MAIZE SUPPLY RESPONSE IN KENYA: A FARM-LEVEL ANALYSIS

BY

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DECLARATION AND RECOMMENDATION

Declaration

I hereby declare that this is my original work and has not been presented in this or any other university for the award of a degree.

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Recommendation

This work has been submitted with our approval as University supervisors.

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DEDICATION

I dedicate this thesis to my step-brother, Eric Otieno Olwande. You took the responsibility of educating me when I had lost hope in schooling. Through your commitment and sacrifice I have made it this far. Through your encouragement that I aim at the sky I am on the right track. May the Almighty God do you good all the days of your life.

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ABSTRACT

Maize is the main staple food crop in Kenya and the government policy objective is to increase maize production in order to achieve food self-sufficiency and security. The government has been applying import tariffs on maize, procuring maize at support prices, and imposing non-tariff barriers on maize imports as measures aimed at motivating farmers to produce more maize. Maize production has not, however, substantially improved in the last 13 years, and consumption demand has remained above domestic supply. This study aimed to assess maize supply response to price and non-price factors and how sensitive fertilizer and labour demand are to prices and non-price factors. The study used cross-sectional farm-level data pertaining to 2003/2004 cropping year for 1187 maize producing households in Kenya. Normalized restricted translog profit function was used to estimate maize supply and variable input demand elasticities. Results showed that own-price elasticity of maize supply is less than unity, implying that maize support price is an unattractive policy for expanding maize supply. Fertilizer use was found to be particularly important in the decisions on resource allocation in maize production. Of the fixed inputs, land area was found to be the most important factor contributing to the supply of maize. Market access and educational endowment of the household head seemed not to have much influence on maize supply. It is suggested that since high maize support price may not be feasible, making fertilizer prices affordable to small holder farmers by making public investment in rural infrastructure and efficient port facilities and promoting standards of commerce that provide the incentives for commercial agents to invest in fertilizer importation, wholesaling and retailing would be desirable. Encouraging more intensive use of other productivity enhancing inputs in addition to fertilizer is also suggested, since land consolidation to achieve economies of scale seems untenable in the light of the existing extensive fragmentation of land parcels into uneconomical units.

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LIST OF ACRONYMS

AGGDP	-	Agricultural Gross Domestic Product
AERC	-	African Economic Research Consortium
AEZ	-	Agro-ecological Zone
ARIMA	-	Autoregressive Integrated Moving Averages
ARZ	-	Agro-regional Zone
CAN	-	Calcium Ammonium Nitrate
CBS	-	Central Bureau of Statistics
CSRP	-	Cereal Sector Reform Programme
DAP	-	Diammonium Phosphate
ECM	-	Error Correction Models
EEC	-	European Economic Community
FAO	-	Food and Agriculture Organisation
FGLS	-	Feasible Generalised Least Squares
GDP	-	Gross Domestic Product
GoK	-	Government of Kenya
KFA	-	Kenya Farmers Association
KG	-	Kilogramme
KMDP	-	Kenya Maize Development Programme
MT	-	Metric tonne
NCPB	-	National Cereals and Produce Board
OPV	-	Open Pollinated Variety
SAP	-	Structural Adjustment Programme
SUR	-	Seemingly Unrelated Regression
TIAPID	-	Tegemeo Institute of Agricultural Policy and Development
WB	-	The World Bank

CHAPTER 1

INTRODUCTION

1.1 Background information

Maize is a major staple food for over 80% of Kenya's population (Nyameino, Kagira, and Njukia, 2003) and shortage in maize supply is, to a large extent, synonymous with food insecurity. It supplies 40% to 45% and 35% to 40% of the calories and proteins, respectively, consumed by an average Kenyan (Mghenyi, 2006). It is grown in virtually all agro-ecological zones of the country, ranging from highlands to semi-arid areas and humid coastal lowlands. It is estimated that maize accounts for 20% of all agricultural production and 25% of agricultural employment (Republic of Kenya, 2003). About 3.5 million small-scale farmers account for about 75% of the total maize produced in the country, while large-scale farmers account for the remaining 25% (Nyoro, 2002). Large-scale commercial farms, however, contribute a significant amount of total marketed maize output.

Due to the importance of maize for food security, the government of Kenya has over the years pursued policies that influence maize production and marketing. The policies, which have gone through several reforms, have been based mainly on the objective of self-sufficiency in maize. Prior to 1987, the government held full control of maize trading environment, as well as that of maize-inputs delivery system. Prices of maize and maize meal were set pan-seasonal and pan-territorial. Prices of inputs such as inorganic fertilizers and seeds were also controlled. The government also controlled inter-district movement of maize. Regulations were effected through the National Cereals and Produce Board (NCPB), which held monopoly of maize marketing.

This strict policy regime changed in 1987 when the country embarked on a Cereal Sector Reform Program (CSRP) as part of its overarching structural adjustment policies. The reform process intensified in the early 1990s when, under pressure from international lenders, the government eliminated movement controls on maize trading, deregulated maize and maize meal prices, and eliminated direct subsidies on maize sold to registered millers (Jayne and Kodhek, 1997). By the end of 1993, the market for maize was fully liberalized. The NCPB, however, remained active in the liberalized market, but its role was reduced from that of a sole trader to an agency buying maize for the purpose of building national strategic reserves.

These reforms, however, received mixed reactions. Farmer lobby groups argued that lower maize producer prices as a consequence of liberalization were a disincentive to production and, therefore, a direct threat to national food security. Consequently in 1999, the government reinstated the NCPB to procure maize at fixed support prices. Currently the government intervenes in the maize market in three ways: variable import tariffs on imports; maize procurement at support prices through the NCPB; and non-tariff barriers on imports. These policies are aimed at maintaining stabilized and reasonably high maize prices as incentives for producers to produce more maize.

With respect to controls in the input delivery systems, the government was involved mainly in the fertilizer market. Between 1974 and 1984, the government provided fertilizer importation monopoly to one firm, Kenya Farmers Association (KFA) (Ariga, Jayne and Nyoro, 2006). The monopoly position of KFA was later viewed as an impediment to the development of the fertilizer market, and during the rest of the 1980s, the government tried to encourage other firms to enter the market albeit under very tight controls. It determined which firms to operate, through licensing requirements and allocation of foreign exchange (Argwings-Kodhek, 1996). The government set official fertilizer prices to which the licensed firms and traders were to adhere. There was also donor fertilizer aid, accounting for over half of total imports during the late 1980s, over which the government was responsible for coordinating with the commercial imports. The government increasingly recognized that its controlled pricing structure did not ensure adequate margins for retailers to supply the relatively distant rural areas. While the controlled pricing structure was designed to improve farmers' access to fertilizer, it had the opposite effect in the more remote areas. These concerns led the government to reform the fertilizer marketing system (Ariga, Jayne and Nyoro, 2006). By 1993, fertilizer prices were decontrolled, donor imports dwindled to 5 % of total fertilizer consumption, and small-scale farmers have hitherto relied exclusively on the private sector and cooperatives for fertilizer supply.

1.2 Statement of the problem

Despite the government's pursuit of maize pricing policies aimed at giving maize producers higher and stabilized maize prices to motivate them to produce more, Kenyan maize production has not kept pace with consumption. In the last 13 years between

1990/1991 and 2002/2003, annual maize consumption averaged 30 million bags while production averaged 28 million bags (Jayne, Myers and Nyoro, 2005). To bridge the ever increasing gap between maize supply and demand, Kenya relies on imports. It is evident that the emphasis on higher and stabilized maize producer prices as a means to motivate increased maize production has not worked. While input prices, including fertilizer prices, as well as non-price factors, including land, access to markets, and household demographic characteristics, including education, often influence farm production, Kenyan maize supply response to these input prices and non-price factors is not known. Consequently, less emphasis has been put on the input prices and non-price factors in the policy objective of increased maize production for food self-sufficiency and security. There is, therefore, a pressing need for empirical understanding of maize supply response to price and non-price factors in order to enable informed policy formulation that will work appropriately towards pursuing the objective.

1.3 Objectives of the study

The overall objective of this thesis is to empirically assess maize supply response to price and non-price factors. The specific objectives are:

1. to estimate maize supply elasticity with respect to maize price;
2. to estimate maize supply elasticity with respect to prices of inputs (fertilizers and labour);
3. to estimate maize supply elasticity with respect to non-price factors (land, access to markets and education); and
4. to examine the relative importance of maize prices, input (fertilizers and labour) prices and non-price factors (land, access to markets and education) on maize supply.

1.4 Hypothesis of the study

This thesis is guided by the following hypotheses:

1. Own-price elasticity of maize supply is inelastic.
2. Positive relationship exists between maize supply and prices of inputs (fertilizers and labour).
3. Negative relationship exists between maize supply and non-price factors (land, market access and education).

1.5 Justification of the study

Understanding maize supply response to maize prices and input prices and how non-price factors, namely land, access to markets and level of education, influence maize supply is inevitable if effective policies are to be designed to encourage maize production. In Kenya, hardly any studies have been conducted on maize supply response taking into account the influence of prices of inputs and non-price factors. The past and present maize price policies have been based on the assumption that higher maize prices induce greater production, which further stimulates demand for purchased inputs. The strategic position of maize in food security considerations in Kenya, and the widening gap between maize production and maize consumption as a result of near stagnant maize production in the face of rising population calls for the stakeholders in the Kenyan maize sector to do more for the sector. This study is an attempt to understand, using farm-level data, maize supply response to maize prices and input prices as well as non-price factors. Estimates of maize supply and variable input demand elasticities with respect to maize price, variable input prices, and fixed inputs are valuable results in themselves, as they are a prerequisite and can be applied to assess the impact of a variety of micro-policy actions. Own-price elasticity of maize supply is important in understanding the effectiveness and impact of maize price policies on maize supply. Relative response of maize supply to maize price and input prices explains whether ‘getting maize prices right’ alone is enough in enhancing maize supply. This serves to inform policy debate on where price policies should be targeted to achieve higher maize production. Elasticities of maize supply with respect to non-price factors, namely land, access to market (measured by distance to motorable road) and household demographic characteristic, namely education level of household head, explain the importance of non-price factors in influencing maize supply. This gives insight into what policies regarding the relevant non-price factors should be pursued to increase maize supply. By providing empirical support to these postulates, this study serves to inform policy debate regarding the relative importance of price and non-price factors in influencing maize supply in Kenya. It is also hoped that the information revealed will complement the store of information that is already available on production in the maize sub-Sector. The present work will, thus, prove useful to public and private researchers and policy makers seeking to understand more of the Kenyan maize sub-sector.

1.6 Scope and limitations

This study is confined to maize as a single commodity and the findings cannot be generalised to other crops even though such crops might be produced under similar environmental and policy conditions as maize. The use of cross-sectional data for the study may imply underestimation of the elasticity of maize supply with respect to non-price factors. This is because if large farm operators were to become smaller over time (say as a result of demographic change), they would adopt the pattern of allocative behaviour of their smaller counterparts only with a lag. This implies that cross-sectional maize supply elasticity with respect to land size may be underestimated, other things remaining the same. For another, price variables may exhibit a significantly lower degree of variation in a cross-section than over time. This may lead to under-estimation of price elasticities.

1.7 Definition of terms

Maize supply: Maize supply in this study refers to domestic maize output (production).

Household: A household refers to a group of people, who live under one roof or compound, make and eat their meals together, and jointly make economic decisions.

The rest of the thesis is organized as follows: Chapter 2 presents a detailed review of studies on supply response in Kenya and other countries, focusing on objectives of the studies, methods used, results obtained and recommendations advanced. Theoretical underpin of the thesis is also discussed. Chapter 3 gives methodology followed, with focus on data sources, and empirical model. Results and discussion are presented in Chapter 4. Chapter 5 concludes by presenting summary of results, policy implications and recommendations and opportunity for further research in this area.

CHAPTER 2

LITERATURE REVIEW

The seminal work of Nerlove (1958) set the pace for studies on agricultural supply response to price and non-price factors. Since then, a number of studies on agricultural supply response to price and non-price factors have been undertaken across many regions, on individual commodities and at aggregate level. A significant number of these studies focus on price elasticity. These studies are important to agricultural response analysis because prices and non-price factors are the channels through which policies affect agricultural variables (e.g. output supply and input demand). Supply response results enhance an understanding of the impacts that alternative policy packages may have on households' production activities and other market participants. This chapter presents a review of some of the studies on agricultural supply response by examining critically the objectives, methodology applied and the findings of each of the studies. The theoretical basis for the present study is also presented.

2.1 Modelling agricultural supply response

Supply response studies have been widely surveyed by many economists. Comprehensive reviews of these studies have been provided by Askari and Cummings (1977), Berhman (1989), Rao (1989), Ozanne (1992) and Mamingi (1997). The reviews reveal that time-series data have been very popular in estimating supply equations for individual annual crops (Nerlove, 1958; Trail *et al.,* 1978; Jaforullah, 1993). The adaptive expectations model of Nerlove (1958), in which the expected price is a function of the most recent past price and past errors in predicting prices, has been the most popular in examining agricultural supply response. The Nerlovian specification of adaptive expectations is based on the history of past prices with weights declining geometrically over time. This approach has been criticized on the grounds that: (1) price weights are subjective as opposed to being the explicit outcome of an optimization process and (2) price predictions under-use the information available to the decision maker (i) on the structural process of price formation, for which one should use knowledge of both supply and demand or whatever more complete structural model is the best available predictor; (ii) on available forecasts about the exogenous variables that affect this process; and (iii) on anticipated policy changes that affect price formation, a process that corresponds to the 'Lucas critique' (Lucas, 1976). Nerlovian models, however, are quite practical, and their numerous variants have been applied to many crops in many countries (Sadoulet and de Janvry, 1995).

Modern research has relied on the more theoretically sound profit function approach to output supply and input demand (e.g. Sadoulet and de Janvry, 1995; Rao, 1989; Mundlak, 1985; Abrar et al., 2004; and Farooq et al., 2001). Compared with a correct theoretical specification of supply response as derived from the theory of producer behaviour, many formulations of the Nerlovian models have not been careful about specification of the estimated equations. Specifically, the estimated supply functions should be homogenous of degree zero in prices, include the prices of important factor inputs such as fertilizers, and make explicit the role of fixed factors. The profit function approach is both more theoretically rigorous and more demanding in terms of data. Profit function approach, however, has not paid attention to the mechanisms of expectations formation for prices and of partial adjustment in production. Sadoulet and de Janvry (1995) suggest that the best of what the two approaches offer needs to be integrated. How this is done depends, in each particular case, on the objectives of the analysis and the data availability, seeking to strike a balance between rigour and convenience. For the moment, theory is on the side of the profit function approach while theory is badly mistreated in most Nerlovian specifications (Sadoulet and de Janvry 1995).

2.2 Agricultural supply response studies

Debate on policy responsiveness of agriculture concentrates on the relative importance of price and non-price factors (Binswanger, 1990). Some researchers attach a pivotal role to price policies (World Bank, 1990), while others argue that policies oriented toward inputs are more effective in raising agricultural output in developing countries (Delgado and Mellor, 1984). Others maintain that prices and the provision of inputs and public support are co-requisites (Schiff and Montenegro, 1997). In developing countries, however, ambiguities abound about the precise role and impact of agricultural policies (Farooq, 2001). Partly this is attributable to the lack of farm-level analysis of the effects of policies (especially relating to prices) on the supply response of peasant farmers (Abrar, Morrisey and Rayner, 2004).

Supply response can be examined for broad agricultural aggregates or for single commodities. It is the supply response of specific commodities rather than of broad agricultural aggregates that is of importance for formulation and proper targeting of policies. There have been few studies conducted in Kenya on supply response of crops. However, studies on supply response are extensive. The few supply response studies that have been conducted in Kenya focused on single commodities (including maize) (Kere, et al., 1989, Kirori and Gitu, 1991, Gitu and Wyckoff, 1984 and Maitha, 1974) and aggregate agricultural supply (Narayana and Shah, 1984). The single commodity studies followed Nerlovian approach and used time-series data to provide predictions on how specific crops and livestock production will respond to variations in producer prices. The study by Kiori and Gitu (1991) focused on disaggregated estimates for each major crop and livestock commodity at both national and district levels and between large and small scale production systems. All the single commodity (crop) studies analysed hectarage response to crop output prices. The results from these studies supported the a priori expectations that producers respond positively to output prices, though there were variability in the elasticities computed.

Narayana and Shah (1984) employed auto regressive intergrated moving averages (ARIMA) estimations of expected prices and yields to estimate Nerlovian response functions for large and small farms in Kenya. The expected prices and yields were forecasted from past prices and yields by identifying the stationery and random components of each past price and yield. The results showed that (expected) yield levels, rather than expected output prices affected the supply response of small farms, whereas large farms reacted more strongly to output prices. The study considered broad agricultural aggregates and focused on the response of acreage on expected output prices and expected yield levels.

Both the single commodity and broad agricultural aggregates studies conducted in Kenya did not, however, take into account the response of farmers to input prices such as fertilizer prices and wage rates and non-price factors such as access to markets and household demographic characteristics such as education, which are also important in influencing farm production. Moreover, several policy changes that affect production and marketing structure of maize have occurred. These include the full liberalization of fertilizer market in 1990, partial deregulation of maize marketing, and imposition of variable import tariff on maize imports.

Several related studies on supply response have been conducted in several developing countries as Kenya. A study by Abrar, Morrisey and Rayner (2004) on the responsiveness of peasant farmers to price and non-price factors in Ethiopia using farm-level data found that own- price output supply elasticity was very low and output supply was not responsive to fertilizer prices or wage rate. Non-price factors were far more important in affecting production and resource use than price incentives. The study employed quadratic production function and compared the use of primal and dual approaches to estimating elasticities and concluded that both approaches give the same result. The study was based on broad agricultural aggregates. While supply response of broad agricultural aggregates rather than of specific commodities is important in analysing the supply response to agricultural policy reforms (since these reforms have a significant impact on the entire economy), its results are less applicable in informing policies targeting a specific commodity.

In another study, Abrar, Morrisey and Rayner (2002) assessed the responsiveness of peasant farmers to price and non-price factors using farm-level survey data from Ethiopia, and the extent to which responsiveness varied with agro-ecology and farming systems. Agro-climatic and farming system differences were explicitly accounted for by estimating separately output supply and input demand elasticities for three different agro-ecological regions. The study found that farmers responded positively and significantly to price incentives, and that responsiveness to prices was far greater in the more climatically favoured and commercially oriented regions. The study also observed some important differences in the relative importance of non-price factors across agro-ecological zones, although the differences were not generally large compared to the effects of prices. The study suggested that there was a need to strengthen market incentives through effective policies that would improve farmers' access to better quality land, credit and inputs, and public investment in roads and irrigation. Abrar, Morrisey and Rayner (2002) based the study on profit function and used normalized quadratic functional form. Again, the study was of aggregate nature and was not targeted to a specific commodity.

Abrar (1996) used farm-level data from Northern Ethiopia to examine aggregate agricultural supply response in the presence of technical inefficiency using profit function approach. He found that farmers in Ethiopia did respond significantly to price incentives. By explicitly incorporating technical inefficiency in the analysis Abrar's study departed from the neo-classical assumption of the existence of technical efficiency (i.e., that farmers use input resources available to them to achieve the maximum output, given the technology) which most micro-economic studies of supply response maintain. The current study, however, assumes the existence of technical efficiency and focuses on maize as a single commodity.

A claim that agricultural liberalisation which introduces price incentives and efficient marketing will encourage producers to respond motivated McKay, Morrisey and Vaillant (1997) to examine the aggregate supply response of agricultural output in Tanzania. Their estimated elasticities were quite high so that they concluded that the potential for agricultural sector response to liberalisation of agricultural prices and marketing may be quite significant in Tanzania. They also suggested that complementary interventions to improve infrastructure, marketing, access to inputs and credit, and improve production technology were also necessary. The study used Error Correction Model (ECM) with time-series data (a variant of Nerlovian models) and did not incorporate the influence on aggregate agricultural supply of non-price factors. The current study seeks to understand under the existing Kenyan maize marketing policy the supply response of maize using the profit function approach with cross-sectional data, examining also the influence on maize supply of non-price factors.

Sidhu and Baanante (1979) employed a restricted profit function approach to estimate jointly the profit and factor demand function from farm-level, cross-sectional data for Mexican wheat varieties in Punjab, India. The focus of the analysis was on fertilizer demand. The results indicated that output price was a more powerful policy instrument than fertilizer price to influence fertilizer use, output supply, and returns to fixed farm resources. The study also found that producers attained allocative efficiency, that education of the farm people significantly influenced agricultural production, and that profit function was a suitable concept for empirical analysis and interpretation. The study employed the Cobb-Douglas functional form, implying that the elasticity estimates were constant. This is unrealistic since diminishing marginal returns was obscured.

In a separate study, Sidhu and Baanante (1981) applied translog profit function to farm-level data from Punjab, India, to analyse supply response of wheat. They compared the translog and Cobb-Douglas profit function formulation and concluded that the flexibility afforded by translog formulation permitted measurement of the different impacts that exogenous variables have within and across input demand and output supply functions. The study found that expansion in farm capital, in the form of implements and machinery, decreased significantly the demand for animal power, contributed positively to wheat supply, but did not significantly influence labour and fertilizer demand. The study also found that expansion of irrigation increased demand only for farm labour and fertilizer but not for animal power. The expansion in education of farm family was found to increase demand for fertilizer and animal power and to significantly influence wheat supply. Exogenous increases in area under cultivation also increased wheat supply and demand for fertilizer, labour and animal power.

A study by Flinn, Kalirajan and Castillo (1982) estimated the supply response and input demand by rice farmers in Laguna, Philippines. Results indicated that farmers did maximize short-term profits and responded to price changes efficiently. Own-price elasticity of rice supply was found to be approximately unity. Changes in real wages were estimated to have a greater impact on rice profit and supplies than changes in real prices of mechanized land preparation, fertilizer or pesticides. The authors also found that production elasticities derived from the profit function were consistent with those estimated directly from the underlying production function. The study used profit function approach in the Cobb-Douglas form and this limited the generality of the results. For example, constancy of the elasticity coefficients implied constant shares regardless of input level. The Cobb-Douglas specification also meant that substitution among inputs was unity. These limitations render the Cobb-Douglas specification incapable of reflecting the reality of the production environment.

Haughton (1986) estimated the responsiveness of farmers to changes in output and input prices using cross-sectional survey data for farms in marginal rice-growing districts in West Malaysia. The purpose of the study was to test a hypothesis that supply response is sensitive to econometric model used and functional form employed. The study found that price elasticities estimated from input demand equations derived from a quadratic restricted profit function were superior to those derived from translog or Cobb-Douglas production functions or from a translog restricted profit function. The study concluded that Cobb-Douglas production function is restrictive and should be used sparingly in estimating output supply and input demand elasticities. The study also suggested that restricted profit functions are only believable if the available price data are of high quality. Despite the study findings, Anderson, *et al.* (1996) point out that economic theory is not sufficient to determine the suitable functional form, although it does aid in identifying relevant variables and homogeneity restrictions. The preferred functional form is both data and method specific and as such there is no universal conclusion as to the superiority of a particular functional form.

Microeconomic output supply and factor demand elasticities in agriculture of the Province of Taiwan were estimated by Yotopoulos, *et al.* (1976). The study employed restricted profit function in Cobb-Douglas form to analyze cross-sectional farm household survey data. The study found that own-price elasticities of output and variable inputs were all greater than one in absolute value, indicating an elastic response of factor utilization. Cross-price elasticities were, however, rather low, with the exception of output price and price of labour. Cross-price elasticities between variable inputs were negative, indicating that all the variable inputs were more complements than substitutes. The use of the Cobb-Douglas functional form of restricted profit to derive output supply and input demand functons from which the elasticities were computed implies that the elasticities were constant at all levels of input and output. This is contrary to diminishing marginal returns principle in production.

In studying determinants of rice supply in Bangladesh, Chowdhry *et al.* (1994) employed profit function approach using cross-sectional data. The study objective was to establish the importance of price and non-price factors in determining rice output. The study found that prices overall were insignificant determinants of rice output, while non-price variables- farm size, adoption of high-yielding rice varieties and farmer's managerial ability- significantly influenced rice supply. The study found that within the class of price variables, wage rate alone mattered in rice supply. Fertilizer prices did not make any difference in rice supply. Chowdhry *et al.* (1994) used normalised Cobb-Douglas profit function to derive output supply and input demand elasticities. Though the study preferred Cobb-Douglas to translog functional form due to the data set available, Cobb-Douglas functional form's limitation of constancy of estimated elasticities was inherent in the study.

Hattink *et al.* (1998) studied supply response of cocoa in Ghana. The study used cross-sectional farm-level production data based on profit function approach. The study found that cocoa producer price had an effect on cocoa production in the short run. In comparing their results with previous time series studies on cocoa supply response in Ghana, Hattink *et al.* (1998) found a somewhat smaller elasticity (0.13) than the elasticities (about 0.2) found in the time series studies. The study's result indicated that prices had a positive but small effect on resource allocation for cocoa production in the short run. For empirical analysis, the study used a normalised quadratic profit function because of the flexibility (non-constant elasticities) of this form as compared to logarithmic formulations. Even though Hattink *et al.* (1989) generalize that logarithmic formulations of profit function derive constant elasticities, elasticities derived from translog formulation (which is a logarithmic formulation) are non-constant. A disadvantage of the quadratic formulation of the profit function is that the choice of the numéraire affects the elasticity estimates.

Farooq *et al*. (2001) studied the supply response of Basmati rice growers in Punjab in Pakistan. The objective of the study was to assess the scope of price support policy to achieve growth targets and whether additional assistance was needed from non-price policy measures. The study employed a translog profit function using farm household cross-sectional survey data. The result of the study was that to increase aggregated production of Basmati paddy, a price support policy was inadequate and supplementary measures aimed at promoting expansion in area under Basmati paddy and improving its varietal age on farmers' fields, possibly through extension projects, were also desirable. The study also revealed that while deciding the support price for paddy, fertilizer prices needed careful consideration. Farooq *et al.* (2001), however, did not include access to markets as a variable in their model, though they had education level of household and farming experience of household head as variables but these were found to be insignificant in contributing to Basmati paddy production. The present study has used the translog profit function approach based on farm-level data to examine the supply response of maize in Kenya. The profit function approach makes it possible to incorporate input prices as well as non-price factors, in addition to maize prices, in the estimation.

2.3 Theoretical framework

Supply analysis encompasses the larger set of techniques that evaluate production responses to output-prices, input-prices and other measurable policy and environmental changes. The theory of the firm is the basis on which supply analysis is conducted (Colman, 1983). Approaches to supply analysis can be classified into two main groups: normative (programming) and positive (econometric) approaches (Day, 1963; Shumway and Chang, 1977; Colman, 1983; Sadoulet and de Janvry, 1995). In this study, a positive (econometric approach is followed).

When the choice falls on a positive (econometric) approach to studying supply response, the next consideration pertains to the two sub-groups of positive analysis: the primal approach and the dual approach (Colman, 1983; Sadoulet and de Janvry, 1995). Assume that the production transformation set is represented by:

$F(\mathbf{y}, \mathbf{x}; \mathbf{z}) = 0$……………………………..…………………………………………1

where **y** represents the vector of *m* outputs; **x** represents the vector of *n* variable inputs; and **z** represents the vector of *k* fixed inputs and other exogenous factors. In the literature, the term primal has been used to refer to an optimization problem consisting of a behavioural assumption (e.g. maximize profit) and a set of constraints (e.g. the production function). From a differentiable form of this specification, output supply and input demand equations can be derived by solving the first order conditions (Abrar, 2001). Output supply and input demand elasticities can then be estimated from the derived output supply and demand functions.

In the dual (or reduced form) approach, the production technology set is not estimated directly. The approach involves estimation of a profit function from either cross-sectional data (that show inter-farm variation in effective prices) or from long run time series data that show variation in prices and fixed factors or from a combination of the two data types (Sadoulet and de Janvry, 1995). Supply and factor demand functions, from which output supply and input demand elasticities are estimated, are then derived analytically. This approach is mainly used in cases with limited information on relevant primal variables and where possible estimation problems are associated with the production function approach (Chambers, 1988; Sadoulet and de Janvry, 1995). In the present study, only farm-level cross-sectional data on maize production were available. Accordingly, the available data could only support a dual approach to studying maize supply response.

Under the dual approach, using profit function,to supply response analysis, Lau (1978) has shown that the restricted profit function, defined as the excess of total value of output over the costs of variable inputs, is expressed as:

$$\pi = \pi(\mathbf{p}, \mathbf{w}; \mathbf{z}) \qquad \ldots\ldots 2$$

where π, **p** and **w**, respectively, represent restricted profit and vectors of output and input prices, while **z** represents quantities of fixed factors of production. This function depicts the maximum profit the farmer could obtain given prices, availability of fixed factors and the production technology (1). The optimization (using Hotelling's Lemma) of the profit function (2) gives the profit-maximizing level of output supply and input demand functions respectively as:

$$\mathbf{y}_m(\mathbf{p}, \mathbf{w}; \mathbf{z}) = \partial\pi(\mathbf{p}, \mathbf{w}; \mathbf{z}) / \partial \mathbf{p}_m, \qquad \ldots\ldots 3$$

and $$-\mathbf{x}_n(\mathbf{p}, \mathbf{w}; \mathbf{z}) = \partial\pi(\mathbf{p}, \mathbf{w}; \mathbf{z}) / \partial \mathbf{w}_n \qquad \ldots\ldots 4$$

where m and n index the outputs and variable inputs respectively. In the case of a single output, a normalized restricted profit function (defined as the ratio of the restricted profit function to the price of the output), π^*, can be specified. It depicts the maximized value of normalized profits given normalized (relative) prices of the variable inputs, $\mathbf{w}_n^*$, and the quantities of fixed factors, i.e.

$$\pi^* = \pi^*(\mathbf{w}^*; \mathbf{z}) \ldots \qquad (5),$$

from which the factor demand equations are derived as:

$$-\mathbf{x}_n (\mathbf{w}^*; \mathbf{z}) = \partial\pi^*(\mathbf{w}^*; \mathbf{z}) / \partial \mathbf{w}_n^*, \qquad (6)$$

In the case of multi-output normalised profit function, the numéraire is the output price of the n^{th} commodity (Färe, *et al.*, 1995). Normalisation has the purpose of removing any money illusion - in other words, producers respond to relative price changes. Normalisation also reduces the demand on degrees of freedom, by effectively reducing the number of equations and parameters to estimate. The system of normalized restricted profit function and factor demand equations are simultaneously estimated. Output supply and input demand elasticities are computed from the estimated parameters of the profit function and input demand equations.

The use of profit function in estimating supply response poses the challenge of the appropriate functional form of profit function to use. The choice of functional form is usually a compromise between theoretical requirements and econometric feasibility. Some of the commonly used functional forms are translog, quadratic and Cobb-Douglas. In this study the traditional Cobb-Douglas functional form was deemed unattractive because of the following limitations it exhibits:

(i) It generates constant elasticities at all levels of output and inputs, so that diminishing marginal returns are unobservable; and

(ii) Inputs must be used in strictly positive amounts. However, it is common to find that only some farmers use, say, fertilizer. In such a case the sample must be divided, or the variable in question eliminated, or a dummy be included. In any of these options information will be lost.

The disadvantage of the quadratic functional form is that the choice of the numéraire does affect the elasticity estimates. This study adopted the translog profit function to estimate maize supply response. The translog profit function has a convenient property of being flexible both in the sense of allowing for theoretical restrictions to be tested and offering a second order approximation of any function.

2.4 Assumptions

The following assumptions were made in this study:

1. Maize producers are profit maximizers. This assumption is necessary when supply response is estimated using profit function approach.
2. Homogeneity, convexity and symmetry conditions hold for the input demand and output supply functions. These conditions are necessary in utilization of duality approach in modelling supply response.

CHAPTER 3

METHODOLOGY

This chapter begins by describing the area of study in Section 3.1. Source of data for the study and sampling procedure followed in selecting the sample are presented in Sections 3.2 and 3.3, respectively. Justification for use of cross-sectional data is provided in Section 3.4. A detailed empirical model for the study is given in Section 3.5. Section 3.6 explains the Heckman procedure, while Section 3.7 describes estimation procedure for the model. The chapter concludes by discussing the variables used in model estimation.

3.1 Area of study

Kenya is located in East Africa and is bordered by Ethiopia to the north, Sudan to the north–west, Uganda to the west, Tanzania to the south-west and Somalia to the east. Indian Ocean borders Kenya to the south-east. The map of Kenya depicting its geographical location is presented in Appendix 1. Kenya has a total area of 582,646 square kilometres, of which 11,230 square kilometres is covered by water. The population of Kenya was estimated at 33.4 million people in 2005, with males numbering 16.2 million and females numbering 17.2 million (Republic of Kenya, 2006).

Kenya has tropical climate. The long rains occur from April to June and short rains from October to December. The long rains period define the main crop season while the short rains period define the short crop season. February and March are the hottest periods, while July the coldest period. Agriculturally, Kenya is divided into nine agro-regional zones (according to TIAPID's agro-regional categorization), namely Western Highlands, Western Lowlands, Western Transitional, High Potential Maize zone, Central Highlands, Eastern Lowlands, Coastal Lowlands, Marginal Rain Shadow and Northern Arid Lands. These zones define agricultural enterprises that can be viably practised in them, but, nevertheless, maize is grown in virtually all the zones.

3.2 Sources of data

This study utilized cross-sectional farm household data on maize production and socio-economic characteristics. The data were provided by Tegemeo Institute of Agricultural Policy and Development (TIAPID), a research institute of Egerton University. The data covers main crop season of 2003/2004 cropping year. The data were collected in the third wave of a country-wide true panel survey on 1397 households conducted between June and August 2004. The first and the second waves of the panel were conducted in 1997 and 2000, respectively. The first and the second waves of the true panel were not used in this study because data on labour input into maize production were limited (the first wave had labour input data only on one maize field while the second wave had data only on hired labour input). One of the agro-regional zones (Northern Arid Lands) was not included in the third wave of the survey.

The choice of the data on 2003/2004 cropping year was based on the data's richness in household agricultural production information, especially on maize production. Out of the 1397 households, 1375 households produced maize in the main crop season in 2003/2004 cropping year. Out of the 1375 households, data on 1187 households were used for the analysis. Households that registered negative profits from maize production were not included in the analysis.

3.3 Sampling procedure

TIAPID's true panel was designed following a mix of purposive, multistage and systematic sampling techniques. Table 1 presents a summary of the stages involved in drawing the sample. Except for the selection of divisions, randomness was observed in the selection of locations, sub-locations, villages and, ultimately, households.

Table 1: Sampling stages and procedure and sample size

Step	Sampling unit	Sampling procedure	Sample size
I	Division	Purposive	41
II	Location	Multistage	47
III	Sub-location	Multistage	66
IV	Village	Multistage	110
V	Household	Systematic	1540

Source: Household Survey, 1997, TIAPID

National Census data of 1989 were used to establish the human populations of all non-urban divisions in Kenya. The divisions were assigned to one or more agro-ecological zones (AEZ) based on secondary data on agronomic characteristics obtained from the District Development Plans and the Farm Management Handbook and experience of the researchers at TIAPID. This process resulted in dividing Kenya's rural population into its make-up by AEZ. Within each AEZ, two or three divisions were chosen on the basis of their importance (population size) within the AEZ. Diversity in cropping patterns was allowed to influence the selection of divisions where it was not clear which divisions to select.

More diversity in cropping pattern within divisions was preferred since the aim was to get a sample that represented well the varied conditions faced by farmers in the country. The selected divisions fell within 24 districts. The divisions were grouped into 9 broad agro-regional zones (ARZ) – a hybrid of administrative boundaries and AEZs. From each of the selected divisions, locations were then randomly selected. From the selected locations, random selection of sub-locations and villages in that order followed. From the selected villages, and with the help of the local administration officials and key informants, all household units within the villages were listed by the name of the head of the household (not in alphabetical order). A systematic sampling technique was used to select the households comprising the sample. Blind chance balloting was applied to determine the beginning selection from each list of households. The sample comprised 1540 households[1] spread in 24 districts out of the country's total of 71 districts in 1997.

Because of the purposive sampling technique employed in selecting divisions and small sample sizes in some districts, concerns have been raised about whether the TIAPID's dataset is representative, and if so at which level. The sampling technique was aimed at selecting divisions among which there were variations in agro-regional zones, and which showed within-diversity in order to ensure that the resultant sample reflected the diverse conditions faced by farmers. The sample thus represents well the diverse farming environments and agro-regional conditions facing Kenyan farmers. TIAPID's dataset can therefore be viewed to be representative at the level of broad agro-regional zones rather than at administrative boundaries such as districts and provinces. Table 2 shows the spread of the sample households in the agro-regional zones, agro-ecological zones, districts and divisions.

[1] The first wave of the panel had 1540 households while the third wave (2004 survey) covered 1397 households. This was due to attrition, as is expected in a panel study.

Table 2: Geographical distribution of the sample of households studied

Agro-regional zone	Agro-ecological zone	District	Division	Number of households
Coastal Lowlands				**30**
	CL	Kilifi	Kaloleni	27
	CL	Kwale	Kinango, Msambweni	3
Eastern Lowlands				**125**
	CL	Taita Taveta	Mwatate	4
	LM3-6	Kitui	Chuluni	18
	LM3-6	Machakos	Mwala	20
	LM3-6	Makueni	Kilome	51
	LM3-6	Mwingi	Migwani	32
Western Lowlands				**148**
	LM3-6	Kisumu	Kadibo, Nyando,Winam	89
	LM3-6	Siaya	Uranga, Bondo	59
Western Transitional				**144**
	LM1-2	Bungoma	Kanduyi	44
	LM1-2	Kakamega	Kabras, Mumias	100
High Potential Maize Zone				**361**
	UM2-6	Bungoma	Kimilili, Tongaren	35
	UM2-6	Kakamega	Lugari	24
	LH	Bomet	Kimulot	34
	LH, UM2-6	Nakuru	Mbogoine, Molo, Njoro	96
	LH	Narok	Ololunga	23
	UM2-6	Trans Nzoia	Cherangani, Saboti	55
	UH, LH	Uasin Gishu	Ainabkoi, Moiben	94
Western Highlands				**133**
	UM0-1	Kisii	Marani	82
	UM0-1	Vihiga	Sabatia	51
Central Highlands				**211**
		Meru	W. Abothogucii	73
	UM0-1, UM2-6	Muranga	Kangema, Kiharu	57
	LH, UM2-6	Nyeri	Othaya, Mukurweini	81
Marginal Rain Shadow				**35**
	L	Laikipia	Lamuria	35
Total				**1187**

Note: CL=coastal lowland; LM3-6=lower midland 3-6; LM1-2=lower midland 1-2; UM0-1=upper midland 0-1; UM2-6=upper midland 2-6; LH=lower highland; L=lowland

Source: Household Survey, 2004, TIAPID

3.4 Justification for use of cross-sectional data

For profit function approach to yield reliable supply response results, sufficient price variation is of necessity. While price variation is seldom a problem in time series data, the nature of price variation in cross-sectional data usually is not as wide as is with time series data. While time series data would have been ideal in this study, such data was unavailable. In Kenya, it is exceedingly difficult, if not impossible, to put together a time-series on fertilizer and labour use for maize cultivation as a precursor to estimating maize supply response while taking into account input prices and non-price factors. Only data on aggregate quantities of fertilizer used are available in time-series, while time-series data on labour use on maize production is completely absent. Panel data sets, generated through sample surveys, while a better basis in this context, are usually rare, and in most cases do not have consistent content across the panel. Hence, in this study it remained an adequate procedure to use cross-sectional data to estimate maize supply and input demand elasticities using the competitive assumptions required by the profit function approach.

3.5 Empirical model

This study adopted profit function approach to estimate maize supply response. Specifically, the farm household is assumed to maximize 'restricted profits', defined as the gross value of output less variable costs, subject to a given technology and given quantities of fixed factors. The resultant profit function depicts the maximum profit attainable for given input and output prices, the availability of fixed factors and the production technology. Since the study focuses on a single output, maize, the profit function is normalized using maize price. The normalized profit (defined as the ratio of profit to the output price) is a function of the relative price of inputs and fixed factors. Since the output price is used as a numéraire in this case, optimization of the normalized profit function derives the behavioural equations of variable inputs demand. The output supply equation is dropped and the profit and variable inputs demand equations are jointly estimated. Such joint estimation of the profit and variable inputs demand equations permitted by the profit function approach ensures consistent parameter estimates (Sidhu and Baanante, 1981). Output supply and input demand elasticities are then computed from the coefficients of the estimated normalized restricted profit and variable inputs demand equations.

The normalized restricted profit function in translog form is given by:

$$In\pi^* = \alpha_o + \sum_{i=1}^{2}\alpha_i In\mathrm{P}_i^* + \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2}\gamma_{ij} In\mathrm{P}_i^* In\mathrm{P}_j^* + \sum_{i=1}^{2}\sum_{k=1}^{3}\delta_{ik} In\mathrm{P}_i^* In\mathrm{Z}_k$$
$$+ \sum_{k=1}^{3}\beta_k In\mathrm{Z}_k + \frac{1}{2}\sum_{k=1}^{3}\sum_{h=1}^{3}\psi_{kh} In\mathrm{Z}_k In\mathrm{Z}_h + DU \tag{1}$$

where,

π^* = Restricted profit, π , normalized by the output price (P) (Ksh/kg)

P_i^* = Price of *i*th input (P_i) normalized by the output price (P) (Ksh/kg)

Z_k = Quantity of fixed input, *k*.

DU = Dummy for Agro-regional Zone (1= High potential zone; 0, otherwise)

$\alpha_o, \alpha_i, \gamma_{ij}, \delta_{ik}, \beta_k, \psi_{kh}$, are parameters to be estimated.

In = Natural logarithm

The corresponding share equations are expressed as,

$$S_i = \frac{\mathrm{P}_i\mathrm{X}_i}{\pi} = -\frac{\partial In\pi^*}{\partial In\mathrm{P}_i^*} = -\alpha_o - \sum_{j=1}^{2}\gamma_{ij} In\mathrm{P}_j^* - \sum_{k=1}^{3}\delta_{ik} In\mathrm{Z}_k \tag{2}$$

$$S = \frac{\mathrm{PX}}{\pi} = 1 + \frac{\partial In\pi^*}{\partial In\mathrm{P}} = 1 - \sum_{i=1}^{2}\alpha_i - \sum_{i=1}^{2}\sum_{j=1}^{2}\gamma_{ij} In\mathrm{P}_j^* - \sum_{i=1}^{2}\ \sum_{k=1}^{3}\delta_{ik} In\mathrm{Z}_k \tag{3}$$

where S_i is the share of *i*th input in the restricted profit, S is the share of output in the restricted profit, X_i denotes the quantity of input *i* and X is the level of maize output.

Since the input and output shares form a singular system of equations (since by definition $S - \sum S_i = 1$), the output share equation was dropped and the profit and factor demand equations were estimated as a simultaneous system. From the parameters estimated, variable input demand elasticities and output supply elasticities were computed at mean values of the variables.

The use of profit function approach in estimating supply response requires that the function satisfy the following regularity conditions:

(i) Linear homogeneity in prices

The profit function is homogenous of first degree in prices, implying that if all prices (of output and inputs) increased by a constant multiple λ, nominal profit (as opposed to normalized profit) will go up by the same multiple λ.[2]

A corollary to the linear homogeneity condition is that output supply and input demand equations are homogeneous of degree zero in prices, implying unchanged output supply and input demands for equal proportionate changes in all prices. That is, output supply and input demands can be expressed as functions of normalized prices.

(ii) Symmetry

This implies that since the profit function is continuous and twice differentiable, its second-order partial derivatives must be invariant to the order of differentiation. That is, for profit function (1), $\gamma_{ij} = \gamma_{ji}$, $\delta_{ik} = \delta_{ki}$, $\psi_{kh} = \psi_{hk}$

(iii) Monotonicity

The estimated values for output supply and input demand associated with the profit function must be positive at all data points; negative quantity makes no economic sense.

(iv) Convexity in prices

The matrix of the second derivatives of the profit function with respect to prices, called the Hessian matrix of price derivatives, must be positive semi-definite.

3.6 Two-step Heckman procedure

It was expected that not all the households used all variable inputs in the production of maize. As such it was expected that the inclusion of such variable inputs in the model would result into some particular problems, which are quite typical for imported, external inputs in low-income countries like Kenya, where markets are often far from perfect. Input market integration is low and constant availability is problematic; therefore the use of purchased production inputs is limited (Hattink, Heerink and Geert, 1998). It is, therefore, questionable whether every household could purchase a variable input at the time it wanted,

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[2] The normalization process discussed before is based on this property. Specifically, setting λ equal to $\frac{1}{P}$ yields the normalized profit function as in (1).

as is implicitly assumed in the neoclassical demand function, (the S_i equation specified before). In such a situation it requires that a correction for zero use of variable input by means of a two-step Heckman procedure is specified (Amemiya, 1984). The first step of the Heckman procedure involves the estimation of the probability of using an input by means of a probit maximum likelihood using the following binary choice model:

$$F^*=H\theta+u$$

where F^* is an unobserved latent variable determining a household's decision to buy an input, H is a set of household characteristics hypothesized to affect the input use, θ is a vector of coefficients to be estimated and u is error term. The observed binary variable will be:

$F^* = 1$ (i.e., $F^*>0$, for users of the input)

$=0$, otherwise (i.e., $F^*<0$, for non-users of the input)

Then, the resulting values of the vector θ are used to compute vectors of inverse Mills ratios, $M_1=\frac{\Theta}{\Phi}$ and $M_2=\frac{-\Theta}{1-\Phi}$, respectively, for sub-samples of users and non-users of the input. $\boldsymbol{\Theta}$ and $\boldsymbol{\Phi}$ are, respectively, the standard normal density and cumulative distribution evaluated at the point Hθ (Savadogo, Reardon and Pietola, 1995). In the second stage, the adjusted demand function for the input in question is estimated along with the other equations in the system by including M_1 and M_2 as regressors for users and non-users, respectively of the input. Once this correction is made, all observations, including observations where the input was not used in production, can be used to estimate the input demand equation. In the context of the present study the adjusted input share equation thus is of the form:

$$S_i = \frac{P_i X_i}{\pi} = -\frac{\partial In\pi^*}{\partial InP_i^*} = -\alpha_o - \sum_{j=1}^{2}\gamma_{ij} InP_j^* - \sum_{k=1}^{3}\delta_{ik} InZ_k + \mu(M_1)$$

and

$$S_i = \frac{P_i X_i}{\pi} = -\frac{\partial In\pi^*}{\partial InP_i^*} = -\alpha_o - \sum_{j=1}^{2}\gamma_{ij} InP_j^* - \sum_{k=1}^{3}\delta_{ik} InZ_k + \mu(M_2) \tag{4}$$

for the users and non-users, respectively, of the input.

Although theoretically the Heckman procedure sounds rather well, applying it in practice is never so straightforward. By including inverse Mills ratio in the demand equation of the input, the equation is only identified from the non-linearity imposed by the Heckman procedure (since the inverse Mills ratio is a non-linear function of the independent variables). But relying purely on non-linearities for identification is not the best strategy and so one needs as a condition at least one variable that enters the probit and not the input demand equation. If such a variable is absent, then the estimation is essentially reduced to a generalized Tobit.

3.7 Model Estimation procedure

For an econometric estimation of the model as represented by (1), (2) and (3) in section 3.5, a stochastic structure for the model is assumed by adding error terms. The error terms are assumed to be additive, and to follow a multivariate normal distribution with a zero mean and a constant variance.

Since the parameters appearing in the input share equations (2) and (3) also appear in the profit function (1), increased efficiency would be obtained if all these equations were estimated jointly. However, after normalization of the profit and input prices by the output price, the output share equation (3) is dropped and the estimation proceeds with the profit equation (1) and the variable input share equations (2) or (4).

The model represented by (1), (2) and (4) involves a system of seemingly unrelated regressions where contemporaneous correlations across equations are assumed. This is a reasonable assumption in that the parameters of the model are shared across equations. However, the application of the Ordinary Least Squares method in this situation would result in inefficiency as it would ignore the correlation of error terms across equations (Greene, 1997, pp. 675). In other words, ‘‘by estimating each equation separately and independently, we are disregarding the information about the mutual correlation of the disturbances, and the efficiency of the estimators becomes questionable’’ (Kmenta, 1986, pp.637). For efficient estimators, Zellner’s estimation technique for seemingly unrelated regressions (Zellner, 1962) was employed.

Seemingly unrelated regression estimation involves the technique of three-stage least squares, which applies the feasible generalised least squares (FGLS) estimation to the system of equations. Note that in this study the output price was chosen as the numéraire in the model and the FGLS estimates are sensitive to the choice of the numéraire. Invariance was, however, achieved by iterating FGLS procedure which also generates the maximum likelihood estimates of parameters (Greene, 1997, p. 691). SUREG command in STATA was used for the estimation.

3.8 Description of variables

The price and non-price variables that were included in the estimation of the model are presented in Table 3. Expected sign of maize supply elasticity with respect to variable inputs' prices and non-price factors are presented in the fourth column of the table.

Table 3: Price and non-price variables included in model estimation

Variable	Description	Measurement	Expected maize supply
Nprofit	Restricted profit normalized by the price of maize	Kenya shillings	
PF	Price of fertilizer normalized by the price of maize	Kenya shillings per kilogram	-
PL	Wage rate normalized by the price of maize	Kenya shillings per day	-
Z1	Land area under maize	Hectares	+
Z2	Distance to the nearest motorable road	Kilometres	-
Z3	Household head's education	Number of years of formal schooling	+
DU	Dummy variable for agro-regional zone	1=high potential 0, otherwise	
M	Inverse Mills Ratio		
Seeduse	Dummy variable for type of maize seed used	1=high yielding maize variety 0, otherwise	
Ofarminc	Household off-farm income	Kenya shillings	

Fertilizer is very important in influencing maize productivity. Fertilizer price is a major component in the farmers' decision to use fertilizer. The price of fertilizer is expected to vary greatly across agro-regional zones and across seasons since input market conditions across the regions are varied. It is expected that an increase in the price of fertilizer will reduce fertilizer demand and depress maize supply. It is also expected that not all the households in the sample used fertilizer in maize production.

Maize production is a labour intensive activity. Operations such as weeding, fertilizer application and harvesting are the most commonly manually performed. Both family and hired labour are used on such activities. Daily wage rates for labour are expected to differ across agro-regional zones and even across villages. Family labour was valued at prevailing market wage rate in the village. As such the wage rate faced by family labour and hired labour in a household was assumed to be the same. The wage rate used is measured in shillings per man-day. In valuing family labour, adult female labour input was assumed to be 75% that of an adult male as women typically have other demands on their time such as preparing food, collecting fuel wood, making purchases at the market and tending to young children in the household. Children's[3] labour was valued at 50% that of an adult male. No discrimination was made between labour input by male and female children. The reasoning is that female children do not have competing activities that would make them contribute significantly less labour input than their male counterparts. It is expected that an increase in wage rate will depress demand for labour and reduce maize supply.

Maize price is used as a numéraire and does not directly enter the model as a variable for estimation. It is expected that elasticity of maize supply with respect to maize price is positive, as theory postulates. Although support prices offered by NCPB provide a floor to average market prices during post-harvest periods, the maize prices received by farmers are expected to depend on their specific market conditions. As such some variation in maize prices is expected even within a village. Households that did not sell maize did not have maize prices reported. However, although maize prices varied even within villages, the variation in prices in a given district was not much, so that mean district maize prices were used as imputed prices for households that did not report maize sales. Maize price is measured in shillings per kilogram.

A number of farm and farm-operator-related variables are defined as fixed factors in the model. Land area planted with maize by the household is considered to constrain maize production in the short run, and so was considered a fixed input. Moreover, decisions on how much of what input (fertilizer and labour) to allocate to maize production are made assuming a fixed area of land allocated to maize production. It is expected that increase in land area under maize will have an expansionary effect on maize output.

Education (years of formal schooling) of the household head was included in the

[3] A 'child' herein is defined as any household member less than 15 years of age.

model to capture the role of human capital in maize production and input use. Some studies (e.g. Sidhu and Baanante, 1981) have used the average number of years of schooling per family member of the farm household to capture the role of human capital in farm production. However, in this study it is believed that the household head takes the leading role in decision making with regard to farm operations, so that his/her level of education is more relevant than the average education level per household member. It is expected that increase in the level of education of a household head will enhance maize production efficiency and increase production

Distance from the household's homestead to the nearest motorable road was used as a proxy for market access to capture the role of access to markets (both for input and output) in influencing output supply and input use. Distance to the market has often been found to be a key issue in production analysis and has been used as a proxy for market access, although, in Kenya, the quality of roads is also becoming an important issue in this debate (Karanja, Jayne and Strasberg, 1998). Another measure often used for market access is walking time to the market place, but this measure ignores the condition of roads and is subjective as the time reported depends on the estimation of the individual reporting. The distances to the nearest motorable road were collected from the respondents and confirmed by the researchers.

To control for agro-regional differences, a dummy variable for agro-regional zones was included in the model. This study, however, departs from TIAPID's classification of agro-regional zones into nine. The zones were grouped into two: high potential and low potential. The high potential zone comprises high potential maize zone, western highlands, western transitional and central highlands. The low potential zone comprises western lowlands, eastern lowlands, coastal lowlands and marginal rain shadow. The major characteristics that differentiate the high potential zone from the low potential zone are that fertilizer use on maize and maize productivity is higher in the former. The dummy variable thus defines whether a household belonged to a high potential zone or not.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter begins by giving a general description of the socio-economic characteristics of maize production in Kenya in Section 4.1. Section 4.2 provides a discussion on maize supply and variable input demand elasticities. Estimation results of the model are reported and tests for suitability of the translog functional form and validity of the regularity conditions for the profit function discussed.

4.1 Socio-economic characteristics of maize production in Kenya

As has been explained in section 3.2, the data used for this study pertain to main season maize crop of 2003/2004 cropping year and covers 1187 households. These households were predominantly small holder maize producers, with 76 % having less than one hectare under maize. Only five out of the 1187 households had more than four hectares under maize. Essentially, therefore, it can be argued that the sample comprised of small-scale maize producers. Of the 1187 households, 61% applied fertilizer on maize while 39% did not apply. 91% of the households that applied fertilizer on maize were in the high potential zone while only 9% were in the low potential zone. Of the households that used fertilizer on maize, 75% used high yielding[4] maize varieties while 25% used local varieties.

Table 4 presents summary of fertilizer application rate, maize yield and household off-farm income by quartiles. Overall mean application rate for fertilizer is 82 kg/ha. The lowest quartile has mean application rate per hectare of zero, while the 4th quartile has an application rate of 252 kg/ha. These rates show wide variations in intensity of fertilizer use among the sample households, which can be attributed to varied ecological and economic conditions the households face. Maize yield averaged 1854 kg/ha. The lowest quartile had maize yield at 388 kg/ha. While mean maize yield difference between the 2nd and 3rd quartiles is not wide, mean maize yield difference between the 3rd and the 4th quartiles is very wide; ranging from a mean of 1946 kg/ha to a mean of 4021 kg/ha. The variation in mean maize yields can also be attributed to ecological and economic variations among the sample households. Most of the households (85%) had off-farm income. The mean off-farm income

[4] High yielding maize variety refers to New hybrid, New OPV, retained hybrid or retained OPV.

for a household was Ksh 77,643, with wide variations across the quartiles.

Table 4: Quartile means of fertilizer application rate, maize yield and off-farm income

Quartile	Fertilizer application rate (kg/ha)	Maize yield (kg/ha)	Off-farm income (Ksh)
1	0	388	373
2	20	1,061	12,683
3	92	1,946	51,519
4	252	4,021	245,778
Overall Sample	**82**	**1,854**	**77,643**

Source: Author's computation

Summary statistics of price and non-price variables are presented in Table 5. The coefficients of variation for prices of fertilizer, labour and maize ranged between 14 % and 41 %, suggesting there was sufficient variation across farms to permit maize supply response analysis using the profit function approach. Education level (number of years of formal schooling) of the household head ranged from zero to 16 years, with a mean of 6.5 years. 19 % of the households had the heads having zero years of formal schooling while 72 % of the households had the heads having below nine years of formal schooling.

Table 5: Summary statistics of price and non-price variables

Variable	Mean	Standard deviation	Coefficient of Variation (%)
Price of maize (Ksh/kg)	13.39	2.66	19.86
Wage rate (Ksh/day)	81.32	33.17	40.80
Price of fertilizer (Ksh/kg)	28.57	4.15	14.53
Land area under maize (Hectares)	0.76	0.86	113.16
Distance to motorable road (km)	1.00	1.27	127.64
Education level of household head (years)	6.56	4.41	67.22

Source: Author's computation

The shares of the variable inputs and output in maize production are reported in Table 6. The share of labour in the profit is the ratio of the total value of labour used in maize production to restricted profit from maize production. Likewise, the share of fertilizer in the profit is the ratio of the value of total fertilizer used in maize production to restricted profit from maize production. Output share is the ratio of the value of total maize output to restricted profit from maize production. By definition, the difference between output share and the sum of variable inputs' share equals one.

Table 6: Share of labour, fertilizer and output in maize production

Type of share	Mean	Standard deviation
Variable input's share		
Labour	0.3924	2.0410
Fertilizer	0.2193	1.1422
Output share	1.6117	2.6834

Source: Author's computation

4.2 Maize Supply and variable input demand elasticities

This section presents estimation results of the model. Test results for appropriateness of the translog functional form and validity of the regularity conditions for the profit function are discussed. Estimated elasticities, which form the crux of this study, are presented and hypotheses discussed on the basis of signs and magnitude of the elasticity estimates.

4.2.1 Factors Influencing probability of use of fertilizer on maize production

In this study it emerged that 39% of the 1187 households did not use fertilizer on maize. It was thus necessary to correct the sample for zero fertilizer use by applying the Heckman procedure, since excluding from the sample households that did not use fertilizer on maize was not feasible. The factors that were hypothesized to influence the decision of a household to use fertilizer on maize were land area under maize, whether a household used improved maize seed or not, agro-regional zone, education level of household head and amount of off-farm income for a household. Since the Heckman procedure requires that at least one variable that does not enter the fertilizer share equation be included in the probit estimation, off-farm income and dummy for use of high yielding maize variety were included in the probit estimation. These variables were not included in the fertilizer share equation.

The results of the estimation of the probit selection model are presented in Table 7. The maximum likelihood probit procedure in Nlogit was used to estimate the model.The results of the goodness of fit (likelihood ratio chi-square of 447.3715 with a p-value of 0.0000) show that the variables are highly significant in explaining fertilizer use and that the model as a whole is statistically significant in explaining fertilizer use, as compared to a model with no predictors. Households that used high yielding maize variety were more likely to use fertilizer in maize production than households that used local maize variety. Level of education of household head significantly affects the probability of using fertilizer on maize production. Households in the high potential zone were more likely to use fertilizer on maize production than those in the low potential zone. This may be due to higher returns on fertilizer use in the high potential zone than in the low potential zone.

Table 7: Factors influencing probability of using fertilizer on maize production

Variable	Coefficient	P>z
Area under maize	0.0218	0.3417
Maize seed dummy	0.7930*	0.0000
Zone dummy	1.3010*	0.0000
Education	0.0408*	0.0001
Off-farm income	0.0000*	0.1861
Intercept	-1.4897*	0.0000

*Significant at 5 % level or below. The Likelihood Ratio chi-square is 447.3715 with a p-value of 0.0000. Predictions were 78 % correct.
Source: Author's computation

The inverse Mill's ratio was generated for each household. This ratio was additively included as a regressor in the fertilizer share equation. This ensured correction for selectivity bias in the fertilizer share equation. The inclusion of the inverse Mill's ratio thus permitted the inclusion into the estimation of the fertilizer share equation cases where there was zero fertilizer use on maize.

4.2.2 Factors influencing fertilizer and labour demand and profit in maize production

Tables 8, 9, and 10 show, respectively, parameter estimates of the share equation for fertilizer, share equation for labour and normalized restricted translog profit function, with symmetry restrictions imposed. Although the tables list all the variables involved in the estimation of the model, some discussion will be devoted to only a few variables that are significant. Here a variable is said to be significant if the p-value of the parameter estimate associated with the variable is less than or equal to 0.05. Much of the discussion is presented in sub-section 4.2.4 where the focus is on the elasticity estimates, the prime concern of this study.

The results of the estimation for the fertilizer share equation (Table 8) show that, using a p-value of 0.05 as the cut-off point, no price variable is significant but the function is, however, downward sloping with respect to fertilizer price. However, for the parameter estimate of the natural logarithm of the fertilizer price, the size of the rejection region is too large to admit any conclusion about the parameter estimate. A test of the null hypothesis that the parameter estimate is zero is only rejected at a level of significance greater than 0.4350.

The parameters associated with land area and zone dummy (p-values of 0.0970 and 0.0000 respectively) are significant. This suggests that land area has a significant positive impact on fertilizer demand. Agro-regional differences too have a significant influence on fertilizer demand.

Table 8: Price and non-price factors influencing fertilizer demand in maize production

Variable	Coefficient	t-statistic	P>|t|
ln (fertilizer price)	-0.099	-0.780	0.4350
ln(wage rate)	-0.084	-1.250	0.2110
ln(land area)	0.052**	1.660	0.0970
ln(distance to motorable road)	-0.013	-0.410	0.6830
ln(education)	-0.001	-0.060	0.9500
Zone dummy (1=high potential, 0 otherwise)	-0.234*	-3.570	0.0000
Inverse Mills ratio	-0.215*	-4.930	0.0000
Intercept	0.204	1.340	0.1790

*Significant at 5 % level or below, **Significant at 10 % level.
Source: Author's computation

Table 9: Price and non-price factors influencing labour demand in maize production

Variable	Coefficient	t-statistic	P>|t|
ln(wage rate)	-0.532*	-4.860	0.0000
ln (fertilizer price)	-0.084	-1.250	0.2110
ln(land area)	0.056	1.340	0.1810
ln(distance to motorable road)	-0.100*	-2.250	0.0240
ln(education)	0.000	0.000	0.9980
Zone dummy (1=high potential, 0 otherwise)	-0.344*	-3.870	0.0000
Intercept	1.172*	5.510	0.0000

*Significant at 5 % level or below, **Significant at 10 % level.
Source: Author's computation

The estimation results for the labour share equation (Table 9) indicate that wage rate has a significant negative influence on labour demand, as is explained by the p-value of 0.0000 of the parameter associated with the natural logarithm of the wage rate. Distance to motorable road and agro-regional differences also have significant influence on labour demand. The coefficient of determination for the labour share equation is -0.0082, although the t-statistics for all except one of the estimated coefficients exceed 1.2. The negative value of the coefficient of determination is due to the cross-equation restrictions imposed on the parameters and the resulting use of the SUR estimation method.

In the profit function, the results indicate that at 5% level only wage rate, land area and level of education have significant influence on profit (Table 10). In-depth discussion on the influence of these variables on output supply and input demand are presented in the next section. Output supply and input demand elasticities were computed from the coefficients of the normalized restricted translog profit function.

Table 10: Price and non-price factors influencing profit in maize production

Variable	Coefficient	t-statistic	P>|t|
ln(fertilizer price)	0.204	1.340	0.1790
ln(wage rate)	1.172*	5.510	0.0000
[ln(fertilizer price)]^2	-0.099	-0.780	0.4350
[ln(wage rate)]^2	-0.532*	-4.860	0.0000
[ln(fertilizer price) x ln(wage rate)]	-0.084	-1.250	0.2110
[ln(fertilizer price) x ln(land area)]	0.052**	1.660	0.0970
[ln(fertilizer price) x ln(distance to motorable road)]	-0.013	-0.410	0.6830
[ln(fertilizer price) x ln(education)	-0.001	-0.060	0.9500
[ln(wage rate) x ln(land area)]	0.056	1.340	0.1810
[ln(wage rate) x ln(distance to motorable road)]	-0.100*	-2.250	0.0240
[ln(wage rate) x ln(education)	0.000	0.000	0.9980
ln(land area)	0.913*	10.060	0.0000
ln(distance to motorable road)	0.149	1.200	0.2310
ln(education)	-0.075	-1.240	0.2160
[ln(land area)]^2	0.149*	4.120	0.0000
[ln(distance to motorable road)]^2	0.131**	1.800	0.0720
[ln(education)]^2	-0.013	-0.700	0.4870
[ln(land area) x ln(distance to motorable road)]	-0.006	-0.220	0.8290
[ln(land area) x ln(education)]	0.008	0.470	0.6400
[ln(education) x ln(distance to motorable road)]	0.010	0.570	0.5690
Zone dummy (1=high potential, 0 otherwise)	1.169*	19.120	0.0000
Intercept	3.640*	15.350	0.0000

Note: *Significant at 5 % level or below, **Significant at 10 % level. Superscript 2 is a square sign for the variables in the parentheses.
Source: Author's computation

4.2.3 Suitability of the translog functional form and validity of the regularity conditions for the profit function

Before further proceeding to discussing the hypotheses stated in section 1.4, a test for the appropriateness of the translog functional form in comparison to the Cobb-Douglas specification is reported. Test results for the validity of the regularity conditions for the profit function are also presented. For the profit function to be Cobb-Douglas, coefficients of all second order terms in the profit equation (1) should be zero. Accordingly, an F-test was conducted to test the null hypothesis that all $\gamma_{ij}=0$, all $\delta_{ik}=0$ and all $\psi_{kh}=0$. The computed $F_{(15,3527)}$ was 3.48 and the critical $F_{0.05(15,3527)}$ was 1.67. Thus, the null hypothesis was rejected at the 0.05 level of significance. The translog representation, therefore, appeared to be more suitable than the Cobb-Douglas representation for the data and model specification being analyzed. This, nevertheless, does not mean that for a different model specification and/or data set the Cobb-Douglas formulation could not be appropriate and analytically useful and convenient.

In terms of the regularity properties of the profit function, homogeneity was automatically imposed because the normalized specification was used. For the monotonicity condition to hold in the translog model, the estimated output shares must be positive at all data points (Farooq, *et. al.*, 2001), which was found in this case. The convexity condition cannot be imposed and can only be subjected to test after estimation. However, in this study the convexity condition was assumed to hold, and was not subjected to test. A formal statistical test was conducted for the validity of the symmetry and parametric constraints across profit and the share equations.

The tests for individual symmetry conditions involved testing the null hypothesis in each case that symmetry condition held, i.e., $\gamma_{ij}=\gamma_{ji}$ and $\delta_{ik}=\delta_{ki}$. The null hypothesis was tested against the alternative hypothesis that the parameter estimates were not equal. Using a significance level of 0.05 as a loose cut-off point, in four out of 12 cases the null hypothesis was rejected; that is, the symmetry condition did not hold for the four cases (Appendix 6). A global test for symmetry condition was also conducted. This was a joint hypothesis on the validity of imposing 12 restrictions to estimate jointly the share equations and the profit equation. An F-test statistic with good asymptotic properties was conducted to test this hypothesis. The computed $F_{(12,\ 3527)}$ was 6.63 and the critical $F_{0.05\ (12,\ 3527)}$ was 1.75. Thus, the null hypothesis (validity of the constraints) was rejected at the 0.05 level of significance. The implication of this is that not all symmetry conditions held across the profit function and the variable input share equations. Thus, the results were not entirely consistent with the maintained hypothesis of symmetry. Whether this inconsistency was because of wrong basic assumptions or inadequacies in model specification, data and /or econometric procedures is impossible to determine. It is likely caused by some combination of these. Whatever the cause, caution is required in interpreting the results since maize supply and input demand equations may not fully reveal the input requirements function if producers do not maximize profits. However, comparing the significance of the parameter estimates in the case where all symmetry conditions are imposed with the case where inappropriate symmetry conditions are excluded gives a clear picture of whether there is significant loss of accuracy in the estimation.

Given the results of individual symmetry conditions, restrictions 8,9,11 and 12 were removed and the global test was conducted on the remaining eight symmetry conditions. The computed $F_{(8,3527)}$ was 1.91 and the critical $F_{0.05(8,3527)}$ was 1.94. The results suggest that we fail to reject the null hypothesis that symmetry conditions held across the system of profit and variable input share equations. Restrictions 8,9,11 and 12 were inaccurate and could not serve as maintained hypotheses. The system of the variable input share equations and the profit equation was re-estimated without imposing restrictions 8,9,11 and 12. The resulting parameter estimates of the profit equation were compared to the parameters of the profit equation estimated with all the 12 restrictions imposed (Appendix 7). The only difference between the two results is that level of education of the household head is significant in the estimation with 8 restrictions (a p-value of 0.0050). In the estimation with 12 restrictions, education level of the household head was not significant and had a p-value of 0.2160. With respect to the prices of the variable inputs (fertilizer and labour), the results of the estimation with smaller set of restrictions and the results of the estimations with all the restrictions imposed do not show much difference. These results thus suggest that there was no loss of accuracy in computing the elasticities from parameter estimates of the profit function with symmetry conditions imposed.

4.2.4 Maize supply response

Discussions on the stated hypotheses are based on elasticity estimates presented in Table 11. The elasticities are functions of the variable input shares, variable input prices, levels of fixed inputs, and the parameter estimates of the normalized restricted translog profit function presented in Table 10. The elasticities were computed at mean values of the variables. The formulae used in computing the elasticities are presented in Appendix 2. All the elasticities have the expected signs and are all (except for elasticity of maize supply with respect to land area) less than unity. The discussions on the hypotheses are based on signs and magnitude of the elasticity estimates. Since the elasticities were computed from coefficients of the profit function, variable input shares and levels of fixed factors, they could not be subjected to statistical test to determine their statistical significance.

Table 11: Price and non-price elasticities of maize supply and fertilizer and labour demand

	Elasticity of:		
	Maize supply	Fertilizer Demand	Labour Demand
With respect to:			
Maize price	0.116	0.776	0.040
Fertilizer price	-0.333	-0.767	-0.004
Wage rate	-0.775	-0.007	-0.036
Land area	1.128	0.726	0.879
Distance to motorable road	-0.049	-0.040	-0.047
Education	0.087	0.392	0.167

Source: Author's computation

4.2.4.1 Maize supply response to maize price

The own-price elasticity of maize supply is positive as expected and is consistent with theory (Table 11). The hypothesis of inelasticity cannot, however, be rejected. A 10 % increase in the price of maize would result into a 1.16 % increase in the supply of maize, holding the prices of the variable inputs and the quantities of the fixed inputs constant. This low elasticity implies that whether maize prices are favourable or not farmers will be reluctant to significantly raise or reduce their maize production. There are reasons for this. Maize is the main staple food for a large section of the population and 75 % of the total maize output is produced by the smallholder farmers. These smallholder farmers are mostly subsistence in nature and rely on maize both for own consumption and for revenue generation. The subsistence nature of maize farmers implies that maize producer price changes may not have a significant influence on the decision of the farmers on whether to produce or not to produce maize. Again, most small scale maize producers are net maize buyers, implying that maize production is not majorly a business enterprise among the small scale producers. As such, maize producer price changes are likely to have little influence on the decision of the small holder farmers to raise or reduce their production.

4.2.4.2 Maize supply response to fertilizer and labour prices

Variable input prices have a depressing effect on maize supply. Hypothesis 2 is therefore rejected. A 10 % increase in the price of fertilizer would lead to a 3.33% reduction in maize supply while a 10 % increase in the price of labour would lead to a 7.75% reduction in maize supply, *ceteris paribus* (Table 11). This elasticity of maize supply with respect to the wage rate indicates that productivity of labour in maize production is considerably high. It is surprising that the elasticity of maize supply with respect to fertilizer price is less than the elasticity of maize supply with respect to wage rate in absolute terms. This is likely to reflect the lower usage of chemical fertilizer compared to labour usage, partly because the effective price of fertilizer is too high for most of the small holder maize farmers.

4.2.4.3 Maize supply response to land area, market access and education

Except for land area, maize supply is far more sensitive to prices of variable inputs than to non-price factors (Table 11). The most important fixed input in terms of maize supply response is area of land (elasticity of 1.128). This suggests that maize supply would expand by about 11% if land area under maize were to increase by 10%. This, however, need not imply support for a general policy of increasing the size of holdings so that more land can be allocated to maize production. It may be that there are many small-holding maize farms that are smaller than the minimum efficient size, so the objective would be to expand area under maize to be above the minimum efficient size. On the basis of land area, therefore, hypothesis 3 is rejected.

Maize supply is least responsive to market access (distance to motorable road) (elasticity of -0.049) (Table 11). Market access has equally low influence on demand for variable inputs (elasticities of -0.040 and -0.047 for fertilizer and labour respectively). Based on the elasticity sign, hypothesis 3 is thus rejected on the basis of market access.

Education of the household head (the main decision maker of the household) is not important, though it positively influences maize supply (elasticity of 0.087) (Table 11). This again emphasizes the dominance of maize production among the Kenyan rural households, irrespective of education level. Hypothesis 3 is rejected on the basis of education level of the household head, which reflects the managerial ability of the household.

Having discussed the hypotheses, section 4.2.5 presents a discussion on the results of the analysis as they relate to demand for the variable inputs (fertilizer and labour).

4.2.5 Fertilizer and labour demand elasticities

Fertilizer and labour are the most important (in terms of their share in total variable expenditures) variable inputs in maize production. Demand for these inputs has an important implication on maize productivity and production. It is, therefore, worthwhile to discuss the elasticity of demand for these inputs with respect to the price and non-price factors considered in this study.

4.2.5.1 Price and non-price elasticities of fertilizer demand

The own-price elasticity of demand for fertilizer is negative as suggested by theory. Fertilizer demand is, however, price inelastic. A 10 % decrease in the price of fertilizer would result into a 7.67 % increase in the demand for fertilizer, *ceteris paribus* (Table 11). This suggests that policies targeting fertilizer price would be reasonable for encouraging fertilizer use on maize to improve productivity and production. Maize price and land area are also important factors affecting fertilizer use, with elasticities of 0.776 and 0.726, respectively. These elasticity estimates imply that fertilizer demand would increase more with an increase in maize prices than with a decrease in fertilizer prices. It is, however, noteworthy that raising maize prices would hurt the welfare of urban maize and maize products consumers and the welfare of small holder maize farmers most of whom are net maize buyers. Furthermore, as has been discussed, own-price elasticity of maize supply is 0.116, which is lower than the elasticity of maize output with respect to fertilizer price (0.333 in absolute terms). The suggestion would be to focus policy on fertilizer prices with the aim of making fertilizer more affordable and available to the majority of small holder maize farmers. The elasticity of fertilizer demand with respect to land area indicates that increased acreage under maize is associated with higher use of fertilizer. Market access (distance to motorable road) has a very low elasticity (0.040 in absolute terms) in the fertilizer demand equation. Fertilizer demand on the other hand is quite sensitive to education level of the household head (elasticity of 0.392).

4.2.5.2 Price and non-price elasticities of labour demand

Labour demand is inelastic to changes in the wage rate, having an own-price elasticity of 0.036 in absolute terms (Table 11), though the negative sign of the elasticity estimate is consistent with economic theory. If this is a general phenomenon in all agricultural areas and across all agricultural enterprises in Kenya, then 'surplus' labour in the agricultural areas will only be absorbed, if it is, by large reductions in wage rates. By the same token, out-migration will have a substantial effect on the rural wage rates. Increases in maize price would encourage the expansion in demand for labour just as it would for fertilizer demand. However, a 10 % increase in maize price would raise the demand for labour by only 0.40 % compared to 7.76 % by which such an increase in maize prices would raise fertilizer demand. This implies that labour is less sensitive to price incentives than fertilizer and would therefore not be a preferred target with a price policy tool aimed at raising maize production. As expected, land area was found to have an expansionary effect on the demand for labour with estimated elasticity close to unity (0.879). Market access (distance to motorable road) had a depressing effect on labour demand (elasticity of 0.047 in absolute terms), though the magnitude of the effect was quite low. Labour demand would also increase with the expansion of the level of education of the household head (elasticity of 0.167). The negative cross-price elasticities of fertilizer and labour demand suggest that fertilizer and labour are more of complementary inputs than substitutes in maize production.

CHAPTER 5

CONCLUSION

This study assessed how responsive maize supply is to price and non-price factors and how sensitive fertilizer and labour demand are to prices and non-price factors. The study analysed cross-sectional farm-level data pertaining to 2003/2004 cropping year for 1187 maize producing households. The data was obtained from Tegemeo Institute of Agricultural Policy and Development. The parameters of a model based on the normalized restricted translog profit function and the derived system of fertilizer and labour share equations were estimated and relevant elasticites computed.

Rather than relying on some ad-hoc output supply and input demand equations, the production technology was specified using relevant economic theory. The estimated model was constrained to preserve the fundamental laws of production economics. Accordingly, the theoretical properties of a profit function, namely homogeneity, monotonicity and symmetry were imposed on the model while convexity was assumed. The symmetry property was tested to verify its validity.

The empirical analysis of maize supply response reported here yielded broadly satisfactory results both in terms of economic theory and statistical fit. While the empirical results of the specification employed were plausible, they also demonstrated in this case a lack of support for the hypothesis of the Cobb-Douglas form of the profit function.

5.1 Summary of results

The inelastic own-price maize supply elasticity (an elasticity of 0.116) implies low sensitivity of maize supply to maize price. It means that a support price to maize producers is an unattractive strategy for expanding maize supply. Fertilizer use was found to be particularly important in the decisions on resource allocation in maize production. Compared with labour, the elasticity of demand for fertilizer with respect to maize price (0.776) and the own-price elasticity of demand for fertilizer (-0.767) were higher in absolute terms. However, elasticity of maize output with respect to wage rate (-0.775) was higher in absolute terms than the elasticity of maize output with respect to fertilizer price (-0.333).

Of the fixed inputs, land area was found to be the most important factor contributing to the supply of maize (elasticity of 1.128). Land area also substantially influenced the demand for fertilizer and labour. Market access and educational endowment of the household head seemed not to have substantial effect on maize supply and variable inputs demand.

5.2 Policy implications and recommendations

Increasing maize production to achieve maize self-sufficiency has been an important objective of the Kenyan government in its national policy on food and nutrition. Price incentives have been a major policy instrument employed by the GoK to achieve this objective. Less attention has been given to input prices, especially fertilizer and labour prices, and fixed inputs, though these too are important in influencing maize production. This study generated elasticity estimates that can shed light on policy-relevant relationships between maize output, fertilizer and labour demand, and fixed factors of production. Based on the elasticity estimates generated, this study advances the following recommendations.

Firstly, it has emerged that to increase aggregate production of maize in Kenya, a support price policy appears to be unattractive. This is so because most of the maize producers are small holders who also double as net maize buyers. A higher maize price support would result into hurting the welfare of the small holder maize farmers, who happen to be the majority. A higher maize price support would favour the larger and commercial maize farmers who are net maize sellers. But these large and commercial maize farmers are few, so that such a price support in the overall will reduce the welfare of a larger section of the population, including the urban population. Instead of emphasising maize producer prices to raise maize production, it would be more economically sound to shift attention from maize support price to input prices such as fertilizer prices and relevant non-price factors such as land.

Secondly, fertilizer price assumes key significance in influencing the fundamentals of maize production. The elasticity of maize supply to fertilizer price (though lower than the elasticity of maize supply to wage rate) combined with the higher own-price elasticity of demand for fertilizer suggest that fertilizer price would be more effective yet less hurting policy target for promoting maize production. This indicates that maize production expansion policy should focus on fertilizer price. But fertilizer price in a liberalized inputs market may not be directly controlled by the government, as used to be before, as this would lead to re-emergence of the limitations that prevailed during the input markets control by the government. The options that could be exploited to make fertilizer prices affordable to small holder farmers include ensuring availability of fertilizer supply when needed. This could be done by making public investment in rural infrastructure and efficient port facilities and promoting standards of commerce that provide the incentives for commercial agents to invest in fertilizer importation, wholesaling and retailing. Inland cost of transporting fertilizer is particularly a major component in fertilizer pricing, so that if road infrastructure, especially rural access roads and major highways linking the countryside to the port of Mombasa and fertilizer depots, could be improved and the railway system improved, a decline in the price of fertilizer would be achieved. These developments would not only increase fertilizer use on maize but also lead to more use of fertilizer on other crops. This would result into a sector-wide increase in agricultural productivity and production.

Finally, land size is found to be far more important in affecting production of and resource use in maize than price incentives. Increasing the size of land holdings through consolidation may be desirable as maize output is responsive to land area, suggesting scale economies. However, in Kenya where population pressure has resulted into extensive sub-division of parcels of land into uneconomical units, consolidation may seem untenable. A more appropriate option may be to encourage more intensive use of productivity enhancing inputs. A part from fertilizer discussed above, high yielding maize seed varieties are another input whose adoption and use could be intensified.

5.3 Opportunity for further research

This study focused on maize as a single commodity and computed the supply response without disaggregating the analysis into gender and agro-regions. The inclusion of zone dummies in the analysis only served to control for zone differences. This study could be extended further by explicitly disaggregating the analysis into gender of the household head and agro-regional zones to assess the extent to which maize supply response varies with gender differences and differences in agro-ecology and farming systems. Such dissagregation would provide valuable information with regard to what policies would need to be put in place to cater for gender and agro-ecological differences in pursuit of the objective of increased maize production. Inclusion of environmental factors such as soil quality and rainfall into the analysis would also provide information on the extent to which these factors influence maize supply.

REFERENCES

Abdallah, O. and Al-Jabari, O.S. (1998), ‘‘Price Supply Response of Vegetables Growers in the Sultanate of Oman’’ *Agricultural Economics,* 19: 349-358

Abrar, S. (1996), ‘‘Estimating Supply Response in the Presence of Technical Inefficiency Using the Profit Function: An Application to Ethiopian Agriculture’’, Department of Economics, University of Leicester, Leicester, United Kingdom

Abrar, S. (2001), ‘‘Duality, Choice of Functional Form and Peasant Supply Response in Ethiopia’’, *CREDIT Research Paper No. 01/20*, Centre for Research in Economic Development and International Trade, School of Economics, The University of Nottingham, United Kingdom.

Abrar, S., Morrissey, O. and Rayner, T. (2004), ‘‘Aggregate Agricultural Supply Response in Ethiopia: A Farm-Level Analysis’’, *Journal of International Development*, 16: 605-620.

Abrar, S., Morrissey, O. and Rayner, T. (2002), ‘‘Supply Response of Peasant Farmers in Ethiopia: A Farm-Level Profit Function Analysis’’, *CREDIT Research Paper No. 02/16*, Centre for Research in Economic Development and International Trade, School of Economics, The University of Nottingham, United Kingdom.

Abrar, S., Morrissey, O. and Rayner, T. (2004), ‘‘Crop-Level Supply Response by Agro-Climatic Region in Ethiopia’’, *Journal of Agricultural Economics,* 55(2):289-311.

Amemiya, T. (1984), ‘‘Tobit Models: A Survey’’, *Journal of Econometrics,* 24: 3-61.

Anderson, D.P., Chaisantikulawat, T., Guan, A.T.K., Kebbeh, M., Lin, N. and Shumway, R. (1996), ‘‘Choice of Functional Form for Agricultural Production Analysis’’, *Review of Agricultural Economics*, Vol 18, pp 223-231.

Ariga, J., Jayne, T.S. and Nyoro, J. (2006), ‘‘Factors Driving Fertilizer Consumption in Kenya, 1990-2006: Sustaining the Momentum in Kenya and Lessons for Broader Replicability in Sub-Saharan Africa’’, Tegemeo Institute of Agricultural Policy and Development, Egerton University.

Argwings-Kodhek, G. (2004), ‘‘Kenya Agriculture Sector Brief’’, Tegemeo Institute of Agricultural Policy and Development, Egerton University

Argwings-Kodhek, G. (1996), ‘‘The Impact of Fertilizer Market Liberalization in Kenya’’, *Working Paper*, Tegemeo Insitute of Agricultural Policy and Development, Egerton University.

Askari, H. and Cummings, J.T. (1977), ‘‘Agricultural Supply Response: A Survey of the Econometric Evidence’’, Praeger, New York.

Behrman, J.R. (1989), ‘‘Agricultural Supply’’, in Eatwell, J., Milgate, M. and Newman, P. (eds), *The New Palgrave Economic Development*, MacMillan, pp. 35-42

Binswanger, H. (1990), ‘‘The Policy Response of Agriculture’’, *World Bank Economic Review*, 4 (2), 231-258.

Chambers, R.G. (1991), ‘‘Applied Production Analysis: A Dual Approach’’, Cambridge University Press, Cambridge.

Chang, A.C. (1984), *Fundamental Methods of Mathematical Economics*, Third Edition, McGraw-Hill, Singapore.

Chowdhury, N., Khan, M.K. and Kabir, M. (1994), ‘‘Determinants of Rice Supply in Bangladesh: A Case of Profit Function Approach Using Cross-Section Data’’, *Bangladesh Journal of Agricultural Economics*, **XVII**, 1 and 2: 1-15.

Colby, H., Diao, X. and Somwaru, A. (2000), ‘‘Cross-Commodity Analysis of China’s Grain Sector: Sources of Growth and Supply Response’’, *Technical Bulletin No.1884,* US Department of Agriculture, Economic Research Service, Market and Trade Economics Division.

Colman, D. (1983), ‘‘A Review of the Art of Supply Response Analysis’’, *Review of Marketing and Agricultural Economics*, Vol. 51: 3, pp. 201-230.

Day, R.H. (1963), ‘‘On Aggregate Linear Programming Models of Production’’, *Journal of Farm Economics*, Vol. 45, pp. 797-813.

Delgado, C.L. and Mellor, J.W. (1984), ‘‘A Structural View of Policy Issues in African Agricultural Development’’, *American Journal of Agricultural Economics,* **66**: 665-670.

Färe, R. and Primont, D. (1995), *Multi-output Production and Duality: Theory and Applications*, Kluwer Academic Publishers, Massachusetts.

Farooq, U., Young, T., Russel, N. and Iqbal, M. (2001), ‘‘The Supply Response of Basmati Rice Growers in Punjab, Pakistan: Price and Non-price Determinants’’, *Journal of International Development*, 13(2):227-237.

Flinn, J.C., Kalirajan, K.P. and Castillo, L.L. (1982), ‘‘Supply Responsiveness of Rice Farmers in Laguna, Philippines’’, *Australian Journal of Agricultural Economics,* 26 (1): 39-48.

Gafar, J.S. (1997), ‘‘The Supply Response of Aggregate Agricultural Output in Jamaica’’, *Agricultural Economics*, 16 (3): 205-217.

Gitu, K.W. and Wyckoff, J.B. (1984), *Econometric Analysis of Kenya's Slaughter Beef Supply and Some Policy Implications for Production*, Ministry of Agriculture and Livestock Development, Republic of Kenya, Unpublished Mimeo

Green, W.H. (1997), *Econometric Analysis*, Prentice-Hall, New Jersey.

Hattink, W., Heerink, N. and Geert, T. (1998), ‘‘Supply Response of Cocoa in Ghana: a Farm-level Profit Function Analysis’’, Journal *of African Economies* 7(3): 424-444.

Haughton, J. (1986), ‘‘Farm Price Responsiveness and Choice of Functional Form: An Application to Rice Cultivation in West Malaysia’’, *Journal of Development Economics* 24: 203-223.

Jaforullah, M. (1993), ‘‘Asymmetric Supply Response: Evidence from Bangladesh’’, *Journal of Agricultural Economics,* 44: 490-495.

Jayne, T.S., T. Yamano, J. Nyoro and T. Awour (2001), ‘‘Do Farmers Really Benefit From High Food Prices? Balancing Rural Interests in Kenya's Maize Pricing and Marketing’’, *Working Paper No. 2b*, Tegemeo Institute of Agricultural Policy and Development.

Jayne, T.S, Govere, J., Mwanaumo, A., Chapoto, A. and Nyoro, J.K. (2002), ‘‘False Promise or False Premise?: The Experience of Food and Input Market Reform in Eastern and Southern Africa’’, in Jayne, T.S, Minde, I.J. and Gem, A. (eds), *Perspectives on Agricultural Transformation : A View from Africa*, Nova Science Publishers, Inc., New York, pp. 198.

Jayne, T.S. and Kodhek, G.A (1997), ‘‘Consumer Response to Maize Market Liberalization in Urban Kenya’’, *Food Policy* 22 (5): 447-458.

Jayne, T.S., Myers, R. and Nyoro, J. (2005), ‘‘Effects of Government Maize Marketing and Trade Policies on Maize Market Prices in Kenya’’, *Working Paper, 15/2005*, Tegemeo Institute of Agricultural Policy and Development

Karanja, D.D., Jayne, T.S. and Strasberg, P. (1998), ‘‘Determinants of Input Use and Maize Productivity in Kenya: Implications of Cereal Market reform’’, Paper presented at the Tegemeo Institute Conference on Strategies for Raising Smallholder Productivity and Welfare, Nairobi.

Kere, P.A. *et al* (1989), ‘‘The Supply Responsiveness of Wheat Farmers in Kenya’’, *Eastern Africa Economic Review*

Kimenyi, P. and Mwangi, S. (2002), ‘‘Agriculture, Economic Growth and Poverty Reduction’’, *Occasional Paper No. 3*, Kenya Institute of Public Policy and Research Analysis.

Kirori, G.N. and Gitu, W.K. (1991), ‘‘Supply Response in Kenyan Agriculture: A Disaggregated Approach. Technical’’, *Paper 91-01*, Ministry of Planning and National Development, Republic of Kenya

Kmenta, J. (1986), *Elements of Econometrics*, Macmillan Publishing Company, New York, pp. 637.

Lau, J. L. (1978), ‘‘Applications of Profit Functions’’, in Jorgenson, D. W. and Waelbroeck, J. (eds), *Production Economics*: *A dual Approach to Theory and Applications. Volume 1*, North-Holland

Lucas, R. (1976), ‘‘Economic Policy Evaluation: A Critique’’, in Brunner, K. and Meltzer, A. (eds), *The Phillips Curve and Labour Markets,* North-Holland, Amsterdam.

Maitha, J.K. (1974), ‘‘A Note on Distributed Lag Models of Maize and Wheat Response: A Kenya Case Study’’, *Journal of Farm Economics,* 25: 183-190.

Mamingi, N. (1997), ‘‘The Impact of Prices and Macroeconomic Policies on Agricultural Supply: A synthesis of Available Results’’, Agricultural *Economics,* 16: 17-34.

McKay, A., Morrissey, O. and Vaillant, C. (1997), ‘‘Aggregate Export and Food Crop Supply Response in Tanzania’’, *CREDIT Research Paper No. 98/4*, Centre for Research in Economic Development and International Trade, School of Economics, The University of Nottingham, United Kingdom.

Mghenyi, W.E. (2006), *Welfare Effects of Maize Pricing Policy on Rural Households in Kenya*, Department of Agricultural Economics, Michigan State University, USA. Unpublished Masters Thesis

Mundlak, Y. (1985), ‘‘The Aggregate Agricultural Supply Response’’, *Working Paper No.8511*, Centre for Agricultural Economics Research, Rehovot, Israel.

Muyanga, M., T.S. Jayne, G. Argwings-Kodhek and J. Ariga (2005), ‘‘Staple Food Consumption Dynamics in Urban Kenya: Trends and Policy Implications’’, *Working Paper No. 19,* Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya.

Narayana, N.S.S and Shah, M.M. (1984), ‘‘Farm Supply Response in Kenya: Acreage Allocation Model’’, *European Review of Agricultural Economics,* 11 (1): 85-105.

Nerlove, M. (1958), ‘‘Distributed Lags and Estimation of Long-run Supply and Demand Elasticities: Theoretical Considerations’’, *Journal of Farm Economics,* XL: 311-313.

Nyameino, D., Kagira, B. and Njukia, S. (2003), *Maize market Assessment and Baseline Study for Kenya*, Regional Agricultural Trade expansion Support Program (RATES), Nairobi, Kenya.

Nyoro, J.K. (1992), ‘‘Competitiveness of Maize Production Systems in Kenya’’, A paper presented at Egerton University’s Policy Analysis Matrix conference on Maize Supply and Marketing under Market Liberalization, 18-19 June at the Kenya Commercial Bank Institute of Banking and Finance, Karen, Nairobi.

Nyoro, J.K, Muyanga, M. and Ayieko, M. (2007), ‘‘The Compatibility of Trade Policy with Domestic Policy Interventions Affecting the Grains Sector in Kenya’’, A paper presented at the FAO’s workshop on Trade and Policy for Food Products Conducive to Development in Eastern Africa, 1-2 March, Rome, Italy.

Nyoro, J.K., Kiiru, M.W. and Jayne, T.S. (1999), ‘‘Evolution of Kenya’s Maize Marketing Systems in the Post Liberalization Era’’, Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya

Nyoro, J. K., Wanzala, M. and Awuor, T. (2001), ‘‘Increasing Kenya’s Agricultural Competitiveness: Farm Level Issues’’, Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya.

Nyoro, J.K (2002), ‘‘Agriculture and Rural Growth in Kenya’’, Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya.

Nyoro, K. J., Kiiru, M. W. and Jayne, T. S. (2001), ‘‘Evolution of Kenya’s Maize Marketing Systems in the Post-Liberalisation Error’’, Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya.

Nyoro, J.K., Lilian Kirimi and T.S. Jayne, (2004), ‘‘Competitiveness of Kenyan and UgandanMaize Production: Challenges for the Future’’, *Working Paper No. 10*, Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya.

Ozzane,A. (1992), *Perverse Supply Response in Agriculture*, Avebury, Brookfield, USA.

Quiggin, J. and Bui-Lan, A. (1984), ‘‘The Use of Cross-Sectional Estimates of Profit Functions for Tests of Relative Efficiency: A Critical Review’’, *Australian Journal of Agricultural Economics,* 28 (1): 44-55.

Rao, M. (1989), ‘‘Agricultural Supply Response: A Survey’’, *Agricultural Economics* 2:1-22.

Republic of Kenya (1990 to 2004), *Economic Survey*, Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi, Kenya.

Republic of Kenya (2004), *Strategy for Revitalizing Agriculture*, Ministry of Agriculture, Ministry of Livestock and Fisheries Development and Ministry of Cooperative Development and Marketing, Nairobi, Kenya.

Republic of Kenya (2003), *A Strategy for Economic Recovery*, Ministry of Planning and National Development, Nairobi, Kenya.

Republic of Kenya (2006), *Kenya Facts and Figures*, Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi, Kenya

Sadoulet, E, and de Janvry, A. (1995), *Quantitative Development Policy Analysis*, pp 61-111. Johns Hopkins University Press , Baltimore, Maryland.

Savadogo, K., Reardon, T. and Pietola, K. (1995), ‘’Mechanization and Agricultural Supply Response in the Sahel: a Farm-level Profit Function Analysis’’, *Journal of African Economies,* 4:337-77.

Schiff, M. and Montenegro, C. (1997), ‘‘Aggregate Agricultural Supply Response in Developing Countries: A Survey of Selected Issues’’, *Economic Development and Cultural Change,* 45:393-410

Sharpley, J. (1984) *Macro Economic Policies and Agricultural Performance in Kenya.* OECD Development Centre, Paris. Unpublished Report

Shumway, C.R. and Chang, A. (1972), ‘‘Linear Programming versus positively estimated supply functions: An empirical and methodological critique’’, *American Journal of Agricultural Economics*, Vol. 59:2, pp. 344-357.

Sidhu, S.S. and Baanante, A.C.(1979), ‘‘Farm-level Fertilizer demand for Mexican Wheat Varieties in the Indian Punjab’’, *American Journal of Agricultural Economics,* 61(3):455-462.

Sidhu, S.S. and Baanante, A.C. (1981), ‘‘Estimating Farm-Level Input Demand and Wheat Supply in the Indian Punjab Using a Translog Profit Function’’, *American Journal of Agricultural Economics,* 63(2):237-246.

TIAPID, (2005), ‘‘Analysis of Smallholder Diversification in Kenya’’, *World Bank Agricultural Policy Review Technical Background Paper*, Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya

Trail, B., Colman, D. and Young, T. (1978), ‘‘Estimating Irreversible Supply Functions’’, *American Journal of Agricultural Economics,* 60:528-531.

Wangia, C., Sabina, W., and Hugo, G. (2002), ‘‘Review of Maize Marketing in Kenya: Implementation and Impact of Liberalization, 1989-1999’’, in Friesen D.K and A.F.E Palmer (eds). *Integrated Approaches to Higher Maize Productivity in the New Millennium*. Proceedings of the 7th Eastern and Southern Africa Regional Maize Conference, Nairobi, Kenya, 11-15 February 2002.Mexico, D.F.: CIMMYT. Pp 10-20

Wanzala, M., Jayne, T.S., Staatz, J.M., Mugera, M., Kirimi, J., and Ouwor, J. (2001), ‘‘Fertilizer Markets and Agricultural Production Incentives: Insights from Kenya’’, *Working Paper No.3*, Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya.

World Bank (2003), ‘‘Kenya: A Policy Agenda to Restore Growth, Poverty Reduction and Economic Management 2’’, *Country Report No. 25840-KE*, The World Bank, Washington D.C.

World Bank (1990), ‘‘Report on Adjustment Lending II: Policies for the Recovery and Growth’’, The World Bank, Washington, D.C.

www.fao.org, 2007

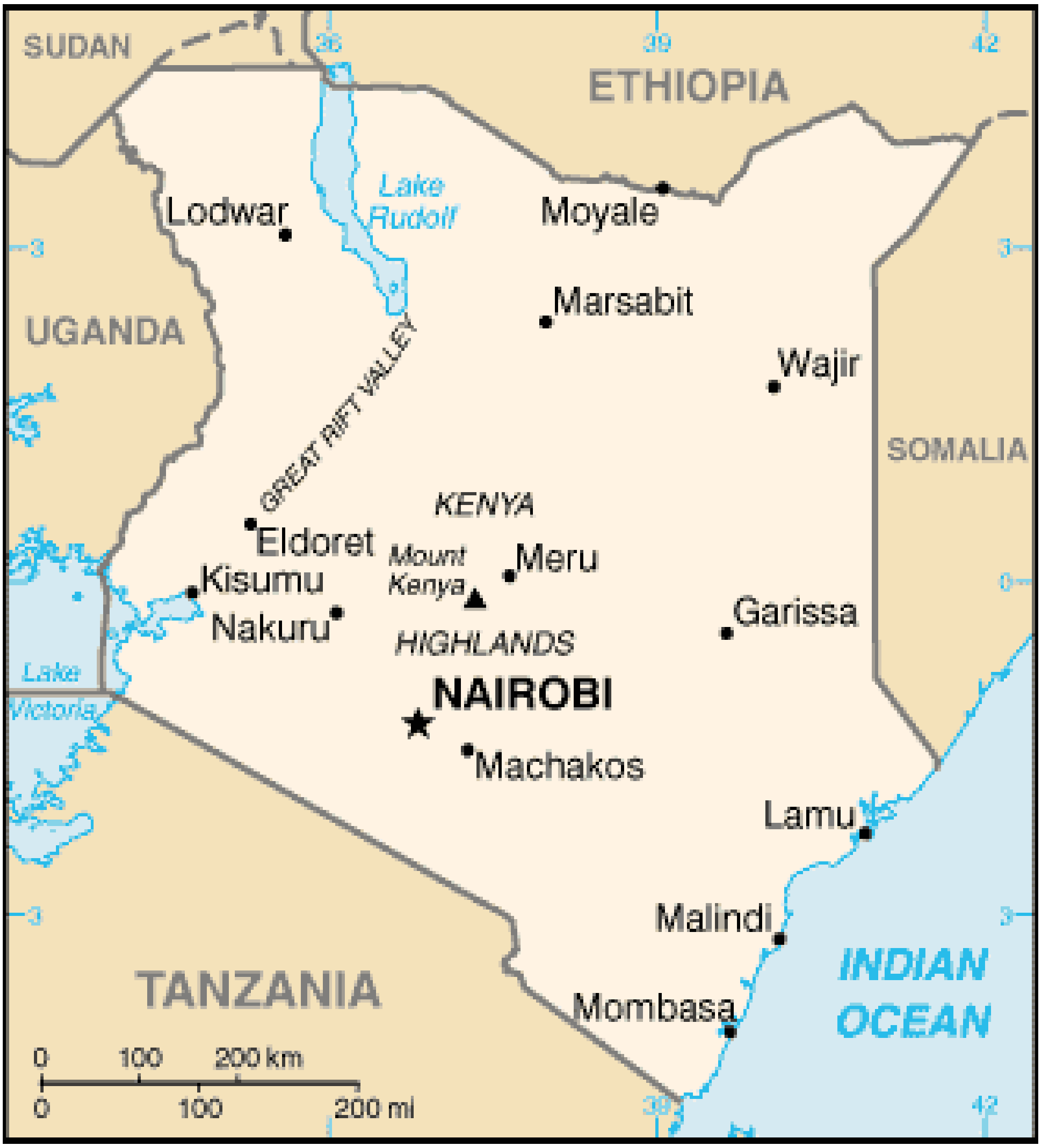
www.reliefonline.org/kenya/kenya_map.htm, 2007

Yotopoulos, P.A., Lau, L.J., and Lin, W. (1976), ‘‘Microeconomic Output Supply and Factor Demand Functions in the Agriculture in the Province of Taiwan’’, *American Journal of Agricultural Economics*, pp 333-340.

Zellner, A. (1962), ‘‘An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias’’, *Journal of the American Statistical Association,* 57: 348-68

APPENDICES

Appendix 1: Map of Kenya



Source: www.reliefonline.org/kenya/kenya_map.htm, 2007

Appendix 2: Computation of production elasticities

The following formulae were used to estimate elasticities.

Variable inputs demand elasticities

The *own-price elasticity of demand for variable input i* (η_{ii}), was estimated as

$$\eta_{ii} = -S_i - \frac{\gamma_{ii}}{S_i} - 1$$

where S_i is the *i*th share equation, at the sample mean.

For the *cross-price elasticity of demand for the* ith *variable input with respect to the price of j*th *variable input* (η_{ij}), the following expression was used:

$$\eta_{ij} = -S_j - \frac{\gamma_{ij}}{S_i} \qquad \text{for} \quad i \neq j$$

Elasticity of demand for variable input i with respect to output price, P_r, (η_{ir}), was estimated as

$$\eta_{ir} = S + \sum_{j=1}^{2} \frac{\gamma_{ij}}{S_i}$$

where S is the output share, at the sample mean.

Finally, the *elasticity of demand for variable input with respect to k*th *fixed factor*, (η_{ik}) was determined as:

$$\eta_{ik} = \left(\beta_k + \delta_{ik} InP_i^* + \sum_{h=1}^{3} \psi_{kh} InZ_h \right) - \frac{\delta_{ik}}{S_i}$$

Output elasticities

To compute the *elasticity of output supply with respect to the price of i*th *variable input*, (ε_{ri}), the following formula was used:

$$\varepsilon_{ri} = -S_i - \frac{\sum_{j=1}^{2} \gamma_{ji}}{S}$$

Elasticity of output supply with respect to own-price, (ε_{rr}), was computed using the formula below:

$$\varepsilon_{rr} = \sum_{i=1}^{2} S_i + \frac{\sum_{j=1}^{2} \gamma_{ji}}{S}$$

Finally, elasticity of output supply with respect to fixed input k (ε_{rk}) was computed using the formula below:

$$\varepsilon_{rk} = \left(\beta_k + \sum_{i=1}^{2} \delta_{ik} InP_i^* + \sum_{h=1}^{m} \psi_{kh} InZ_h \right) + \frac{\sum_{i=1}^{2} \delta_{ki}}{S}$$

Appendix 3: Chronology of maize market reforms in kenya: 1979-2007

1979-1986	• Strict control of maize price, movement and storage under the NCPB
1986-1990	• Limited relaxation of control of maize price, movement and storage under the NCPB Government • First serious market reform under the CSRP conditional to EEC/WB aid
1990-1995	• Gradual reduction of control of maize price, movement and storage under the NCPB Government • Market reform under the CSRP/KMDP conditional to aid
1995-1999	• Full liberalization • NCPB buyer and seller of last resort • Private sector participation increased • Government intervenes by imposing variable import tariff and financing NCPB operations
1999-2007	• Maize price stabilization policy; NCPB purchasing domestically produced maize at support price and maintains grain strategic reserve • Variable import tariff on maize imports retained

Source: Wangia, *et* al, 1999; Jayne, *et al*., 2002

Appendix 4: Estimation results of probit model for fertilizer use

```
--> PROBIT;Lhs=FERTUSE;Rhs=ONE,ACRES,SEEDUSE,DU,Z3,OFARMINC$
Normal exit from iterations. Exit status=0.
+---------------------------------------------+
| Binomial Probit Model                       |
| Maximum Likelihood Estimates                |
| Model estimated: Nov 12, 2007 at 08:42:15AM.|
| Dependent variable             FERTUSE      |
| Weighting variable                None      |
| Number of observations            1187      |
| Iterations completed                 5      |
| Log likelihood function      -569.2483      |
| Restricted log likelihood    -792.9341      |
| Chi squared                   447.3715      |
| Degrees of freedom                   5      |
| Prob[ChiSqd > value] =        .0000000      |
| Hosmer-Lemeshow chi-squared = 11.83949     |
| P-value=  .15851 with deg.fr. =       8      |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
         Index function for probability
 Constant     -1.48966107      .11827614   -12.595   .0000
 Z1             .02178320      .02291027      .951   .3417    1.87238964
 SEEDUSE        .79299741      .09675343     8.196   .0000     .67228307
 DU            1.30100914      .10426820    12.478   .0000     .71524853
 Z3             .04078131      .01047997     3.891   .0001    6.55518113
 OFARMINC     .462123D-06    .349542D-06     1.322   .1861    77642.9643
```

Matrix: Las
[6,4]

```
+-----------------------------------------+
| Fit Measures for Binomial Choice Model |
| Probit   model for variable FERTUSE    |
+-----------------------------------------+
| Proportions P0= .388374   P1= .611626  |
| N =    1187 N0=     461   N1=     726  |
| LogL =  -569.24832 LogL0 =  -792.9341  |
| Estrella = 1-(L/L0)^(-2L0/n) = .35776  |
+-----------------------------------------+
|     Efron |  McFadden  |  Ben./Lerman  |
|    .35018 |    .28210  |        .69139 |
|    Cramer | Veall/Zim. |      Rsqrd_ML |
|    .35045 |    .47861  |        .31401 |
+-----------------------------------------+
| Information  Akaike I.C. Schwarz I.C.  |
| Criteria         .96925    1180.97174  |
+-----------------------------------------+

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.
Threshold value for predicting Y=1 = .5000
            Predicted
------  ----------  +  -----
Actual      0    1  |  Total
------  ----------  +  -----
  0       299  162  |    461
  1        94  632  |    726
------  ----------  +  -----
Total     393  794  |   1187
```

```
=======================================================================
Analysis of Binary Choice Model Predictions Based on Threshold =  .5000
-----------------------------------------------------------------------
Prediction Success
-----------------------------------------------------------------------
Sensitivity = actual 1s correctly predicted                  87.052%
Specificity = actual 0s correctly predicted                  64.859%
Positive predictive value = predicted 1s that were actual 1s  79.597%
Negative predictive value = predicted 0s that were actual 0s  76.081%
Correct prediction = actual 1s and 0s correctly predicted     78.433%

-----------------------------------------------------------------------
Prediction Failure
-----------------------------------------------------------------------
False pos. for true neg. = actual 0s predicted as 1s          35.141%
False neg. for true pos. = actual 1s predicted as 0s          12.948%
False pos. for predicted pos. = predicted 1s actual 0s        20.403%
False neg. for predicted neg. = predicted 0s actual 1s        23.919%
False predictions = actual 1s and 0s incorrectly predicted    21.567%
=======================================================================
```

Appendix 5: Estimation results of normalized restricted translog profit function and fertilizer and labour share equations

```
Iteration 1:   tolerance =  .280638
Iteration 2:   tolerance =  .00947654
Iteration 3:   tolerance =  .00038946
Iteration 4:   tolerance =  .00001784
Iteration 5:   tolerance = 8.893e-07

Seemingly unrelated regression, iterated
Constraints:
 ( 1)  [sf]lnPL - [sl]lnPF = 0
 ( 2)  [lnnprofit]lnPFlnPF - [sf]lnPF = 0
 ( 3)  [lnnprofit]lnPLlnPL - [sl]lnPL = 0
 ( 4)  [lnnprofit]lnPFlnPL - [sf]lnPL = 0
 ( 5)  [lnnprofit]lnPFlnZ1 - [sf]lnZ1 = 0
 ( 6)  [lnnprofit]lnPFlnZ2 - [sf]lnZ2 = 0
 ( 7)  [lnnprofit]lnPFlnZ3 - [sf]lnZ3 = 0
 ( 8)  [lnnprofit]lnPLlnZ1 - [sl]lnZ1 = 0
 ( 9)  [lnnprofit]lnPLlnZ2 - [sl]lnZ2 = 0
 (10)  [lnnprofit]lnPLlnZ3 - [sl]lnZ3 = 0
 (11)  [lnnprofit]lnPF - [sf]_cons = 0
 (12)  [lnnprofit]lnPL - [sl]_cons = 0
```

Equation	Obs	Parms	RMSE	"R-sq"	F-Stat	P
lnnprofit	1187	21	.9432831	0.6120	100.56	0.0000
sf	1187	7	1.130755	0.0258	6.36	0.0000
sl	1187	6	2.054601	-0.0082	8.66	0.0000

	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnnprofit						
lnPF	.203728	.1516163	1.34	0.179	-.0935366	.5009925
lnPL	1.172284	.2128201	5.51	0.000	.7550212	1.589547
lnPFlnPF	-.0987958	.1264242	-0.78	0.435	-.3466677	.149076
lnPLlnPL	-.532173	.1095792	-4.86	0.000	-.747018	-.317328
lnPFlnPL	-.0844354	.0675097	-1.25	0.211	-.2167974	.0479265
lnPFlnZ1	.0519338	.0312972	1.66	0.097	-.0094286	.1132962
lnPFlnZ3	-.0133535	.0326803	-0.41	0.683	-.0774277	.0507207
lnPFlnZ2	-.001236	.0196861	-0.06	0.950	-.0398333	.0373612
lnPLlnZ1	.0562521	.0420472	1.34	0.181	-.0261871	.1386914
lnPLlnZ3	-.0996241	.0441851	-2.25	0.024	-.1862551	-.0129931
lnPLlnZ2	.0000505	.0265504	0.00	0.998	-.0520051	.0521061
lnZ1	.9126124	.0906826	10.06	0.000	.7348168	1.090408
lnZ3	.14944	.1246866	1.20	0.231	-.0950251	.393905
lnZ2	-.0753542	.0608464	-1.24	0.216	-.194652	.0439435
lnZ1lnZ1	.1494679	.036314	4.12	0.000	.0782695	.2206664
lnZ3lnZ3	.1305938	.0726583	1.80	0.072	-.0118627	.2730503
lnZ2lnZ2	-.0131328	.0188884	-0.70	0.487	-.0501661	.0239006
lnZ1lnZ3	-.00594	.02755	-0.22	0.829	-.0599555	.0480756
lnZ1lnZ2	.007685	.0164276	0.47	0.640	-.0245235	.0398935
lnZ2lnZ3	.0100608	.0176535	0.57	0.569	-.0245512	.0446729
DU	1.168657	.0611195	19.12	0.000	1.048823	1.28849
_cons	3.63986	.2370623	15.35	0.000	3.175067	4.104653

	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
sf						
lnPF	-.0987958	.1264242	-0.78	0.435	-.3466677	.149076
lnPL	-.0844354	.0675097	-1.25	0.211	-.2167974	.0479265
lnZ1	.0519338	.0312972	1.66	0.097	-.0094286	.1132962
lnZ3	-.0133535	.0326803	-0.41	0.683	-.0774277	.0507207
lnZ2	-.001236	.0196861	-0.06	0.950	-.0398333	.0373612
DU	-.2341084	.065546	-3.57	0.000	-.3626202	-.1055966
IMRF	-.2147117	.0435793	-4.93	0.000	-.3001549	-.1292684
_cons	.203728	.1516163	1.34	0.179	-.0935366	.5009925
sl						
lnPL	-.532173	.1095792	-4.86	0.000	-.747018	-.317328
lnPF	-.0844354	.0675097	-1.25	0.211	-.2167974	.0479265
lnZ1	.0562521	.0420472	1.34	0.181	-.0261871	.1386914
lnZ3	-.0996241	.0441851	-2.25	0.024	-.1862551	-.0129931
lnZ2	.0000505	.0265504	0.00	0.998	-.0520051	.0521061
DU	-.3437795	.0888504	-3.87	0.000	-.5179828	-.1695762
_cons	1.172284	.2128201	5.51	0.000	.7550212	1.589547

Appendix 6: Test of symmetry conditions

Symmetry condition	F-value	Prob>F
1. [sf]ln(wage rate)= [sl]ln(fertilizer price)	2.34	0.1265
2. [lnnprofit][ln(fertilizer price)]^2 + [sf] ln(fertilizer price)=0	2.74	0.0980
3. [lnnprofit] [ln(wage rate)]^2 + [sf] ln(wage rate)=0	0.00	0.9910
4. [lnnprofit] [ln(fertilizer price) x ln(wage rate)] + [sf] ln(wage rate)=0	2.81	0.0940
5. [lnnprofit] [ln(fertilizer price) x ln(area under maize)] + [sf] ln(area under maize)=0	2.86	0.0909
6. [lnnprofit] [ln(fertilizer price) x ln(education)] + [sf] ln(education)=0	0.05	0.8162
7. [lnnprofit] [ln(fertilizer price) x ln(distance to motorable road)] + [sf] ln(distance to motorable road)=0	0.98	0.3231
8. [lnnprofit] [ln(wage rate) x ln(area under maize)] + [sl] ln(area under maize)=0	3.65	0.0561
9. [lnnprofit] [ln(wage rate) x ln(education)]+ [sl] ln(education)=0	7.12	0.0076
10. [lnnprofit] [ln(wage rate) x ln(distance to motorable road)] + [sl] ln(distance to motorable road)=0	0.29	0.5894
11. [lnnprofit] ln(fertilizer price) + [sf] intercept=0	5.99	0.0145
12. [lnnprofit] ln(wage rate)+ [sl] intercept=0	3.92	0.0478

Note: lnnprofit refers to the normalized restricted translog profit equation, sf refers to the fertilizer share equation, sl refers to the labour share equation

Source: Author's computation

Appendix 7: Estimates of the normalized restricted translog profit function with some restrictions dropped

	Estimation with 12 restrictions			Estimation with 8 restrictions		
Variable	**Coefficient**	**t-statistic**	**P>|t|**	**Coefficient**	**t-statistic**	**P>|t|**
ln(fertilizer price)	0.204	1.340	0.1790	-0.142	-0.820	0.4110
ln(wage rate)	1.172*	5.510	0.0000	1.394*	6.540	0.0000
$[\ln(\text{fertilizer price})]^2$	-0.099	-0.780	0.4350	-0.152	-1.190	0.2340
$[\ln(\text{wage rate})]^2$	-0.532*	-4.860	0.0000	-0.491*	-4.530	0.0000
[ln(fertilizer price) x ln(wage rate)]	-0.084	-1.250	0.2110	-0.040	-0.580	0.5600
[ln(fertilizer price) x ln(land area)]	0.052**	1.660	0.0970	0.068*	2.080	0.0380
[ln(fertilizer price) x ln(distance to motorable road)]	-0.013	-0.410	0.6830	-0.015	-0.470	0.6350
[ln(fertilizer price) x ln(education)	-0.001	-0.060	0.9500	-0.017	-0.810	0.4150
[ln(wage rate) x ln(land area)]	0.056	1.340	0.1810	-0.014	-0.240	0.8100
[ln(wage rate) x ln(distance to motorable road)]	-0.100*	-2.250	0.0240	-0.109*	-2.510	0.0120
[ln(wage rate) x ln(education)	0.000	0.000	0.9980	0.080*	2.160	0.0310
ln(land area)	0.913*	10.060	0.0000	1.000*	8.770	0.0000
ln(distance to motorable road)	0.149	1.200	0.2310	0.173	1.400	0.1610
ln(education)	-0.075	-1.240	0.2160	-0.210*	-2.820	0.0050
$[\ln(\text{land area})]^2$	0.149*	4.120	0.0000	0.149*	4.120	0.0000
$[\ln(\text{distance to motorable road})]^2$	0.131**	1.800	0.0720	0.119**	1.650	0.0990
$[\ln(\text{education})]^2$	-0.013	-0.700	0.4870	-0.013	-0.680	0.4970
[ln(land area) x ln(distance to motorable road)]	-0.006	-0.220	0.8290	0.007	0.250	0.8050
[ln(land area) x ln(education)]	0.008	0.470	0.6400	-0.004	-0.250	0.8030
[ln(education) x ln(distance to motorable road)]	0.010	0.570	0.5690	0.012	0.680	0.4940
Zone dummy (1=high potential, 0 otherwise)	1.169*	19.120	0.0000	1.264*	19.930	0.0000
Intercept	3.640*	15.350	0.0000	3.322*	13.520	0.0000

*Significant at 5 % level or below, **Significant at 10 % level.
Source: Author's computation