance in explaining fertilizer demand, while the contribution of the price, the education level and awareness declines.

**Stage III:** In this stage, the farmers are well informed, have used fertilizer over a long period, and understand how price affects profitability. Price sensitivity becomes the most important factor affecting fertilizer use.

Following is a summary of the results taking into consideration the above framework.

The results for DAP indicate that the price and level of contact are statistically significant. If the stages of fertilizer use outlined above are valid and applicable to the Kenyan conditions as they are in the African country, Ivory Coast, then it can be inferred from the high price elasticity values of DAP fertilizer that, DAP use in Vihiga is in the third stage of fertilizer use. This seems reasonable given the fact that DAP is used by the highest number of farmers in this region. In addition, a comparison of the price elasticities for DAP, CAN and NPK indicates that DAP is the most price sensitive of the three fertilizers.

The fact that the DAP results indicate statistical significance for higher contact levels may be due to the fact that the appropriate intensities of fertilizer use (quantity of fertilizer applied per acre), have not been achieved in this region. This would imply that agricultural extension activities are still important. Another reason may be the influence of contacts on non-users, since not all the farmers use DAP. The implications of these results are that increased agricultural extension and research programmes, that inform farmers about fertilizer will increase the chances that a non-user will use fertilizer. From the intensity of use elasticity associated with the higher levels of contact, it appears that a one percent increase in extension programmes would encourage the farmers currently using these fertilizers to increase the intensity of use.

Prior expectations were that the coefficient of the variable DISTANCE would be negative and statistically significant. However, the recurring statistical insignificance of the variable DISTANCE implies that the fertilizer distribution system in this region is well structured and not as inefficient as was initially hypothesized. If indeed the distribution system is not well structured, then it is likely that once a farmer starts using fertilizer, the benefits outweigh the additional transportation costs, making distance insignificant.

Under the assumption that PCINC captures the effect of working capital, it can be concluded that the level of working capital affects CAN demand. Hence the working capital, the higher education level and the higher level of contacts, change both the probability of CAN use by the non-users, and the intensity of use by the users. Assuming that the stages of fertilizer use reviewed earlier are valid and applicable to Kenyan farmers, the results for CAN imply that CAN use is in the later phase of stage I or the early phase of stage II. CAN use is influenced by the higher level of education and the higher level of contact as would be expected for communities in stage I. In addition, CAN use is also affected by the levels of working capital. This would suggest that some of the farmers using CAN have realized the benefits associated with its use and would use more CAN if it were not for the working capital constraint. The importance of working capital in CAN use is confirmed by the fact that of the three fertilizers, CAN has the highest income elasticities for both the probability and the intensity of use. The assumption that CAN use is in transition between stage I and II is consistent with the earlier view, that the knowledge of the benefits of CAN use may not be as widespread as those of DAP. The lower number of farmers using CAN fits well in this picture.

It is the objective of this study to examine the change in the smallholder farmers' fertilizer demand, and subsequently identify the possible avenues of increasing the smallholder farmers' food supply. The ultimate objective is to increase the nation's supply of food to enable food self sufficiency. Because NPK is predominantly used in cash crops, the results of the NPK demand analysis do not contribute much towards the above mentioned objective of this study. However, it appears that working capital, as represented by ANIMALS, is the important determinant of NPK demand. These results indicate that NPK fertilizer may be in stage II of fertilizer use. In addition, the Tobit results indicated that access to fertilizer credit increases the probability of NPK fertilizer use, as well as the intensity of fertilizer use for those already using NPK fertilizer. An important implication of these results is that a fertilizer in stage II is very responsive to credit accessibility.

# CHAPTER 6

# SUMMARY AND CONCLUSION

## 6.1 INTRODUCTION

The first part of this chapter consists of a summary of the objectives and the methodology used in this study. The conclusions drawn from the results are presented followed by a discussion on the recommendations made from these conclusions. Suggestions for further research are outlined in the last sub-section of this chapter.

## 6.2 SUMMARY

The three objectives of this study were outlined in Chapter One:

(i) To develop a model for Kenyan smallholder farmer fertilizer demand.

(ii) To use the developed model to investigate the factors that influence the decision to apply and the decision on the intensity of fertilizer application.

(iii) To suggest ways of increasing the low levels of fertilizer use in the smallholder sector.

### 6.2.1 A Model for Smallholder farmers

Past studies reviewed in Chapter Two were from both developing and developed countries. The aim of reviewing past studies on fertilizer demand was to solicit ideas for developing a fertilizer demand model for the smallholder farmer in Kenya. In Chapter Three, a model was developed to analyze the smallholder fertilizer demand in Kenya. Profit maximization under uncertainty was used as a base model for formulating the fertilizer demand functions. The smallholder farmer's fertilizer demand $X_F^*$ was modelled as:

(1) $X_F^* = f\,[r_i, r_F, d_F, p, K^o, O^o, \lambda, Z, \partial Var(\pi)]$

The fertilizer price and other input prices are represented by $r_F$ and $r_i$ respectively. $d_F$ is the distance of the homestead from the fertilizer selling point and $p$ is the output price. The farmer's total annual income is represented by $K^o$, and the expenditure on other items by $O^o$. The farmer's risk-aversion coefficient $\lambda$ and the variance of profits $\partial Var(\pi)$ make up the risk effects on fertilizer demand. The final variable $Z$ is a vector of fixed inputs, which includes the farmers' level of education, credit accessibility, the level of contact with fertilizer information activities, manure availability, per capita income, and indicators of wealth such as the number of livestock owned.

Demands for the three fertilizer types DAP, CAN and NPK were estimated. The Tobit estimation method used all the observations with values for independent variables while the OLS estimation procedure was used on only those observations with a non-zero value for the dependent variable.

### 6.2.2 Results: factors affecting fertilizer use and ways of increasing fertilizer use

The coefficient estimates of the Tobit model showed that price and contact levels greater than once a month were the factors influencing the use of DAP fertilizer. In addition, these results suggested that the fertilizer DAP in Vihiga District, is in an advanced stage of use where DAP price plays an important role. Government policies to increase the use of DAP fertilizer in this region should therefore be aimed at subsidizing the price of DAP. Such a fertilizer price subsidy should only be implemented for as long as is necessary to bring fertilizer demand to the required levels.

The Tobit results indicate that the demand for CAN is influenced by contact levels greater than once a month, higher levels of education and per capita income. Using de Guia's study as a frame of reference, it can be inferred from these results that CAN is in the later part of stage I fertilizer use and into the early parts of stage II. Since improvements in the education level involve a time lag, the suggested strategies for increasing this region's CAN use in the short run include increased extension and increased access to credit. An example of a programme that might enhance farmers' access to credit by increasing their income is an output price support programme. Unfortunately, the magnitude of the effects produced by an output price policy are not known.

An alternative to an output price support programme would be the introduction of attractive credit support programmes. Credit is an alternative here because the farmer must otherwise maintain liquid cash reserves to purchase fertilizer. If credit is available, the cash constraint for fertilizer purchase is removed. A credit programme that relaxes the working capital constraint is likely to increase the number of farmers using fertilizer and the intensity of CAN fertilizer use.

Finally, for the fertilizer NPK, credit accessibility and a contact level greater than once a month were found to be the factors which influenced NPK fertilizer demand. The results suggest that based on de Guia's study, NPK in Vihiga district is in stage II of fertilizer use. Currently, the terms and conditions that farmers need to meet to obtain credit mainly favour the cash crop farmers and those who are better off. In addition, the loan acquisition process involves delays and complicated loan application forms. A suggested policy would be one that makes the credit terms more attractive than they are presently. The lack of attraction of the current credit system is evidenced by the low number of farmers in this area using credit (14.7%).

### 6.2.3 Conclusions and Recommendations

The extension of the results of this study to other smallholder regions in Kenya, and/or the interpretation of these results in terms of policies to adopt in order to increase the level of food supply in Kenya is only possible if certain assumptions are made. This is due to the specific nature of this data set. It appears crucial that any recommendations made for a given community must take into account the stage of fertilizer use that the given community is in. Kenyan farming communities may be in different fertilizer use stages implying that any national policies to increase fertilizer use should be considered region by region, and possibly fertilizer type by fertilizer type.

If all the smallholder regions in Kenya have similar fertilizer use patterns, then direct inferences can be made from the results of this study. The recommendations below assume that a policy ensuring physical availability of fertilizer already exists as a priority in Kenya, and that, all the smallholder regions have similar use patterns.

A limited period fertilizer price subsidy would be the best policy for increased levels of food production through increased DAP use. As has been shown, a one percent subsidy of DAP price would increase the probability of DAP use by 1.76% and also increase the intensity of DAP application by 1.501%. Likewise, if all the smallholder regions in Kenya have CAN use in the later part of stage I and moving into the early part of the stage II, then a better fertilizer credit policy, coupled with increased levels of contact, would ensure nationwide increased CAN use. Increased CAN use would subsequently lead to increased food supply. A better fertilizer credit policy would also increase NPK use, as it is also in stage II of use.

The results of this study indicate that there are farm level factors that influence fertilizer use. It can be inferred from these results that the existing gap between recommended fertilizer levels and current levels of use are explained by these factors. While a lot of studies in Kenya have had the objective of determining optimal levels of fertilizer use, the findings of this study suggest that little effort should be aimed at determining the optimal or appropriate levels of fertilizer use in Kenya. Recent studies (Chege, 1992; FURP ongoing) have identified a gap between the recommended and actual levels of fertilizer use as the problem yet in their conclusions have recommended even higher levels of fertilizer use. It is felt that such research efforts and the associated funds should be directed at finding out why farmers are not using the recommended levels. A better understanding of the factors affecting the farmer's (large scale and smallholder) demand for fertilizer will allow policy makers to tailor region-specific and possibly fertilizer-specific policies that will increase the current low levels of fertilizer use, and subsequently the levels of food produced.

## 6.3 AREAS FOR FUTURE RESEARCH

It is felt that a more appropriate smallholder model would be one of subsistence followed by profit maximization, as opposed to profit maximization alone. The low numbers of smallholder farmers who sold their crop in this region is an indication that the smallholder farmers' primary goal is subsistence. Thus a study of subsistence farming and the use of a model that incorporates this behavioral aspect of the smallholder farmers, may be more representative of the smallholder farmer's situation. In addition, it is felt that the smallholder farmers' production function should include the whole management package in fertilizer demand analysis. The whole management package, as suggested by de Janvry (1972), would take into account the different cultural practices across farms. The inclusion of the whole management package in fertilizer demand analysis is expected to yield results that generate relevant policies. Such policies can bring the farmers yield to the high levels realized in experimental stations.

A broader area for future research, which is related to the objective of food self-sufficiency, is the need for a welfare analysis to evaluate the effects of reducing the present area under export cash crops and replacing it with food crops. The need for this evaluation arises because of various reasons. First, coffee and tea are protected crops by the government of Kenya. This means that the reduction of the acreage under these crops, or the intercropping of these crops with any other crop is illegal. A farmer who previously grew a cash crop a few years back, and who wishes to replace it with another crop cannot do so. In addition, much has been said about the extent to which foreign export prices are transmitted to the farmers in developing nations. As such it is questionable whether the foreign export prices are fully transmitted to the farmers, which raises the issue of the farmer's welfare. Further, the fact that the Government of Kenya allows the production and exportation of export crops and yet imports food crops is an issue worth addressing. The latter case is worth addressing because it is necessary for any country to weigh the costs and benefits of food self-sufficiency.

# REFERENCES

Abebe, K., Dahl, D. C., and Olson, K., D. (1989). "The Demand for Fertilizer". *University of Minnesota, Department of Agricultural Economics Staff Paper.* No. p89-44, November 1989.

Government of Kenya (1991), Ministry of Agriculture, Annual Report, Farm Management Division.

Baanante, C., A. and Sidhu, S. S. (1979). "Farm Level Fertilizer Demand for Mexican Wheat Varieties in the Indian Punjab." *American Journal of Agricultural Economics*, Vol. 61. 455-462.

Beattie, B. R. and Taylor C.R., (1985). *The Economics of Production*. New York: John Wiley & Sons.

Chambers, R. G. (1988). *Applied Production Analysis: A Dual Approach.* Cambridge University Press.

Chege, D. N. (1992). "Optimal fertilizer use recommendations in maize production: An analysis of experimental data." Unpublished Master of Science Thesis. University of Nairobi.

Chiang, A. C. (1984). *Fundamental Methods of Mathematical Economics*. Third Edition, Mc Graw-Hill, Inc.

de Janvry, Alain (1972). "Optimal Levels of Fertilization under Risk: The Potential for Corn and Wheat Fertilization under Alternative Price Policies in Argentina. "*American Journal of Agricultural Economics*. Vol. 2 part 1

de Guia, Eric, O. (1972). "A Comparative Study of Fertilizer Distribution Systems in Five Developing Countries." *Development Centre of the Organization for Economic Co-operation and Development (OECD).*

Food and Agricultural Organization of the United Nations, FAO (1989). Current World Fertilizer Situation and Outlook, 1983/84 to 1989/90.

Forth, Henry, D. and Boyd, Ellis, G. (1988). *Soil Fertility* First Edition. John Wiley and Sons Incorporation, New York.

FURP (1982). The Fertilizer Use Recommendations Project (FURP). Terms of Reference for Project Design. Ministry of Agriculture, Nairobi, Kenya.

Gerhart, J. D. (1974). "The Diffusion of Hybrid Maize in Western Kenya." Ph. D Thesis, Princeton University.

Green, William, H. (1981). "On the Asymptotic Bias of the Ordinary Least Squares Estimators of the Tobit Model." *Econometrica*. Vol. 49, 502-513.

Green, William, H. (1990). *Econometric Analysis.* MacMillan Publishing Company.

Green, William, H. (August 1991). *LIMDEP Version 6.0. Users Manual and Reference Guide*. Econometric Software, Inc.

Grilliches, Z. (1959). "Distributed Lags, Dissagregation, and Regional Demand Functions for Fertilizer." *American Journal of Agricultural Economics*. Vol.51,

Heady, E. O. and Tweeten, G. L. (1963). *Resource Demand and Structure of the Agricultural Industry*. Ames: Iowa State University Press, 1963.

Heady, E. O. and Yeh, M. H. (1959). "National and Regional Demand Functions for Fertilizer." *Journal of Farm Economics*. Vol. 41.

Henderson, J. M. and Quandt R.E. (1980). *MicroEconomic Theory: A Mathematical Approach*. Third Edition. McGraw-Hill Inc.

Hotelling, H. (1929). "Stability in Competition." *Economic Journal*. Vol. 39, 41-57.

Jaetzold, R. and Schmidt, H. (1982). *Farm Management Handbook of Kenya.* Vol. 1, Farm Management Section. Nairobi, Kenya.

Judge G. G., Griffiths, R.C., Lutkepohl, H. and Lee, T.C. (1988). *Introduction to the Theory and Practice of Econometrics.* New York: John Wiley and Sons.

Just R. E. and Pope. R. O. (1979). "Production Function Estimation and Related Risk Considerations." *American Journal of Agricultural Economics.* Vol 61(2). May, 1979, 276-84.

Karuri, P. T. (1991). "Crop Production and Input Usage." A Paper Presented at a Seminar Held for Provincial and District Crops Officers, Kenya Institute of Special Education, Nairobi, 4th - 10th August, 1991.

Koutsoyianis, A. (1987). *Theory of Econometrics.* Second Edition, Totowa, New Jersey: Barnes Noble Books.

Lau, L. J. and Yotopoulos P. A. (1972). "Profit Supply and Factor Demand Functions in the Agriculture of the Province of Taiwan." *American Journal of Agricultural Economics*. Vol. 54.

Lau L. J., Lin, W. and Yotopoulos P. A. (1976). "Microeconomic Output Supply and Factor Demand Functions in the Agriculture of the Province of Taiwan." American Journal of Agricultural Economics. Vol. 58.

Lambert, D. K. (1990). "Risk Considerations in the Reduction of Nitrogen Fertilizer Use in Agricultural Production." *Western Journal of Agricultural Economics*. Vol 15(2). December 1990:234-44.

Maddala, G. S. (1989). ***Limited-Dependent and Qualitative Variables in Econometrics.*** Cambridge University Press.

McDonald, J. G. and Moffit, R.A. (May 1980). "The Uses of Tobit Analysis." *The Review of Economics and Statistics*. Vol 62, 318-321.

Mwangi, W., M. (1978). "Farm Level Derived Demand Responses for Fertilizer in Kenya."Ph.D. Thesis, Michigan State University, 1978.

NDP (1978). "National Development Plan for the Period 1979 to 1983." Republic of Kenya, Government Printer, Nairobi.

NDP (1983). "National Development Plan for the Period 1984 to 1988)." Republic of Kenya, Government Printer, Nairobi.

NDP (1988). "National Development Plan for the Period 1989 to 1993." Republic of Kenya, Government Printer, Nairobi.

Ngigi, M. W. (1991). "Key Policy Issues Related to Development of Smallholder Farming and Potential Sources of Farm Level Information for their Analysis." FAO Workshop, Arusha, 1991.

Robison L. J. and Barry Peter J. (1987). "***The Competitive Firm's Response to Risk.***" Macmillan Publishing Company.

Republic of Kenya (ROK), (1981). "Sessional Paper No.1 of 1981. Government Printer, Nairobi, Kenya.

ROK (1981). "Sessional Paper No.4 of 1981 on the National Food Policy. Republic of Kenya, Government Printer, Nairobi, Kenya.

ROK (1986). "Sessional Paper No. 1 of 1986. Economic Management for Renewed Growth. Republic of Kenya, Government Printer, Nairobi, Kenya.

ROK (1990). Statistical Abstract. Central Bureau of Statistics, Ministry of Planning and National Development, Government Printer, Nairobi, Kenya.

Ruigu, G., and Schluter, M. (1990). "Fertilizer and seed requirements in Kenya from 1983/84 to 1990/91." A World Bank Working Paper. Nairobi.

Sprecher, Darryl. (1990). "An Investigation of Two Empirical Issues Associated with the Tradition Cost Model". Non Thesis Project, Master of Arts in Economics, Department of Economics, University of Alberta.

Stefanou, S.E, and Saxena S.(1988). "Education, Experience and Allocative Efficiency: A Dual Approach." *American Journal of Agricultural Economics.* Vol.70, 338-344.

Timmer, P. C. (1974). "The Demand for Fertilizer in Developing Countries." *Food Research Institute Studies*, Vol. 13.

World Bank, (1990). Kenya Agricultural Growth Prospects and Strategy Options (Draft Reports). Regional Mission Office, Nairobi, Kenya.

Young, D. L., Mittelhammer, R. C., Rostamizaden, A. and Holland, D. W. (1987). "Duality Theory and Applied Production Economics Research: A Pedagogical Treatise". *Extension Bulletin.* Cooperative Extension College of Agriculture and Home Economics, Washington State University. Pullman.

Zschernitz, K., (1972). "Marketing of Fertilizer Through Local Stockists in Kenya." A Project report

# Appendix A. Sample Questionnaire

**(This section to be completed by the interviewer directly)**

No: ..............

DISTRICT: ..............

DIVISION: ..............

VILLAGE: ..............

Distance of village from fertilizer sales point..... kms.

Interviewers Name: ...........................

Time for Interview: ...........................

Reasons for not interviewing (if applicable )

................................................

(Interviewer should observe the type of housing and check the appropriate category).

Temporary................

Permanent................

Mixed...................

The following information is to be obtained by the interviewer in consultation with the farmer.

1. Who in your household makes the major decisions?............ (Indicate the position of this person in the household/family. This is the person who should be interviewed).

2. (Interviewer should record the sex of the respondent).

Male ........ Female ........

3. What is the age of the person being interviewed:........... years.

## FARM OPERATIONS

4. What major crops are you growing this year?.

(a) ........................

(b) .......................

(c) ......................

(d) ......................

5. a) What price did you receive per unit last year for crop?. (a) ..........(enumerator should fill in crop (a) above) Kshs................

(b) Do you expect to receive a

Lower................

Same................

Higher................price this year

Don't know ................

(Enumerator should tick appropriate answer)

6. What price did you receive per unit for crop (b) ............ above Kshs ................

Do you expect to receive a lower ........ Same........ Higher........ Do not know........price this year.

7. What price did you receive per unit for crop (c)................ above Kshs..........

Do you expect a lower........Higher........ Same........ Do not know........price this year.

8. What price did you receive per unit for crop (d)............ above ?.

Kshs................

Do you expect to receive a lower........Higher........Same........Do not know ........price this year .

9. How far do you travel to sell your output ......... km.

10. Do you incorporate crop residue in your land ? Yes........ No........

11. a) Do you own livestock Yes........ No ........

If yes,

b) How many?. ........

c) Do you zero graze or herd them?................

d) Do you incorporate the manure into your field? Yes........No........

12. a) How many acres of agricultural land do members of your household own?................acres.

b) How much land do members of your household cultivate?................acres.

c) How much land is not cropped................ acres.

d) How much land do members of your household cultivate which does not belong to anyone in this household?. ................acres.

## FERTILIZER USE AND AWARENESS

13. What are the benefits of fertilizer?.

.......................................................

14. What are your sources of information on the benefits of fertilizer?.........................................................................................................

15. Is fertilizer always available for purchase when you need it? Yes ........ No ........

16. How far would you travel to buy fertilizer? .........km.

17. What was the price of fertilizer this season?............

18. How much would it cost you for transportation if you bought one bag of fertilizer?. Kshs................

19. a) Have you ever used fertilizer?. Yes........ No......

b) If no identify the reasons .....................................................

c) If Yes,

i) How many years have you used fertilizer?........ years

ii) How do you apply your fertilizer? .............

iii) How much fertilizer did you buy this year?....

iv) How much land did you apply this fertilizer on?

.......................................

v) What crops did you use fertilizer with?.

...........................................

vi) How much fertilizer did you buy last year?. ................

vii) What types of fertilizer do you use?.

TSP ................

CAN ................

DAP ................

Others (specify ) ................

20. a) How do you purchase your inputs?.

Cash ................

Credit ................

Instalment payment.......(Tick appropriate answer).

b) If you purchase inputs with credit, which inputs are these?.

Fertilizer................

Seeds................

Others (specify)................

21. How often do you participate in the following agricultural information activities?.

| | Once a week | Once a month | Quarterly | Yearly | Never |
|---|---|---|---|---|---|
| On farm trials | | | | | |
| Agricultural Demonstrations | | | | | |
| Agricultural Field days | | | | | |
| Agricultural shows | | | | | |
| Visited a Research Centre | | | | | |
| Read farmer magazines | | | | | |

22. How often do you meet the following officials.

| | Once a week | Once a month | Quarterly | | Never |
|---|---|---|---|---|---|
| Agricultural Extension Officer | | | | | |
| Technical Assistant | | | | | |
| Divisional Agricultural Officer | | | | | |
| District Agricultural Officer | | | | | |

23. Do your neighbours use fertilizer?

Yes................ No................

## LEVEL OF EDUCATION

24. a) Have you ever attended school?.

Yes........ No........

b) If Yes, have you attended (check appropriate answer).

Primary school........

Secondary or High School........

Diploma college or university........

25. How many members of your family have attended a Diploma College or university?. ................

## TYPE OF CAPITAL OWNED

26. Which of the following modes of transportation do you own?

Bicycle........

Motorcycle........

Car .......

Truck........

27. Which of the following farming equipment do you own?.

Pangas........

Harrow/Forks........

Jembes........

Sprayers........

## DISPOSABLE INCOME

28. a). How many members of the family live on the farm?

................................

b). How many people work off the farm?........................

(This question applies only to those who live on the farm)

c). How much does <u>each</u> of these earn?.

Kshs .................

................

................

................

d). How much do you receive per year for each of the crops you named in Q.4

| | Crop | amount received |
|---|---|---|
| a) | ........ | ................ |
| b) | ........ | ................ |
| c) | ........ | ................ |
| d) | ........ | ................ |
| Others | ........ | ................ |

e). What is the total family monthly expenditure on the consumption of food items?........................

How far do travel to buy this food?. ................ kms