SOCIAL INTERACTIONS AND RETURNS TO FARM INPUTS IN SMALLHOLDER AGRICULTURE IN KENYA

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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This thesis has been submitted for examination with our approval as university supervisors

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ABSTRACT

This study is motivated by a desire to establish the extent to which social interactions affect production behavior of farmers and returns in smallholder agriculture in Kenya, aspects that are absent from the existing literatures in Africa. Social interactions include learning and peer relationships that exist among economic agents. The study is further motivated by concerns about poverty effects of incomes that are mediated through social interactions.

In the empirical analysis of the thesis, a variety of regression methods are applied to primary data collected from Nyeri, a rural district in Kenya to estimate effects of social interactions on demand for farm inputs and on returns to these inputs. Since data on social interactions are not available, interactions are proxied by fertilizer application, animal feeds, soil conservation efforts and property rights, all measured at the village level.

There are three main findings from the thesis. The first finding is that there are sizeable returns to fertilizers and animal feeds in smallholder agriculture in the study district. The elasticity of crop output with respect to fertilizer is 0.2 while the elasticity of livestock output with respect to animal feeds is 0.6. The production effects of basic inputs, notably land, capital and labor are all positive and statistically significant. The second finding is that social interactions have large effects on demand for farm inputs and on their returns. Finally, simulation results show that increasing farm output through application of productivity-enhancing inputs such as fertilizers and animal feeds can contribute significantly to closing the poverty gap in the study area.

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DEDICATION

This thesis is dedicated to my departed parents, Zipporah Njoki and David Gathiaka, for their support and inspiration in educational pursuits even though they themselves were not educated.

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CHAPTER 1 : BACKGROUND AND CONTEXT

1.0 Introduction

Agriculture is an important economic activity employing nearly 70 percent of the labor force and contributing about 25 percent of the gross domestic product (GDP) in Kenya, valuation problems of subsistence output notwithstanding (Republic of Kenya, 2006; 2007a; 2010). Much of the farming takes place in only 20 percent of Kenya's landmass (approximately 116,528 sq. km.), which is classified as of medium-to-high agricultural potential. In this area also lives 75 percent (over 25 million people) of the country's population. Majority of the farms are small-sized, measuring less than 5 acres in medium-to-high potential areas and less than 50 acres in low agricultural potential zones.

In some of the smallholder farms, food crops are grown exclusively while in others a mix of food and cash crops is grown. In yet a few other farms, mono-culture cash crop agriculture is practiced. A majority of the smallholder farmers rear livestock, the most common types of which are chicken, goats, sheep, pigs and cattle. The most commonly produced livestock products are milk, eggs, hides and skins. They serve household consumption needs with surpluses being sold off in the local markets, including cooperative societies, and in foreign markets.

Population growth in medium- to high- potential areas is quite high, causing farms to suffer continuous fragmentation into ever more smaller units, some of which are uneconomical (Republic of Kenya, 2007b; 2010). These units form much of what is called smallholder farms. Other smallholder farms are situated in forestlands in a controversial arrangement commonly referred to as the *shamba* (farm) system (Republic of Kenya, 1994).

1.1 Smallholder Farms

(i) Location and Potential

According to Heyer and Waweru (1976), smallholder farms in Kenya are found in the former 'African areas', settlement schemes, irrigation schemes and 'illegal settlements'. These are quite heterogeneous areas in terms of climate, natural resource endowments, intensity of land use and farming technologies.

Most of the smallholder farms are situated in climatic conditions that vary from cold-wet to warm-wet in the highlands, and warm-dry climate in the lowlands and semi-arid zones. The highlands are zones of high agricultural potential with comparatively better physical infrastructures. They are relatively better served by roads, piped water, communication network, extension services, farmer education, and input distribution channels.

Farms in the highlands could realize high to average returns to investments but they are intensely cultivated without soil conservation measures to replenish lost nutrients. The use of fertilizer, animal manure, soil terracing and ridging, tree planting among other soil conservation measures have the potential to improve productivity and returns to inputs in smallholder agriculture. However, these inputs usually fall below optimal application levels in smallholder agriculture thereby denying farmers the benefits of maximum returns from the available inputs. There is need for an investigation into the determinants of inputs demand in smallholder agriculture with a view to increasing knowledge on how interventions that can boost input demands and raise farm productivity can best be implemented.

In the semi-arid zones, farming activities pose serious soil conservation problems. Through over-grazing and inappropriate cultivation methods, soil erosion is accelerated, reducing the agricultural productivities in these areas.

Smallholder farmers rely heavily on domestic inputs and family labor. Their activities are labor intensive, use capital equipments sparingly and earn low incomes from crop and livestock activities. The farms are characterized by family economies of scale, use of family labor, subsistence consumption, use of self-grown inputs, simple technologies and machinery, and by weak linkages with the market (Heyer, Maitha and Senga, 1976; Spencer, 2001). Other aspects of smallholder farmers include low business skills and scale, limited access to research, technical advice, skills, markets, transport and to finance (Senga, 1976). The Kenyan government in its strategy for revitalizing agriculture (Republic of Kenya, 2004a) notes that farm input prices in the local agricultural markets are erratic and at times higher than in international markets, and that this has discouraged investments particularly in smallholder agricultural production.

Many smallholder farmers are efficient users of resources. Total labor employment per acre and use of 'appropriate' technology in small farms is said to be impressive going by empirical evidence, but this evidence is contestable (Heyer, Maitha and Senga, 1976). What is not in contest is that returns to smallholder farms especially in Africa are low, and that this sub-sector has many poor families or households (Lipton, 2005).

Due to aforementioned factors, yields in smallholder farms fall below potential levels. This undermines not only food security in the country but also the ability of small scale farmers to earn a decent livelihood out of agriculture. In spite of the negative influence of their characteristics on profitability, smallholder farming remains the most common mode of farming in Kenya. It appears that to some extent, smallholder farming is less of a commercial activity and more of a way of life as well as a medium through which social interactions occur.

(ii) Institutional Environment

A major problem facing smallholder farms is underdeveloped physical capital. Poor roads, in particular, reduce market access and render farmers vulnerable to manipulation by middlemen. Some perishable farm produce go to waste during rainy seasons when roads become impassable.

Expectations are that farmers would reap highest returns during rainy seasons when harvests are highest, but with poor roads the opposite usually happens. Poor roads may also force farmers to adopt different technologies between plots near home and those at a distance, with home plots benefiting more from higher investments (Kabubo-Mariara *et al.*, 2010).

Many smallholder farms are far from markets. They lack adequate extension services and credit facilities. They operate in risky institutional environments that lack property rights such as title deeds and incentives to invest in soil and environmental conservation (Kabubo-Mariara *et al.*, 2010).

Property rights confer on individuals and groups the right to use, dispose, and exclude others from a property. Property rights in land relate to private leaseholds, private freeholds, common property, state farms and forests, squatter-tenancy in private and state lands, and co-operatives. Freehold represents the strongest bundle of rights that an individual can enjoy in a property (Republic of Kenya, 2007b). The owner of a freehold private property has the rights to enjoy direct utility from the property, to withdrawal resources from the property for profit, to set own rules for use of the property, to exclude other users from the property, and the right to sell, lease or bequeath the property. In other words, ownership of a private property entails the right to acquire, retain, use for profit, dispose or transfer the property to another person (Republic of Kenya, 2007b).

Each property rights regime has implications on the type of agriculture and technology-mix that can be practiced on a farm. Regimes that offer security of tenure induce better management decisions that lead to higher output on average (Kabubo-Mariara *et al.*, 2010). Ineffective regulation of property rights has been blamed for encouraging unplanned settlements and environmental degradation that has been taking place in forests and unoccupied areas (Republic of Kenya, 2007b).

Land tenure is one of the available bundles of property rights. The Government defines land tenure as the "terms and conditions under which rights to land and land-based resources are acquired, retained, used, disposed of, or transmitted" (Republic of Kenya, 2007b:1). Tenure rights in Kenya have been skewed in favor of individualized ownership.

Although individual land ownership encourages long-term investments on land and environment (Kabubo-Mariara *et al.*, 2010; Fenske, 2010), it has been blamed for depriving many indigenous Kenyans access to land, and for fragmentation of agricultural land into uneconomic units. It has also contributed to disruption of indigenous cultures and conservation systems. By individualizing land tenure, traditional resource management institutions have collapsed, while access and use of land particularly in pastoral lands has become uncertain (Republic of Kenya, 2007b). This trend has implications for agricultural practices and investments.

(iii) Land Pressure and Land degradation

Although smallholder farms are of great economic benefits to the country in terms of food production, employment and hosting majority of the population, they have problems. Some of their units are uneconomical, but more importantly, their modes of production cause land degradation and create negative externalities. Libecap and Hansen (2002) observe that farm size and land use practices contribute to soil erosion particularly by wind more than does natural geologic and climatic conditions. Smallholder farmers cultivate their lands intensively and render the topsoil thinner, lighter, drier and vulnerable to agents of erosion. Libecap and Hansen (2002) observe that small farmers are less likely to invest in erosion control measures such as fallowing because their holdings are small. As a result of these factors, agricultural productivity in these farms has been declining (Fulginiti and Perrin, 1998).

The proliferation of smallholder farms is testimony to the rising land pressure in agricultural areas of Kenya. Land pressure is closely associated with (but not necessarily a cause of) land degradation. According to the government's draft policy on land, rising population without adequate means of support has entrenched poverty in the country.

Poverty breeds livelihood strategies that encourage inappropriate land-use practices, soil erosion and squatter phenomenon. It also drives farmers into encroaching on gazetted lands, destroying forests, water catchments and biological diversity. Some of the 'excess' population migrates to areas of low agricultural potential where they practice farming using technologies only suitable for high-potential zones. The consequences of these farming practices and their effects on land, environment and returns to inputs need careful study.

The link between poverty and environment has been examined by Kabubo-Mariara *et al.* (2010). The examination shows that poor households and those with weak or no tenure security make little or no investment in soil and water conservation. Subsequently, soil quality in their lands deteriorates thereby denying them good harvests. Poor harvests deny the farmers a good return on inputs and undermine farmers' ability to invest in new technologies, e.g., fertilizers, animal feeds or soil conservation.

Failure to invest in erosion control increases the risk of erosion in smallholder farms. The damaging effects of soil erosion spread to neighbors, their erosion control measures notwithstanding. Running water may cross neighborhood boundaries and erode soil in farms with and without conservation measures. With such cross-cutting damages, non-conserving farmers send a negative externality to other farmers (Nyangena and Kohlin, 2008). If the victims and villains are many poor small farmers, coordinating collective action to fight soil degradation is difficult. To control the negative externalities may require government intervention in either incentives or regulations as argued by Coase (1960).

In the absence of such interventions, farmers continue drawing declining returns from their inputs (Libecap and Hansen, 2002). When fortunes decline in mismanaged plots, some farmers may look to forestlands and exert the same damage as has happened with the *shamba* system in Kenya.

(iv) Smallholder Farms in Nyeri

In Nyeri district, small farms are said to have great potential to deliver residents out of poverty, but the reality is quite different. According to the Nyeri District Development Plan (1997-2001), poor or inadequate physical infrastructures are a problem to farmers, causing them to reap low returns from their investments. During rainy seasons, a lot of harvested crop rots on the farms since the roads become impassable hindering their transportation to the markets (Republic of Kenya, 1997).

Land degradation and low productivity undermine the potential of smallholder farms to deliver farmers out of poverty. Population pressure has resulted in over-exploitation of natural resources including soils, and this has accelerated land degradation. Consequently, farm yields are far below their potential (Republic of Kenya, 2002).

Mismanagement of cooperatives and inaccessibility of credit facilities constrain small-farm operations in the district. Creditor institutions demand title deeds as collateral for loans but most people do not have the deed documents

(Republic of Kenya, 1997). These issues point to deeper problems of property rights and their effects on investments in land and agriculture in Nyeri district.

1.2 Research Problem

Smallholder farms occupy a central place in Kenya's agriculture. In addition to meeting subsistence needs, they are expected to produce food and raw materials for local and overseas markets, create jobs and contribute towards poverty reduction. However, they may not be up to these tasks for several reasons, the principal one being economic viability of small farms. The farms are too small in size and some farmers possess only weak property rights. These aspects discourage optimal utilization of farm inputs, and investments in soil conservation in smallholder farms. As a result, the yields in smallholder farms are low. There is need to investigate whether returns to smallholder farming justify the many contributions expected from this sub-sector as outlined in the Economic Recovery Strategy (ERS) paper (Republic of Kenya, 2004a).

Agricultural production does not take place in a 'black box' but in a social context characterized by social interactions among farmers (Munshi, 2004). These interactions generate social learning, peer effects and externalities that are important in farmers' decisions regarding choice of inputs and their levels of usage. Social interactions may significantly influence returns to inputs and should not be ignored when estimating production functions or calculating returns to farm inputs. Failure to control for social effects can introduce bias in the estimated returns (Kimenyi *et al.*, 2006). The bias may prevent proper assessment of the contribution of the various inputs into smallholder farming, and the importance of smallholder farms in alleviating poverty.

Estimates of returns to farming have conventionally measured the marginal value product of an input (Randrianarisoa and Minten, 2001) and monetary returns for money invested (Farquharson, 2006). While these conventional measures are by all means useful, they may be biased because they ignore social interactions and externalities. For example, Farquharson (2006) in simulating wheat production response to fertilizer does not consider that fertilizer demand may be influenced by social interactions among farmers. Previous studies in Kenya have also not taken into account the effect of social interactions in smallholder agricultural production (see for example, Nyangena and Kohlin, 2008; Kabubo-Mariara, 2010; Kabubo-Mariara *et al.*, 2010). There is need to investigate how input demand and returns to farming behave in the presence of social interactions because these social phenomena are common in farm environments.

From the foregoing, it can be seen that there is an important issue that arises when estimating returns to farm inputs in the presence of neighborhood effects. In particular, returns to fertilizer and animal feeds, two key inputs in smallholder agriculture, have previously not been estimated accounting for neighborhood effects. This study addresses this research gap using cross sectional data from Nyeri, a rural district in Kenya.

1.3 Research Questions

The following issues are investigated:

(1) What are the determinants of demand for factor inputs in smallholder agriculture?

(2) What are the magnitudes of returns to these inputs?

(3) What is the effect of social interactions on demand for farm inputs and on returns to these inputs?

(4) Given the prevailing returns, how would farm production and incomes change in response to variations in farm inputs?

(5) What are the poverty reduction implications of such variations?

1.4 Research Objectives

The general objective of the thesis is to establish the extent to which social interactions influence smallholder farm input demands, and the associated returns. The specific objectives are to:

1) Estimate parameters of farm input demand functions in smallholder agriculture in the presence of neighborhood effects.

2) Measure returns to farm inputs controlling for neighborhood effects.

3) Explore the extent to which production and incomes in smallholder agriculture can be increased to alleviate poverty, using existing farming technologies.

1.5 Justification of the Study

Why was this study necessary? The effects of social interactions and externalities on returns to farm inputs in Kenyan agriculture have not received due attention in previous investigations, despite the evidence on the pervasive nature of these effects in other parts of the world. Studies on this area from other countries (see for example, Foster and Rosenzweig, 1995; Munshi, 2004; Bandiera and Rasul, 2006; Conley and Udry, 2001, 2007) provide a solid foundation on which to carry out investigations of the kind conducted in this thesis.

Smallholder farms play an important role in the Kenyan economy. They are an important source of subsistence while the surplus is sold in the market. The contribution of smallholder farms to total agricultural marketed production has, however, declined over time. This trend has implications on food self-sufficiency and security. If the contribution of the small farm sector is to be enhanced and sustained, deliberate policy efforts to revitalize the sub-sector are essential. The findings reported in this thesis can help in addressing this issue.

1.6 Organization of the Thesis

This thesis is organized into seven chapters. The first chapter presents the background and context of the study, including the research problem, and the purpose of the study. Chapter two reviews both theoretical and empirical literatures on smallholder farming. Chapter three discusses the analytical issues essential for understanding smallholder agriculture. The fourth chapter presents a profile of the study area, focusing on sampling procedures and descriptive statistics. Chapter five presents econometric results on returns to farm inputs in crop and livestock segments of smallholder farming. The sixth chapter presents simulation results while chapter seven summarizes the thesis and draws its policy implications.

CHAPTER 2 : LITERATURE REVIEW

2.0 Introduction

This chapter presents a review of relevant studies on smallholder agriculture. The first section reviews the literature on the role of smallholder farms and issues facing them. The second section looks at theoretical and empirical studies on demand for farm inputs. Demand for inputs is one of the first steps in producing any output. Section three reviews studies on determinants of agricultural production. An important determinant of inputs demand and agricultural production that is less understood is social interaction. The sections that follow review mechanisms through which smallholder farmers interact with neighbors and also trace the externalities arising from such interactions. The review concludes with an overview of the literature covered. The review brings out the strong divergence of researchers' views on small farm enterprises and on production effects of social interactions in these enterprises.

2.1 Smallholder Farms

Some researchers view small farms as commercial, profit-seeking, family enterprises (Lipton, 2005). They have been hailed and condemned at the same time. Those who look at them favorably cite their superiority in activity mix. It is argued that by planting several other crops between rows of one crop, the 'ecological niche space' is fully utilized and total production per unit area is maximized.

Small farmers are said to be efficient producers in an integrated crop-livestock system. For example, they use animal manure as fertilizer, while parts of crops not used by humans are used to feed the animals. Through this way, there is recycling of nutrients and biomass in smallholder farms (Rosset, 2000). Rosset argues that the family labor used in small farms is of higher quality compared to hired labor since family labor is tied to the fate of a piece of land, and therefore has an incentive to care for the land to maintain its productivity.

Scholars who view smallholder farms favorably see them as having a bright future, but requiring support in social infrastructure, especially in form of agricultural credit, improved road network, efficient marketing outlets, favorable pricing policy and reliable input supplies. Rosset (2000) and Nagayets (2005) argue that small farms are victims of liberalization, of government neglect and of multinational companies that export grains to low income countries at prices below the cost of production thereby driving small farms out of business. In the Kenyan context, the multinational aspect may not be quite relevant but it may be correct to argue that small farms are victims of governmental and bad agricultural policies.

Spencer (2001) in support of small farm enterprises argues that they are efficient users of resources though poverty stricken. He attributes poverty in small farms to inadequacy of social services, such as roads, extension services, and argues for government investment in social infrastructures that serve small farms. Jansen (2006) is of the opinion that off-farm employment would go a long way towards poverty reduction in smallholder farms.

Lipton (2005) advances the same view and argues that small farms are a source of employment for the poor and of low-cost food staples. Low food prices benefits net buyers of farm products (Levin, 2010) but render small farmers highly susceptible to poverty and hunger (Lipton, 2005). Unlike Spencer, Lipton (2005) argues for crop science technology that is tailored to small farms, rather than for social infrastructure as a mechanism for increasing productivity and incomes in smallholder agriculture.

Scholars opposed to small farms cite environmental degradation by these enterprises emanating from intensive farming (Libecap and Hansen, 2002), usage of inappropriate technology that degrades the land (Republic of Kenya, 2007b), and their unprofitability thereby rendering them the 'parking lots for the poor' (Lipton, 2005; Nagayets, 2005). The critics see no future in smallholder farms and consider them transitional in the development process.

2.2 Demand for Farm Inputs and Agricultural Production

Agricultural production is important as a source of food, animal feeds and industrial raw materials. Demands for these outputs determine demand for farm inputs. Other factors affecting demand for inputs include farming practices and access to extension services and to credit (Ogundari, 2008).

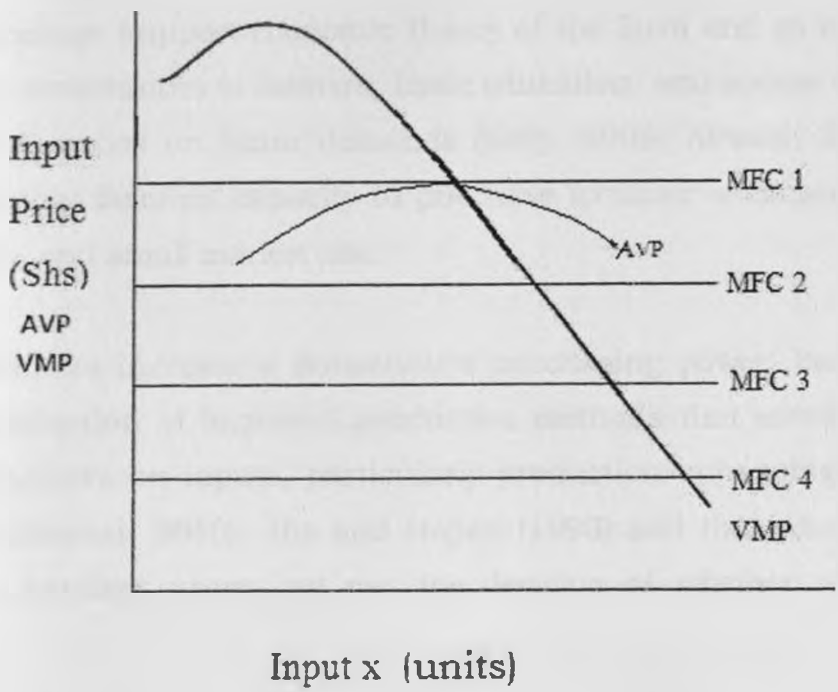
Farmers demand inputs which they combine in a certain manner, called production technology to produce an output or outputs. An input may be described as any material or service that contributes to production. The technology of producing an output is part of a firm's production plan (Varian, 1992). To the extent that farmers demand inputs and transform them into outputs, they are firms.

Traditionally, factor inputs are classified as capital, labor, land and materials (Bureau of Agricultural Economics, 1976). Materials could be purchased inputs such as chemical fertilizers, agricultural chemicals, energy and animal feeds, or they could be self-produced seeds, manure and fodder. Capital embodies machinery, buildings, livestock, and land improvements such as drainage, irrigation and farming technology. Labor refers to the human factor or persons engaged in agricultural production. The input of labor could be sourced from within farming households or hired from outside. Land embraces all natural factors used in agricultural production such as area under cultivation (Bureau of Agricultural Economics, 1976).

From economic theory, an input demand function gives the optimal choice of an input as a function of prices (Varian, 1992). Demand for farm inputs is a derived demand that is dependent on price of the output produced. Thus, input demand is a function of price of input, prices of substitute or complementary inputs to the production process, the price of output and the technical coefficients that describe the technical transformation of inputs into output. Availability of money to purchase inputs, i.e., the budget constraint affects input demands (Debertin, 1986).

Following Debertin (1986), the input demand curve for a hypothetical profit maximizing farmer operating in a competitive market and using a single variable input can be depicted as follows:

Figure 1. Inverse Demand Function for an Input



Source: Debertin, 1986.

Figure 1 depicts the average variable product (AVP) curve and the value of marginal physical product (VMP) curve in a hypothetical farm. The horizontal lines trace levels of input prices. Since the farmer is assumed to use only one input, each price represents a constant marginal factor cost (MFC) for the underlying production technology.

When input price is equal to the value of marginal physical product (VMP), input demand is optimal. This occurs every time the marginal physical product curve intersects a horizontal line tracing input price. The points of intersection trace out an input demand curve. At each point, the first order condition for profit maximization is satisfied. Put differently, the demand for an input can be found by solving the first order condition for profit maximization. An increase in output price increases input demand while a decrease has the opposite effect. A rise in the productivity of an input raises the marginal physical product of an input.

Empirical findings support economic theory of the farm and go a little further to show that remittances to farmers, basic education, and access to credit have important influences on factor demands (Kelly, 2005; Akwasi, 2010). Akwasi (2010) finds that farmers' capacity to purchase fertilizer is constrained by low farm incomes and small market size.

While remittances increase a household's purchasing power, basic education encourages adoption of improved production methods that entail significantly higher expenditure on inputs, particularly production enhancing inputs such as fertilizer (Akwasi, 2010). Jha and Hojjati (1993) add that education affects intensity in fertilizer usage but not the decision of whether or not to use fertilizer.

From a series of studies on fertilizer usage in Africa, Kelly (2005) has observed that poor output response (output-nutrient ratios of less than 10 for cereals) is a disincentive to input usage at the farm level. Her findings reveal that fertilizer's agronomic potential is often unrealized because of poor husbandry lines trace levels of input prices. Since the farmer is assumed to use only one input, each price represents a constant marginal factor cost (MFC) for the underlying production technology.

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Unfavorable price relationships (input-output price ratios greater than 2) and low net returns (value-cost ratios less than 2) constrain effective demand for factor inputs (Kelly, 2005). Differences in transaction costs for different rural locations affect the return to individual farm households obtained from purchased fertilizers (Akwasi, 2010). Kelly further shows that disincentives to use purchased farm inputs are stronger in food crops than in cash crops.

Kelly (2005) observes that African smallholder farmers face significant information and liquidity problems, in addition to risks and technical constraints that make it difficult to use recommended crop management practices. Institutional constraints limit human capital development and market performance thereby weakening demand for inputs. In particular, markets for agricultural outputs are weak and risky. Kelly concludes that input demand is the net result of dynamics of interactions of government policies, investment decisions, market forces, as well as decisions by farmers. These dynamics effectively influence agricultural production. Decisions on input usage by an individual farmer could be influenced by the decision taken by other farmers with whom the farmer interacts (see section 2.4).

2.4 Social Interactions in Farming

In production and consumption, economic agents do not always possess full information when making decisions. The agents may try to overcome the problem of information asymmetry by learning from other agents such as neighbors, peers or extension officers. Learning can take place during social interactions or can result from an agent's inferences from observations of the behavior of other agents.

A smallholder farmer is one such economic agent who does not always possess full information regarding best input combinations or technology use. The farmer may complement whatever knowledge in his possession with information gathered from elsewhere to make production decisions.

A farmer may interact with other farmers and with extension officers and in the process gather new ideas on farming (Munshi, 2004). In addition, a farmer may observe his neighbor's activities regarding usage of inputs and production of farm produce and form opinions about particular aspects of farming (Conley and Udry, 2007; 2008), a process known as learning by observation. A farmer may also learn through discussing with other more informed farmers, a process known as learning through the word-of-mouth. Thus, social interactions are important in farm enterprises and have a bearing on their profitability. A farmer could also learn from a local extension agent. The agent may provide precise and unbiased estimates of expected crop yield. A farmer can also learn from his or her past farming experience (Munshi, 2004).

Munshi (2004) argues that in the absence of a local extension agent, a farmer may base his current input decisions on past observations of his neighbors' actions regarding input usage, e.g., the acreage planted or the amount of fertilizer applied and the outcome thereof. A farmer may also take into account average village level yields in the past to make current decisions on input usage on his own plot as well as in updating his own estimates of expected yields.

Thus, neighbors' experiences with inputs can importantly influence a farmer's decision-making process. A neighbor's previous decisions and plot-level outcomes when observed properly and repeatedly may provide credible basis for social learning.

In the extreme case, a farmer may make decisions solely on information learnt from neighbors and completely ignore his own experience or private information (Banerjee, 1992). This phenomenon suggests that there may be times when the neighbors' and a farmer's own experience are perfect substitutes in the process of making decisions about technology choice.

The process by which a farmer learns from neighbors' experiences or actions is referred to as social learning (Munshi, 2004; Eisenkopf, 2010). A learning farmer must be able to observe his neighbors' circumstances in order to learn from them. However, even when the neighbors' experiencces are observed, they may not be useful to an observing farmer. This is particularly so if the characteristics that determine actions are varied within the population of neighbors. If neighbors' decisions are functions of unobserved characteristics peculiar to them, social learning breaks down because such characteristics are not available to an observing farmer.

Ellison and Fudenburg (1995) propose a rule of thumb that individuals only learn gainfully from neighbors with characteristics similar to theirs. If that is the case, then farmers only learn from peers. Peer farmers are neighbors that a given farmer interacts with. Social learning thrives in a context of social interactions. To that extent, individual characteristics of interacting neighbors are important determinants of an individual farmer's knowledge in agriculture and his crop yields (Munshi, 2004).

Munshi (2004) observes that in the absence of social learning, a farmer will tend to experiment on his plot in a bid to generate information that he desires. Social learning is a way of passing on information that is generated from field trials through farmers who have acquired it. Farmers who receive such information, therefore, save on costs of experimenting. The disadvantage of social learning is that it curtails generation of new information that could emerge from further field trials by farmers (Munshi, 2004).

Social learning is time-sensitive because it decreases with time as a learner gets more informed or experienced (Conley and Udry, 2007). In a situation where every agent has acquired information, social learning ceases.

There is need to distinguish between social influence and social learning. Social influence or peer effect is a situation where a farmer takes an action on the basis of dominant opinions and behaviors in his social environment (Kohler, Behrman and Watkins, 2001; Argys and Rees, 2008; Borelli, 2009; Bobonis and Finan, 2009; DeGiorgi, Pellizzari and Redaelli, 2009; Eisenkopf, 2010). For example, a farmer may copy the behavior of neighbors in order to conform, or in response to prevailing opinions. Such copying is as a result of social influence and does not entail social learning (Foster and Rosenzweig, 1996).

According to Hogset and Barret (2008), a learner may closely monitor the actions of some particular individuals of interest and acquire precise information. The process of monitoring individuals closely is social learning. Should the learner, however, monitor a whole population, he acquires general and imprecise information that does not entail social learning. This may happen when an observer draws conclusions on a population behavior, say, adoption of a new technology, on the basis of population adoption rate. Such conclusions are based on social influence rather than social learning. The observer lacks details of the behavior, and his conclusions are based on general perceptions.

Social learning emphasizes that an agent's decision is subject to uncertainty and that by learning other agents' experiences, uncertainty is reduced and the probability of an agent taking an action increases (Kohler, Behrman and Watkins, 2001). Foster and Rosenzweig (1996) add that for social interactions with neighbors to result in social learning, there must be distinguishable change in an individual's productivity and not just his behavior. Social learning provides positive information externalities that should be reflected in an increase in an individual's productivity.

Foster and Rosenzweig (1996) assert that identification of learning from neighbors requires information on the learner's productivity or returns to effort in addition to identifying neighbors' characteristics or behavior relevant to productivity growth. In other words, social learning externalities should be tested in terms of learner's productivity rather by his copying behavior. The test for knowledge spillovers and learning externalities require a precise specification of the learning mechanism and of production technology. Kohler, Behrman and Watkins, (2001) argue that social learning is maximized when the density of group network is so sparse that partners do not interact with one another but serve as relatively independent sources of information for each other.

When a farmer takes an action in response to his neighbors' decisions or decision outcomes and this action becomes a basis for social learning by neighbors, social interactions arise (Hartmann *et al.*, 2008). In other words, when there is a flow of information among neighbors in alternating periods (e.g., experience of farmer *m* at time *t-1* serves as social information for farmer *n* in time *t*, and farmer *n* responds to that information and takes a decision and action that serves as a lesson for farmer *m* in time *t+1*), the learning that takes place is characterized by feedbacks and indicates active social interactions. That farmer *n* was able to learn from *m* suggests *m* and *n* share common characteristics and are able to interact.

However, should the flow of information from *m* to *n* not elicit a response action from *n*, the information so received becomes a spillover or an externality to *n* (Hartmann *et al.*, 2008). Thus, it is the feedbacks of actions between *m* and *n* that constitute social interaction. If *n* does not observe *m*'s experience properly such that *n* takes no action in response, the social information arising from *m*'s experience is an externality to *n* since it does not elicit any feedback from *n* (Hartmann *et al.*, 2008).

In a situation where no farmer has taken up an action or does not possess a characteristic of interest, farmers in that neighborhood exchange externalities. For instance, if in a neighborhood fertilizer application is desirable yet no farmer is using it in large quantities, the farmers in that village exchange externalities. Thus, when the mean of an action or characteristic in a neighborhood is zero or close to zero, the farmers in that neighborhood generate and experience externalities because of the absence of feedbacks with respect to the action or characteristic

According to Hartmann *et al.* (2008), social interactions occur whenever one agent in a network affects other agents' choices directly without the intermediation of the market. Kohler, Behrman and Watkins, (2001) contend that the content of social interaction can be distinguished by the proportion of adopters in a network. When the proportion of adopters of an action or behavior is modest, social interactions create room for social learning. When every agent has taken up an action or adopted a characteristic of interest, social interaction has reached equilibrium, and there is no room for social learning.

Social interactions lead to social effects. The effects only relate to members of a defined group. Social interactions are therefore in relation to group members. The group is a point of reference in social interactions. A reference group is a set of other agents whose behavior affects the focal or agent of interest. At a micro level, a reference group could be a neighborhood or a village (Ellison and Fudenburg, 1995).

Due to social interactions, persons in the same group tend to exhibit similar behavior (Manski, 2000). The similarity has been hypothesized to obtain because of three reasons. The first is that persons have a propensity to behave in some way that varies positively with the prevalent behavior in their group. This phenomenon is variously referred to in the literature as endogenous interaction, peer influence, neighborhood effect, social norm, conformity, imitation, herd behavior, among other terms.

Endogenous interactions have the characteristic that decision of one agent is influenced by peers' average decision. However, this one agent could also be shaping group decision in one way or another through his actions or characteristics. This is the reflection problem identified by Manski (1993). Individual and group decisions are simultaneously determined. There is therefore a problem of simultaneity bias in identifying peer effect.

The second explanation is that individuals that form a group may behave in the same ways because of some exogenous characteristics common to all group members. For instance, group members may have similar family backgrounds (parents' have same income or education) and this may drive them to behave in similar ways. The social influence from such similarity is referred to as contextual effect (Manski, 1993).

Thirdly, individuals in the same group may exhibit similar behavior because of similar individual characteristics or sharing of a similar institutional environment, e.g., a school. The social effects associated with such external factors are referred to as correlated effects (Manski, 1993). That is behavior is correlated with some external factor, e.g., school rules.

Manski (2000) presents the economists' view of social interactions distinctly by defining interacting parties as agents (persons, firms, non-profits, and governments) who are decision-makers endowed with the ability to express preferences, form expectations and operate amidst constraints. The agents interact through actions that each agent chooses. One agent's action may affect the constraints, expectations, or preferences of other agents, thus influencing the actions that the other agents choose. In other words, actions of agents in a network have cross-effects (Lalive and Cattanco, 2009).

Preferences find formal expression through utility functions; expectations through subjective probability distributions; and constraints through choice sets (Manski, 2000). Actions that take place through the market have features that constrain interactions. In instances when an agent has to make a decision without full information, he forms expectations of the outcomes that would follow from choosing different actions.

An agent forming expectations may seek to draw lessons from observing actions chosen by others and their outcomes. Such observational learning generates expectations interaction. Observational learning reveals private information of other agents that the observing agent uses to form rational expectations of his own. Preference interaction occurs when an agent's preference ordering over alternatives in his choice set depends on actions or preferences chosen by other agents.

Hartmann *et al.* (2008) model social interactions as being determined by actions and characteristics of interacting agents. The interactions generate either multiplier or spillover effects. Multiplier effects obtain when one agent's action affects the other agent's action and vice versa, with the effect being direct and symmetrical. Agent 1's action affects agent 2's action and agent 2's action affects agent 1's action. Spillovers exist when social interactions are characterized by asymmetry in action. In other words, agent 1's action affects agent 2's action but agent 2's action does not affect agent 1's action. In such a case, agent 1's action is a spillover or an externality to agent 2.

Another instance when spillovers occur is when agent 1's characteristics (rather than action) affect agent 2's action symmetrically (i.e. agent 2's characteristics also affects agent 1's action). Here, the cross effects are via characteristics only. There is no action. In that case there will be no feedback from one agent to the other and the social interaction results in a spillover.

2.5 Other Externalities

Non-information externalities are generated and felt in the course of production or consumption. They are effects on production or consumption of one agent from production or consumption activities of another agent (Nicholson, 1985).

As people engage in consumption and production, they generate externalities that affect the welfare of others. Externalities are costs or benefits outside the price system. They are third party, spillover or external effects for which no compensation is paid. They occur in virtually all areas of economic activity causing inefficiencies in resource allocation, yet they are not reflected in market prices (Nicholson, 1985).

Externalities can also be 'pecuniary' or 'technological' (Nicholson, 1985). Pecuniary externalities are the effects of one economic agent's action in the market that affects another economic agent, e.g., a purchase of an item by a consumer may raise its price generally and that may affect the welfare of other buyers of the item.

Technological externalities are the effects of one economic agent's activities that affect another agent in ways that market operations cannot handle (Nicholson, 1985). A classic example is a bee farmer situated near an apple farmer such that bees collect nectar from the apple blossoms, and as they move from flower to flower, they cross-pollinate the apple trees (Meade, 1952). This is a case of mutual positive externalities with no market price.
Needless to say, some externalities are quantifiable while others are not. A rancher's cows' trampling on a neighbor's cabbages is an example of a

quantifiable negative externality (Coase, 1960). An example of non-quantifiable externality is air pollution where simultaneous pollution of numerous agents is felt by numerous other agents.

By merging the activities of the liable and affected agent, a negative externality can be internalized. The liable and the suffering party together determine how far the negative externality should be stretched. In this case, both have a stake in the activities that generate the externality. The externality-producing activity will be stretched up to the socially optimal level as shown in Figure 3.

Figure 2. Externalized externalities

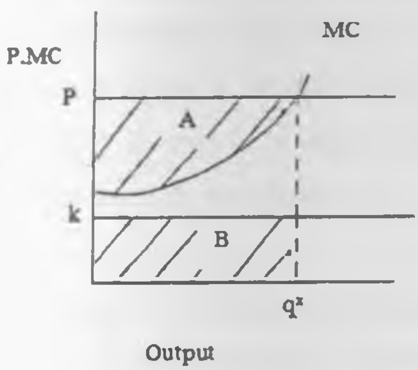
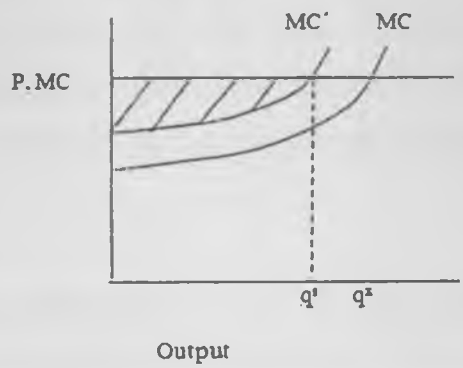


Figure 3. Internalized externalities



Source: Adapted from Lofgren, 2000.

Figure 2 depicts a situation of production without internalizing externalities. The marginal cost curve of the firm, MC(q) is as shown. A profit maximizing firm will produce an output q^x and reap profits as shown in the shaded area, A, which is equivalent to producer surplus. Assuming the amount of externalities varies directly with output and that externalities impose a cost of Ksh k per unit, total externality costs associated with output q^x is $k.q^x$ or the shaded area

B. Figure 3 depicts a situation where externalities are internalized. Costs of production rise for each level of output. Thus MC (q) shifts upward to MC'. MC'= MC (q+k). Profit maximizing level of output falls from q^x to q^s. The new level of profit is the shaded area in Figure 3 and is less than A.

As to how fast profits decline in the process of internalizing externalities will depend on the type of technology adopted to do so. Some internalizing methods can have an opposite effect of raising productivity and output thus enhancing profits.

Another approach to resolving the problem of negative externalities is to charge rent equivalent to a tax for externalities generated. The rent could be made equal to what it costs to correct the externality. Collected revenue could then be used to mitigate any undesirable outcomes or to encourage technologies that abate the nuisance.

In a case of a beneficial externality, Pigou offered that firms that produce them should be subsidized in order that they produce more (Nicholson, 1985; Kaldor and Hicks, 1939). And in a case of negative externality, the liable party should compensate the victim for the damage.

Coase (1960) finds Pigou's approach to be not only inappropriate but also inefficient. In the Coasian approach, the problem of externalities can be explained by the divergence between private and social products. Using the example of straying cattle trampling on a neighbor's crops, Coase argued that the problem lies in calculation of returns. The rancher producer would prefer to ignore the damage done to the crops in his calculation of returns. He would only take into account private costs and benefits and effectively ignore social costs. Since private costs are lower than social costs in the presence of negative externalities, too many cattle (and less food) would be produced. There would therefore be a misallocation of resources between ranching and farming. Such a misallocation would mean a loss to society and would require policy actions to protect the victims (Silberberg, 1978).

But to Coase, the problem is reciprocal rather than one-sided and its solution lies in avoiding the more serious harm through bargaining. The liable and the affected parties bargain and arrive at a settlement. A bargain could probably lead to a contract that would resolve the problem of externalities to the mutual gain of the victim and the villain. A private bargain, if possible, would also eliminate the need for government intervention other than in the enforcement of the contract. But for a bargain to be possible, Coase argued that property rights have to be clearly defined.

Property rights establish "the legal owner of a resource and specify the ways in which the resource may be uscd" (Nicholson, 1985: 703). The holder of the rights can either be compensated for any negative externalities or else he can induce the other party to scale down the activity that is causing the negative externality.

Coase recognized that even with clearly defined property rights, a settlement might not be forthcoming if transaction costs are too high. Transaction costs rise with the number of parties involved in the bargain, costs of searching for information and costs of policing to enforce a contract.

A settlement may also not be forthcoming if the externality emanates from activities in a common property resource and victims downplay the effects of harm done to them. Victims may also suffer silently to avoid paying the liable party an incentive to reduce the activity that produces a negative externality (Stigler, 2006).

A settlement will also not be forthcoming if an externality affects many parties and costs of transactions are prohibitive. The alternative to voluntary settlement is a governmental administrative regulation. Market mechanisms have to be replaced with direct government regulation that states what people must do or not do.

In a case where property rights rest with a producer of a negative externality, a public authority can intervene and determine the amount of a nuisance that is tolerable. The producer is allowed to create nuisance only up to a certain level. If the amount allowable from each producer were clearly defined, a market for tradable nuisance permits would be possible. A producer who reduces his nuisance too easily could sell some of his nuisance rights to another producer who might want to exceed his allowable level.

2.6 Stylized Facts on Social Interactions

The few empirical studies on social interactions in agriculture include Foster and Rosenzweig (1995), Conley and Udry (2003), Munshi (2004) and Bandiera and Rasul (2006). These studies show that a farmer's initial decision to adopt a new technology is influenced by decisions taken by others in his or her social network of relatives, friends and neighbors. These are the individuals with whom a farmer holds strong ties with, and is likely to exchange information and learn from. The influence is referred to in the literature as social effect (Munshi, 2004), learning externality or learning spillover (Foster and Rosenzweig, 1995).

Bandiera and Rasul (2006) in a study of social networks and sunflower (an exotic crop) adoption in Zambezia province of Northern Mozambique find an inverted-U relationship in social effects. When adopters in a network are few, social effects are positive and when the adopters are many, the social effects are negative. Other researchers have found an "S" curve in new technology adoption in agricultural set-ups (Feder *et al.*, 1985; Foster and Rosenzweig, 1985).

Social effects are also strong among farmers that lack adequate information about a new crop or new technology for that matter. Farmers with better information are insensitive to adoption choices of others (Bandiera and Rasul, 2006).

Foster and Rosenzweig (1985) in a panel data study of adoption and profitability of high-yielding varieties (HYV) of rice and wheat during the Green Revolution era in India find that a farmer's own as well as neighbors' experience with HYVs affect profitability positively. Farmers learn from neighbors' experience. The average cumulative experience of neighbors provides positive learning externalities or spillovers that impact positively on profit growth.

These externalities of information flows are weaker in heterogeneous population particularly when the performance of a new technology varies with unobserved individual characteristics. The variation prevents a farmer from learning from neighbors' experiences (Munshi, 2004). When learning externalities are curtailed, farmers experiment more in their own lands to compensate for the deficiency in social information. Munshi (2004) on a revisit to data on HYVs in India during the Green Revolution finds that rice growing regions were more heterogeneous while wheat growing regions were homogeneous. Rice farmers tended to experiment a lot unlike the wheat growers.

In a study of how farmers in the eastern region of Ghana learnt about appropriate use of fertilizer in a new farming system of pineapples for export, Conley and Udry (2001) find that information regarding farming flows through relatively sparse social networks rather than being freely available in a village. The networks are based on geographic proximity and other factors. Bandiera and Rasul (2006) identified religion to be one of the factors determining social networks.

Social interactions only provide limited information with regard to inputs usage and output harvests. Thus, farmers possess only relative information regarding other farmers' actions. For instance, a farmer does not know the actual input use or harvest by the other farmer; instead he knows if the other farmer harvested more or less output than the village average or than himself (Conley and Udry, 2001).

Social learning therefore provides incomplete information of broad facts without specific details, i.e., information from some farmers but not from all farmers. To apply information gathered through social learning, a farmer needs additional information. This may come from inferences drawn from reviewing histories of actions and outcomes of everyone the farmer interacts with (Conley and Udry, 2001).

Non-information externalities are well captured in studies on returns to education and to human capital. In a study of private returns to human capital in Kenya, Kimenyi *et al.*, (2006), find that human capital of other people has a positive effect on earnings of a worker in an urban place. In this case, if the average education of other people in a locality rises, the earnings of an individual urban worker within that locality also rise *ceteris paribus*. Interestingly, average education of women nationally also impact positively on male earnings. These situations show that average actions of other agents affect outcomes of an individual agent.

2.7 Overview of Literature

The contribution of smallholder farms to total agricultural production is limited by both internal and external factors that limit their productivity. Among the internal factors is the slow pace in adopting new technologies. New technologies offer poor farmers hope for better incomes but the process of adoption is complex, slowing down the rate. Without new technologies, smallholder farmers are better off looking for income opportunities outside agriculture.

The literature suggests that social effects are important in farm inputs demand, and in agricultural production. There is, however, a dearth of literature on the impact of social interactions on agricultural production.

This study builds on available literature by focusing on smallholder farms with regard to input demands and with respect to returns to inputs while paying due attention to social effects. It estimates parameters of input demand functions controlling for social interactions. Social interactions are proxied by average neighborhood variables of fertilizer usage, animal feeds usage, conservation efforts, soil ridging practices, grass stripping efforts and property rights bundles. Each of the neighborhood variables excludes the observation of farmer of interest.

CHAPTER 3 : ANALYTICAL ISSUES

3.0 Introduction

This chapter discusses frameworks for analyzing agricultural production, farm inputs demand, and the influence of social interactions on farm production processes. The discussion of social interactions and externalities in farming start by examining the linear-in-means model as in Gaviria (2001) and Halliday and Kwak (2007) before turning to simultaneous equations model of Hartman *et al.* (2008).

Since yield response affects agricultural production, a clear understanding of the relevant elasticities is crucial. Section 3.4 explores the methodologies, paying attention to elasticity of farm output with respect to changes in inputs, and the elasticity of input demand with respect to changes in input prices.

3.1 Agricultural Production Function

A small farm is a production unit. The farmer as a producer combines various inputs in some technological manner so as to produce crop or livestock output. If the production is successful in producing output, the farmer reaps the gains and if not, he bears the loss. Thus, the farmer is an entrepreneur in so far as he makes production decisions and takes risks by engaging in production.

The farmer chooses levels of inputs that will maximize profits in a production activity. Suppose that the farmer uses only three inputs namely, labor, L (measured in person-days), capital, K (an index of various types of equipments) and materials, M (measured in quantity consumed per production period). Suppose further that the inputs are contracted in a competitive market such that the farmer can buy all he wants at the prevailing wage (w), rental rate (v) and unit price (m). Under these simplifying assumptions and following Varian

(1984) and Debertin (1986), the farmer's production function is:

$$Q = f(L, K, M) \quad \ldots\ldots(1)$$

and the total cost of purchasing the input combination L,K and M at prices w, r and m is:

$$C = wL + rK + mM \quad \ldots\ldots(2)$$

Assuming that a farmer chooses a production plan so as to maximize profits and that he operates in a competitive market such that he has sufficient information about costs and the nature of the market to which he sells, his augmented objective function is:

$$\text{Maximize } \pi = P f(L, K, M) - wL - rK - mM \quad \ldots\ldots(3)$$

The farmer's profit is determined by market price for output (P), an endogenous output (Q), and input costs. The farmer can increase his profit as long as the addition to his revenue from employment of an additional input exceeds its cost.

The first order condition for profit maximization requires that application of each input be increased up to the point at which the value of its marginal product equals its price. Solving the first order partial derivatives of the normal equations yields the optimal levels of factor inputs, L^*, K^* and M^*. These are the input demand functions. At these levels, the farmer's profits are maximized and cannot be improved upon by changing the amount of any of the inputs. That is, given the optimal input demands, an optimal farm output is produced.

From equations (1) to (3), the direct linkage between input demands and the level of farm output produced can be observed. It should also be appreciated that output supply function Q(P) can directly be obtained from equation (3) using Hotelling's derivative property of the profit function, i.e., by differentiating the profit function with respect to output price, P. Similarly, input demands can be obtained by differentiating the profit function with respect to input prices.

A farmer's production function may also be influenced by a vector of other covariates. Available literature suggests that in addition to farm inputs, household characteristics such as education of the farmer, conservation efforts, property rights, availability of extension services, and soil quality augment productivity of farm inputs in smallholder agriculture (Singh, Squire and Strauss, 1986; Kabubo-Mariara, 2010; Kabubo-Mariara *et al.*, 2010). Expanding equation (1) to include the influence of these other covariates, the general production function for a smallholder farmer can be expressed as follows:

$$Q = f(L, K, Acr, Ft, Af, W, Ed, Age, Prt, Cn, Ext, Ch, B) \quad \text{..............(4)}$$

where, Q = farm output

L = total labor input

K = total capital input

Acr = farm size

Ft = fertilizer

Af = animal feeds

W = rainfall

Ed = education level of the farmer

Age = age of the farmer

Prt = bundle of property rights held by a farmer

Cn = conservation efforts

Ext = extension services

Ch = agricultural chemicals

B = soil fertility

It is important to note that some inputs applied to a farm, e.g., fertilizer could be endogenous because of several reasons. First, the measurement of an input could be with some margin of error, and the error could be captured in the disturbance term of a production model. The disturbance term and the erroneously measured input are correlated. Secondly, usage of an input could be influenced by unobserved variables that are omitted in a production function but captured in the disturbance term. The omission makes the input and the disturbance term correlated. Lastly, an input and the output could be simultaneously determined. Simultaneity makes an input endogenous.

Fertilizer application in a farm is, for example, determined by a farmer. The quantities used may be influenced by an unobserved variable that is omitted in the production model. The influence of this other variable is captured in the disturbance term. To this extent, the correlation between fertilizer and the disturbance term is not zero and fertilizer is endogenous. In addition, the farmer may report the amounts of fertilizer that he applies on the farm with error. The error is captured in the disturbance term and the correlation between fertilizer and the disturbance term is not zero making fertilizer endogenous.

To assess the impact of fertilizer on output taking into account the problem of endogeneity, fertilizer has to be instrumented when estimating parameters of a production function. In this case, the instrumental variable has to have the property that it affects demand for fertilizer without influencing farm output. A good instrument is uncorrelated with the error term and only partially correlated with the variable it stands for once other exogenous variables are netted out.

A farmer may have special natural ability in production which makes his yields higher for a given level of input. Natural ability is unobserved and not easily captured in a model. Such unobserved heterogeneity is controlled for using instrumental variables method.

The method of instrumental variables is illustrated in equation (5). Suppose demand for fertilizer is determined by three factors as shown below:

$$D_{Ft} = f(P_{Ft}, P_m, V) \quad \text{...(5)}$$

where, D_{Ft} = demand for fertilizer

$P_{Ft,}$ = price of fertilizer

P_m = price of a substitute farm input

V = other exogenous covariates that must be included in equation 4.

D_{Ft}, the predicted demand for fertilizer should replace the actual measure of fertilizer input in the estimated farm output in equation (4), but the instruments for fertilizer (P_{Ft} and P_m) should be excluded from it (see Greene, 1997). The instrumental variables method can be used to deal with any endogenous input in a production function. If endogeneity is not controlled for, the estimated parameters will be biased and inconsistent.

The effects of the endogenous soil conservation efforts (Cn) in equation (4) are estimated controlling for endogeneity, but the results are insignificant. The instruments for soil conservation practices or efforts (e.g., terracing, gabions, and hedges) are the costs of undertaking these investments, including distances to market centers and cooperative societies where conservation materials are purchased (Kabubo-Mariara, 2010).

3.2 Social Interactions

(i) Theory and Assumptions

Farm production is the outcome of decisions made by a farmer regarding inputs and of the effects of factors exogenous to the farm, such as rainfall and soil fertility. A farmer may form opinions on inputs to use based on social interactions with neighbors and friends.

In farm production, observable as well as unobservable inputs determine output level. While observable inputs are clearly understood and have a market value, unobservable inputs are not. The linear-in-means model can capture the influence of observable as well as unobservable inputs in a production function. The starting point is to view a farmer as an agent whose action is determined not only by his own characteristics but also by unobservables associated with other agents. In the model, individual action or behavior is assumed to vary linearly with mean action or behavior in the group (expressing endogenous interactions), with mean values of exogenous attributes of group members (expressing contextual interactions) and with personal characteristics that may be similar across group members (expressing correlated effects). The model is applied with modifications to suit smallholder farming context in this study.

In a farming situation, neighborhood behavior (with regard to production choices), exogenous attributes of the neighborhood and personal characteristics of the neighbors could influence input usage by any one farmer within a neighborhood. Their effects are externalities shown by the coefficients of the means of respective variables in a production equation. In so far as they are felt by every farmer in a village, they are social externalities in form of public goods or public bads. The externalities are transmitted through social interactions.

The property rights system in a locality can also influence output (via input demands) for an individual farmer within the neighborhood (Goldstein and Udry, 2008). If the prevalent land tenure in a neighborhood is private property, it may, under certain assumptions suggest that most farmers have the incentive to practice good farming techniques and to invest in conservation (Fenske, 2010). A farmer in a neighborhood no matter his tenure system receives spillover benefits in form of demonstration effects. For a given level of inputs, productivity can be expected to be higher due to demonstration effects of good farming practices. A private land tenure system creates positive externalities while common property and poorly defined regimes may be associated with negative externalities.

(ii) The Linear-in-means Model

Following Halliday and Kwak (2007), Gaviria and Raphael (2001) and Fletcher (2010), the linear-in-means model can be modified to show the crop output of farmer *i* in village *s* as follows:

$$Y_{is} = a_0 + a_1 X_i + a_2 \bar{Y}_{is} + a_4 F_i + a_4 W_i + a_5 V_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

where,

Y_{is} = crop output of farmer *i* in village *s*

X_i = endogenous input used by farmer *i* (e.g., fertilizer)

$\bar{Y}_{is}$ = mean crop output of farmer *i*'s peers in village *s* when farmer *i*'s output is excluded

F_i = vector of farmer *i*'s observable characteristics or observed heterogeneity

W_i = vector of other covariates of inputs demanded by farmer *i*

V_{is} = village *s* fixed effects

a_i = parameters (i=0,1,...)

ε_i = error term.

Livestock output function can similarly be formulated. In equation (6), Y_{is} is output of farmer i in village s and is synonymous to Q in equation (4). $\bar{Y}_{is}$ is a neighborhood variable of social interactions between a farmer and his neighbors in village s. X_i is an endogenous input, say fertilizer. To estimate equation (6) without the problem of endogeneity, X_i has to be instrumented.

Instrumentation requires that demand for fertilizer be predicted, and the actual fertilizer variable in equation (6) be replaced with the predicted fertilizer demand. Predicting fertilizer demand involves estimating a fertilizer demand function with some exclusion restrictions being included in the demand function. An exclusionary variable has the property that it affects demand for fertilizer but has no effect on crop output. It explains a demand function in the first stage regression but is redundant in the output function (the second stage regression), which is why it is excluded from it. To stress this point, an exclusion variable is an instrument for an endogenous input, with the word exclusion denoting that the variable is excluded from the second stage regression. In this model, C_{di}, the distance from a household to the nearest cooperative society is an instrument for fertilizer. The predicted fertilizer demand is a reduced form of equation (6) and can be expressed as:

$$X_{is} = b_0 + b_1\bar{X}_{is} + b_2F_i + b_3W_i + b_4C_d + b_5V_{is} + \varepsilon_{fi} \quad \text{.................................(7)}$$

where,

X_{is} = amount of fertilizer used by farmer i in village s

$\bar{X}_{is}$ = mean fertilizer used by farmer i's neighbors in village s when farmer i's fertilizer usage is excluded

F_i = vector of farmer i's observable characteristics

W_i = vector of other covariates of inputs demanded by farmer i

V_i = village s fixed effects

C_{di} = distance to the cooperative society nearest to farmer i

b_i = parameters to be estimated (i=0,1...)

ε_{fi} = error term

Equation (7) is the same as equation (5). Reduced form animal feeds demand can similarly be formulated. The reduced form fertilizer demand, X_{is}, replaces X_i in estimating parameters of equation (6). The variables used in estimating equations in this study are shown in Table A-1 in Appendix 1.

As already noted, social interactions generate externalities in form of social learning or peer effects. Applying the argument by Foster and Roweinzweig (1995) that social learning increases factor productivity, returns to factor inputs are higher in the presence of social interactions than in their absence. This means that estimates of the returns to factor inputs in the presence of the village level variable $\bar{Y}_{is}$ must be higher if the variable captures social learning. However, should returns decrease, the presence of negative externalities is suggested. Peer effects in production of crops, and in production of livestock output are shown to be strong and positive. Log of average crop output in a village and log of average livestock output in a village proxy peer variables in this study.

(iii) The Simultaneous Equation Model

Social interactions may have multiplier or spillover effects. Hartmann *et al.* (2008) uses a simultaneous equation model of actions and characteristics to show these effects. Consider two interacting farmers, *i* and *j* with characteristics F_i and F_j and taking actions Y_i and Y_j, respectively. The actions are the outcomes of mutual interactions and can be modeled as

$$Y_i = a_1 F_i + a_2 Y_j + a_3 F'_j + \varepsilon_i \quad \text{.....(8)}$$

$$Y_j = b_1 F_j + b_2 Y_i + b_3 F'_i + \varepsilon_i \quad \text{.....(9)}$$

F'_j and F'_i are the characteristics of *i* and *j* that affect *j* and *i*, respectively. The a_1 and b_1 parameters represent the effect of farmer-specific characteristics on the action of the respective farmers. Parameter a_3 shows the causal effect of the characteristic of farmer *j* on the action of farmer *i* while b_3 shows the causal effect of the characteristic of farmer *i* on the action of farmer *j*. The parameter a_2 estimates causal effect of farmer *j*'s action on the action of farmer *i* while b_2 estimates causal effect of farmer *i*'s action on the action of farmer *j*.

When a_2 and b_2 parameters are non-zero and of the same sign, the social interactions between the farmers generate multiplier effects, i.e., farmer *i*'s action affects *j*'s action, which in turn affects *i*'s action. Farmer *i*'s action feeds back upon itself through *j*'s action.

A small increase in Y_j increases Y_i through a_2 which in turn increases Y_j further through b_2. Thus, a small change in, for example, Y_i will have a greater total effect than a_1 on Y_i because of feedback effects through a_2 and b_2. The process of feedbacks goes on until equilibrium is attained. At equilibrium, the actions of the agents have direct and similar effects on each other.

If $b_2=0$ and $a_2 \neq 0$ or $a_2=b_2=0$, there are no feedbacks when say, Y_j changes. In such a case, Y_j is a spillover on Y_i. A spillover is a positive or negative externality.

The model depicted in equations (8) and (9) may be interpreted from a game theoretic approach. Equation (8) can be viewed as a reaction function of player *i* in relation to the strategy of player *j*, and equation (9) as the reaction function of player *j* in relation to the strategy of player *i*. Since the two equations are mutually interdependent, they represent strategic interdependencies between players *i* and *j*. If a_2 and b_2 are positive coefficients, the actions of *i* and *j* are strategic complements, and if a_2 and b_2 are negative coefficients the actions are strategic substitutes. However, game theory is outside the main focus of this study.

3.3 Input Demand Elasticities

Farmers demand farm inputs to produce output of crops and livestock products. Whereas some inputs are sourced from the farm, others are acquired from the market. For the latter inputs, market dynamics influence their usage on the farm. This section examines the response of input demand to changes in market prices.

Suppose, for example, that the price of fertilizer rose by some percentage. As a result demand for fertilizer will decline, either by a big or small margin. The margin will be determined by price elasticity of demand for fertilizer. If fertilizer is a necessary input in the production process, its demand will change little in response to variations in its price.

Own price elasticity of demand for fertilizer may be defined as the percentage change in the quantity of fertilizer taken from the market divided by the percentage change in the price of fertilizer (Debertin, 1986). The formula for own price elasticity of demand for fertilizer is:

$$\frac{dX_i}{dP_{X_i}}\frac{P_{X_i}}{X_i} = \frac{dlnX_i}{dlnP_{X_i}} \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

where, X_i = amount of fertilizer bought, and P_{X_i} = price of fertilizer

In farm production, more than one input is used to produce output. For example, fertilizer may be used alongside labor, capital, and other inputs in farm production. Should the price of say, labor, increase by some percentage, demand for fertilizer will be affected. The effect is the cross-price elasticity of demand which is defined as the percentage change in the quantity of fertilizer

(X_i) taken from the market divided by the percentage change in the price of labor (P_l) (Debertin, 1986). Cross-price elasticity shows whether inputs are complementary or substituting in production. The expression for the cross-price elasticity of demand for fertilizer may be written as:

$$\frac{dX_i}{dP_l}\frac{P_l}{X_i} = \frac{d\ln X_i}{d\ln P_l} \qquad (11)$$

where, X_i = amount of fertilizer bought, and P_l = price of labor.

Demand for an input is a derived demand. It is derived from demand for output. Any change in output price will not only affect demand for output but also demand for inputs. The output-price elasticity of demand for fertilizer can be defined as the percentage change in the quantity of fertilizer taken from the market divided by the percentage change in the price of the output. Using calculus and following Debertin (1986), the output-price elasticity of demand for fertilizer can be written as:

$$\frac{dX_i}{dP}\frac{P}{X_i} = \frac{d\ln X_i}{d\ln P} \qquad (12)$$

where, X_i = amount of fertilizer bought, and P = price of output.

An increase in fertilizer price may raise production costs significantly if expenditure on fertilizer is a big share of total costs. A farmer may pass over the extra costs of production to the consumer through higher output prices or he may absorb the costs.

If a farmer absorbs costs of production, his profits decline. Consequently, he may demand less of the input whose price has risen or cut down production altogether and reduce demand for all variable inputs. These decisions depend on input and output price elasticities.

Input demand elasticities can be derived from production function data (Yotolopous, Lau and Lin, 1976), from a flexible profit maximization model (Chaudhary, Khan and Naqvi, 1998), or from flexible functional forms that depict farm production structure (Sindhu and Baanannte, 1981). In primary data, zero 'values' can be encountered and present problems in, for instance getting elasticities, since the logarithm of zero is undefined. This problem is addressed in this study by adding one to all the observations of a variable that contains zero values. A zero becomes a one, and the logarithm of one is known.

3.4 Farm Output Elasticities

Yield response is the elasticity of farm output with respect to factor inputs. It is the percentage by which output changes when an input, say, fertilizer is changed by one percent. The elasticity of output with respect to factor inputs can be written as:

$$\frac{dY}{dX_i}\frac{X_i}{Y} = \frac{d\ln Y}{d\ln X_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

where, Y = output, X_i = fertilizer input.

Y could be crop or livestock output, and X could be an input such as fertilizer. It is assumed that output responds positively to changes in factor inputs, first at an increasing rate and then at a lower rate, when input usage is stretched out (law of diminishing marginal returns). Thus, output elasticity with respect to a factor input is greater than unity ($\eta > 1$) over some range, and less than one ($\eta < 1$) over the rest of a production range.

CHAPTER 4 : STUDY SITE, SAMPLING PROCEDURES AND SAMPLE STATISTICS

4.0 Introduction

The data for this study were collected from Nyeri district in Central Province. This chapter presents basic characteristics of the district, the sampling procedures employed, the data sources and types of data collected.

4.1 The Study Site

(i) Natural Conditions

Nyeri district is in the eastern highlands of Kenya. According to Nyeri District Development Plan 2002-2008, the district occupies an area of 3266 sq. km and lies at an altitude of between 3076m and 5188m. The most salient physical features of the district are Mount Kenya to the east, standing at 5199m above sea level and the Aberdares Range to the west, at 3999m. The two volcanic mountains determine the relief, drainage, climate, soils and hence the population distribution and agricultural potential of the district (Republic of Kenya, 2002).

Generally, the area has an equatorial climate with bi-modal rainfall pattern that falls from March to May (long rains) and October to December (short rains). Areas on the windward side of the two relief features receive higher precipitation than those on the leeward side. Thus, it is wetter in Mathira, Othaya, Tetu and Mukuruwe-ini than in the rain shadowed area of Kieni.

At a micro level, hills such as Tumutumu, Nyeri and Karima influence rainfall patterns and agricultural activities in the southern part of the district. The western part of the district is flat and dry, with a mean annual rainfall of

500mm. In the rest of the district, the terrain varies from undulating to rolling topography with a monthly average rainfall of 2400mm.

Rainfall has a particularly strong impact on agricultural and population distribution in the district (Republic of Kenya, 2002). In the wetter areas, cash and subsistence crops as well as dairy farming predominate. Population density in the wetter areas is high. In the drier western zone, subsistence farming and ranching are the prevalent economic activities with sparse population density.

Temperatures in the district vary widely with altitude and season. Generally, they range from less than 13^0 C on the slopes of Aberdares to 21^0 C in Kieni. They also vary from 8^0C during the cold month of July to 28^0 C during the hottest month of January. On average, the district has a cool mean temperature of 17^0C.

Besides rainfall, relief and temperature have a strong influence on agriculture and population distribution in the district. Mathira, Nyeri town, Othaya and Tetu have undulating hills, moderate temperatures and high rainfall. They attract the highest concentration of people and agricultural activities. Cash and food crops are grown alongside livestock rearing. In Mukuruwe-ini division, the terrain and temperatures are equally favorable but rainfall is low. Thus, population density and agricultural activities are at a comparatively lower scale in this division.

In Kieni, the terrain is level with temperatures rising sharply during day time but it can be chilly at night. The rainfall here is much lower and human population sparse. Agricultural activities consist mainly of drought resistant crops and ranching. However, population spillover from the wetter parts is rapidly transforming the area. The migrants have brought with them agricultural activities of wet areas changing economic activities in the area dramatically.

Soils in the district vary with altitude. According to the Farm Management Handbook of Kenya (2006), soils in the mountains largely comprise of loam and clay-loam with rock outcrops. These soils vary in depth from shallow to moderately deep. Their fertility varies from moderate to high, but due to low temperatures, their utilization for agricultural purposes is limited.

Lower down the mountains, natural forestry thrives with bamboos dominating. At the foot of the mountains, the soils are well-drained, and consist of deep dark-red clay soils with acid humic top. These volcanic soils are rich in organic matter and vary in fertility from moderate to high. They cover much of the district and support a wide range of agricultural activities such as forestry, growing of tea, coffee, horticultural and food crops and dairy farming.

The soils in the plateaus and high-level structural plains on the western part of the district have deep firm clay that varies in fertility from moderate to high. These too support agricultural activities of a narrow range due to low rainfall.

In and around the hills in the southeastern part of the district are to be found sandy clay loam and sandy clay soils. These vary in fertility from moderate to high; however, they are excessively drained in most parts, limiting their agricultural value. The Farm Management Handbook considers soils in minor valleys to be the most complex of all. They consist of rocky, stony or gravel clay, some of which are well drained and fertile.

Overall, 67 percent of the total area in the district can be classified as arable land (Republic of Kenya, 2002). The high potential zones are in Othaya, Tetu, Mukuruwe-ini and Mathira divisions. Low potential areas are in Kieni East and Kieni west divisions.

The district is well served by two major rivers, Sagana and Chania, with many streams draining into the two rivers. The district planning unit reckons that these water sources can serve domestic, agricultural and industrial needs of the district sufficiently (Republic of Kenya, 2002).

The district is rich in forests, with 9 percent of total land area being covered by forests (Republic of Kenya, 1997). Virtually all forests are gazetted state resources. The forest zone cuts across Kieni West, Tetu and Othaya to the west and Kieni East and Mathira to the east. The forests are a source of timber, fencing poles, firewood, grazing pastures and direct and indirect employment to area residents.

Although Nyeri has fairly good soils for agriculture that are deep, well drained and fertile, natural soil fertility in the area has been declining steadily due to permanent cultivation without replenishment of lost soil nutrients (Republic of Kenya, 2006). This aspect coupled with shrinking land holding reduces farm output and earnings, rendering the district food insecure. Differences in rainfall amounts and temperatures across the district cause variations in farm productivity. At the farm level, differences in management practices are major sources of variation in farm productivity.

(ii) Population

The Kenya National Population and Housing Census of 1999 shows that Nyeri district had a population of nearly 700,000 people, with an average density in excess of 200 persons per sq km. The municipality division is the most densely populated, with over 600 persons per square kilometer closely followed by Mathira with 586 while Kieni West is the least populated with just over 100 persons per square kilometer at the time of census (Republic of Kenya, 2002). A majority of the rural population is engaged in small scale farming and occupies 80% of the district's total land area (Republic of Kenya, 1997).

Population pressure in the district has not only led to intensive cultivation and soil exhaustion as a result of continuous cultivation but has forced area residents to encroach into Aberdares and Mount Kenya forests. After years of unsustainable exploitation of resources from these two physical features that are also water catchments, water volume in rivers that flow from these sources has gone down, creating shortages in domestic water supply in the district and beyond (Republic of Kenya, 2002).

Urban growth in the district is rapid with Nyeri Town, Karatina, Mukuruwe-ini, Mweiga, Othaya and Naromoru in that order having already developed into modern urban centers (Republic of Kenya, 2002). One of the handicaps to rapid urbanization in the district is electricity connection. Out of the 229 trading centers, 155 do not have electricity.

(iii) Socio-economic Indicators

Nyeri district is predominantly agricultural and rural. In addition, the district has more females than males with a female-male ratio of 105 (Republic of Kenya, 2002). This is because more men migrate to towns in search of jobs. Subsequently, there are many female-headed households in the district. Although there is nothing wrong with female headship, it has implications for household structures, land management and farm productivities that must be considered in a study of the kind undertaken here. Currently, over 30 percent of the households are female-headed and half of these households can be classified as poor (Republic of Kenya, 2002; 2007a).

According to the Nyeri District Development Plan 2002-2008, the area hosts 168,786 households of 4 persons each on average. The mean household adult population is highest in Municipality at 4.1 adults per family and lowest in Kieni at 2.1 (Republic of Kenya, 2006). Population growth rate currently stands at 0.8 percent and dependency ratio at 77 percent. The district's contribution to national poverty has been on the rise from less than 1 percent in 2002 to 1.5 in 2006 (Republic of Kenya, 2007a). Households below the poverty line are close to

40,000 while individuals below the line are in excess of 200,000 and their number is growing.

Household incomes are mainly derived from agriculture (53%) and to a lesser extent from wage employment (20%) and rural self employment (10%). Casual labor engagement is widespread, ranging from 0.63 to 3.2 (Republic of Kenya, 2002) and varying with seasons. The unemployment rate in the district is reported at 40%. The average farm size in the district has been falling steadily as a result of land subdivision. Currently, small scale farms measure on average less than 0.6ha in the high potential zones, and about 0.88 ha in low potential zones (Republic of Kenya, 2002).

The main food crops grown include maize, beans, potatoes and bananas. Use of improved seeds during planting is slightly above 50 percent (Republic of Kenya, 2002). Maize and beans are intercropped and are the most common annual food crops in the district while coffee, tea and horticultural crops comprise the main cash crops.

Cash cropping is said to take up 65 percent of total farming area leaving little land for livestock and food crops. Coffee has until recently been on the decline because of low prices, mismanagement of cooperatives and non-payment of farmers' dues (Republic of Kenya, 2002). Consequently, some farmers have taken to non-acceptable practice of intercropping coffee with maize, beans and potatoes.

Dairy farming is widespread in the district, with average cow holding ranging from 1.27 in the municipality to 14.5 in Kieni (Republic of Kenya, 2002). Traditional Zebu cows and their crosses are the main breeds. In Kieni, Zebu beef cattle are common while in Mathira, Othaya, Tetu and Mukuruwe-ini crosses of dairy cows are the most common. Dairy goats are being introduced into the district slowly in view of rising demand for milk in a situation of declining land holding. Virtually every rural household keeps at least one livestock type especially the small stocks to cater for household needs (Republic of Kenya, 1997). Chicken is the most common livestock.

Paradoxically, the District Agricultural Office cites shortage of labor as a major cause of declining farm yields in the district (Republic of Kenya, 1997) yet unemployment in the district stands at over 40 percent (Republic of Kenya, 2002). Youth idling in shopping centers is a cause of worry in the district. Unwillingness of the youth to work in the farms is an issue that needs investigation. Extension services also need attention to reverse the trend of declining farm yields. The government argues that extension services can be strengthened through private sector provisioning (Republic of Kenya, 2004a).

Education provisioning in the district is quite good. According to the district fact sheet, the district had by 2002 a total of 567 pre-primary schools, with nearly 100 percent enrolment; 458 primary schools with about 90 percent enrolment; and 136 secondary schools with over 70 percent enrolment (Republic of Kenya, 2002). Today, there are in addition to schools for basic education, over 10 major tertiary institutions, three of which are university colleges.

Communication in the district is fairly good. The district had by 2002 nearly 1800 km of classified roads, over 1200 km of rural access roads, 78 km of railway line, with 3 defunct stations, 3 airstrips and mobile telephone connectivity of nearly 100 percent (Republic of Kenya, 2002). Nonetheless, there were some 16,000 households without a radio. Some access roads are impassable during rainy seasons, and this is an obstacle to increasing farm earnings, especially from tea (Republic of Kenya, 2002), as a lot of tea is wasted during wet seasons.

The cooperative movement has registered mixed fortunes in the district. The Nyeri District Development Plan (2002) shows that savings and credit cooperatives have been doing quite well relative to producer cooperatives of coffee and dairy products, which have declined, with several collapsing. Consequently, coffee and dairy industries have been facing major challenges in marketing their products. These industries are riddled with corruption and farmers belonging to them hardly receive a fair return for their produce. Nevertheless, producer cooperatives remain the most dominant, numbering 65 in 2002 with tea cooperatives being the majority (Republic of Kenya, 2002).

Household electricity connection is low in the district. Out of the 168,786 households enumerated in 2002, only 11,053 had electricity. Use of solar power in the district is negligible. Firewood, charcoal and paraffin are the most commonly used forms of energy. This state of affairs impacts negatively on productivity of farm inputs. For instance, without electricity a chaff-cutter can only be operated manually, making its use unattractive. Thus, only a few of smallholder farmers use chaff-cutter services in the district.

The district is host to a sizeable number of landless squatters. The squatters were once living in forestlands eking out a living through agro-forestry in what is called the *shamba* system, but have since been evicted on grounds of them causing deforestation and soil degradation. The squatters who could not find an alternative place to live resettled illegally on roadsides in Mathira. These squatters together with the slum dwellers in Karatina, Othaya and Nyeri towns comprise some of the poorest households in the district. Other households living in extreme poverty are to be found in Rutune location of Mukurweini division and among the female-headed households in the semi-arid parts of Kieni (Republic of Kenya, 2002). For this latter group, harsh environmental factors account for their absolute poverty. Rainfall in there is inadequate for gainful farming so that drought and crop failure are frequent (Republic of Kenya, 2002).

4.2 Sampling Procedures

Nyeri was purposively selected because it has smallholder farming as the dominant land use activity. The area's ecology, climate as well as infrastructure favor agriculture. The farming activities are diverse and intense, providing a suitable case study of issues at hand. The unit of analysis is the household and the data was collected in face-to-face interviews with farmers. The questionnaire that was used is attached in Appendix 3.

Sample selection was guided by the National Population and Household Survey framework of the Kenya National Bureau of Statistics (KNBS), Nyeri. The framework is based on the KNBS's National Sample Survey and Evaluation Program (NASSEP III) frame. NASSEP III maps the whole country into enumeration areas (EAs) first, and then classifies them into clusters based on population density. A cluster contains between 50 and 150 households. The households are listed in the order in which they occur on the ground. The name of a household head and the physical location of his or her homestead are used to identify each household that is then given a number. The household listings for Nyeri district were used as the sampling frame for this study.

According to the NASSEP frame, Nyeri district covers roughly three enumeration areas with 34 clusters, of which 24 are rural and 10 urban. One of the 10 urban clusters is classified as peri-urban because of its agricultural activities. The study drew its sample from the 24 rural clusters and from the single peri-urban cluster so that the sampled households were spread over a total of 25 clusters. Due care was taken to ensure clusters were picked from all the five divisions of Nyeri district.

The number of clusters selected in a division was based on a weight of population distribution in the district. The weight was the ratio of divisional population to district population. According to the 1999 Population and Housing Census, Nyeri district had 661,156 people distributed as follows: Kieni East, 83,635; Kieni West, 68,461; Mukuruwe-ini, 97,447; Mathira, 150,998; Tetu 80,100; Municipality, 101,238 and Othaya, 88,291.

On the basis of division to district population ratio, more clusters were selected from populous divisions. Accordingly, 6 clusters were selected from the populous Mathira, 4 each from Mukuruwe-ini and Municipality, 3 each from Othaya, Tetu and Kieni East, and 2 clusters from Kieni West division. These clusters that formed the sampling frame and their characteristics are summarized in table 4.1.

Table 4-1 Sample Clusters and their Characteristics

Division	Clusters
Kieni West	Kangiri, Ngano-ini
Kieni East	Manyatta, Ragati/Guara, Mbogoini
Mathira	Gachiura, Unjiru, Umbui, Kiamucheru, Giagachucha, Rathithi
Mukuruwe-ini	Gaithumbi, Gitura, Gatongu/ Karigu-ini
Othaya	Gikira 'A'&'B', Mugumo-ini, Nduyi/ Gachami
Tetu	Nyakirutu, Karigu-ini
Municipality	Gathugu/Chiara-ini, Maharu, Kanuna 'A', Thunguma

In each cluster, a sample of 17 households was systematically selected but in a random fashion to arrive at the desired sample size of 425 households, consistent with Yamane's (1967) sample size formula. Yamane (1967) proposed the following equation for determining sample size:

$$n = \frac{N}{1 + N(e)^2}$$

where, n=sample size, N=population size, e= desired level of precision.

In this study, N=168,786 households (Republic of Kenya, 2002) and e=$\pm$5 percent giving $n = 400$. To compensate for any unforeseen nonresponses, the study expanded the sample by 6 percent yielding a sample of 425 households. The expansion was modest since not much variability among the households was anticipated.

In order to pick a particular household without bias, systematic random selection was applied. By dividing total population of households in a cluster by 17, a number, say x, could be obtained and used to guide random selection of households. As an example, if x=4, any of the first four households in the sampling frame was picked randomly to form a starting point for sample taking. If household 2 in the list was picked, then the next household was the sixth, the next tenth and so on. In other words, from household number 2 in the list, the next was (2+x), where x is the sampling interval. By selecting households in this manner, sample representativeness was ensured.

The study gathered cross-sectional primary data from the sampled households between July and September 2007. The data relate, *inter alia,* to farm activities, inputs and their usage, land tenure, farm output, marketing, infrastructure, and soil conservation practices.

The data was entered into the computer using the Census and Survey Processing System (CSProS) software. This package is quite appropriate for entering, editing, and tabulating data from censuses and surveys but is not suitable for statistical analysis. Once the data sets were entered into the computer system, they were transferred to SPSS and STATA packages for cleaning and analysis.

4.3 Descriptive Statistics

Some key household characteristics of smallholder farmers of Nyeri district are presented and discussed in this section. The descriptive statistics cover a wide range of agricultural development indicators in the district, including demographic and socioeconomic characteristics of households and clusters.

(i) Demographic and Social Characteristics

Table 4.2 shows selected household characteristics. The characteristics relate to gender, age, household size, marital status, education and agricultural training. Majority of the households (76%) are male-headed, with the heads being middle aged. The average household size is 4.3, a number that is close to the 4.0 provided by the Kenya National Bureau of Statistics (Republic of Kenya, 2002; 2007a).

Table 4-2 Selected Household Characteristics

Variable	Mean	Std. Dev
Head is male	0.76	0.43
Age of household head	51.00	13.90
Household size	4.30	1.75
Marital status of household head		
Married	0.78	0.42
Widowed	0.13	0.34
Single	0.02	0.14
Separated	0.02	0.14
Other	0.05	0.22
Highest level of education of head		
No education	0.13	0.34
Primary	0.50	0.50
Secondary	0.32	0.47
Post-secondary	0.05	0.21
HH head trained in agriculture	0.15	0.35
Other HH members trained in agriculture	0.04	0.20

The table also shows that on average the household heads are literate, with at least primary school education. The main occupation for most of the household heads is farming. Most households undertake farming without any training in agriculture.

(ii) Economic Characteristics

Table 4.3 shows the household economic features. The salient feature is that 59% of the labor force is employed in agriculture on full-time basis. Although the remaining 41% is engaged elsewhere, it still practices farming as a subsidiary activity.

Table 4-3 Occupational Distribution of Adult Household Members

Main Occupation	Mean	Std Dev.
Farmer	0.59	0.49
Casual employment	0.13	0.34
General business	0.11	0.31
Formal employment	0.08	0.26
Other	0.04	0.20
None	0.05	0.23

The farmers grow a variety of subsistence and cash crops. Maize, beans, potatoes and bananas are the main subsistence crops. Other subsistence crops include sweet potatoes, cassava, millet, sorghum, arrow roots and peas. The farmers also grow horticultural crops such as cabbages, kales, spinach, carrots, tomatoes, onions and passion fruits. As to cash crops, tea and coffee are the main crops. Wheat is also grown as a cash crop but on a small scale. Other minor cash crops include onions, garlic, macadamia, cut flowers and beans. Except for coffee, tea and cut flowers, cash crops also cater for household subsistence needs. Table 4.4 shows the main crops in the study area.

Table 4-4 Intercropping in Nyeri district

Crop	Mean	Std. Dev.
Maize	0.91	0.28
Beans	0.81	0.40
Irish potatoes	0.56	0.50
Coffee	0.41	0.49
Bananas	0.33	0.47
Horticultural crops	0.15	0.36
Tea	0.15	0.35

Maize and beans are the most widely grown crops. Maize is grown by 91% of the farmers while beans are grown by 81%. The two crops constitute the staple foods in the district, closely followed by potatoes, grown by 56% of the farmers. In cash crops, coffee is the most widely grown, but by only 41% of the farmers. However, its prevalence exceeds by a wide margin that of horticultural crops and tea which are grown by 15% of farmers.

The farmers rear a variety of animals. The main livestock include dairy cattle, sheep, goats and chicken. The mode of rearing varies from farmer to farmer and from area to area. While most livestock farmers practice zero-grazing, a combination of zero-grazing with open grazing is widespread. The farmers adjacent to forests practice open grazing. Virtually every homestead rears chicken. The information on farm produce is summarized in table 4.5.

Table 4-5 Characteristics of the Farm Enterprises

Variable	Mean	Std. Dev.	Min.	Max.
Crop output per annum in kilograms				
Maize harvest	304.41	391.77	0	3240
Beans harvest	116.96	231.56	0	1920
Irish potatoes harvest	165.03	367.22	0	3500
Bananas harvest	12.9	44.22	0	620
Coffee harvest	367.35	843.25	0	9000
Horticultural crops harvest	620.00	3018.08	0	40000
Tea harvest	694.68	7506.33	0	150000
Crop output prices (Ksh per kilogram) as of July 2007				
Price of maize	14.29	4.86	10	27
Price of beans	28	16.4	12	50
Price of potatoes	11.57	4.04	8	20
Price of bananas	10.75	3.55	5	15
Price of coffee	20.2	5.36	5	35
Price of horticultural crops	12.52	16.03	3	120
Price of tea	18.2	6.58	10	27
Livestock owned (units)				
Cattle	1.82	1.3	0	10
Sheep	4.4	6.0	0	35
Goats	3.6	5.98	0	45
Livestock output in kilograms				
Chicken meat	10	17	0	200
Milk output	1953	1534	40	7301
Eggs output	1238	1533	60	6840
Livestock output prices (Ksh per kilogram) as of July 2007				
Price of a cow	18165	9188	5000	60000
Price of a sheep	2266	1082	1000	5000
Price of a goat	2246	1113	1000	5000
Price of a chicken	236	90	100	500
Price of milk	15.4	1.79	12	20
Price of an egg	7.5	0.9	6	8

(iii) Land and Tenure Rights

Land holding in Nyeri varies according to population density. In the high potential zones of Othaya, Tetu, Mathira, and Mukuruwe-ini, where population density is high, the mean land holding small. In the municipality, land is of low potential for agricultural production but the urban effect has produced small holdings just as in high potential areas. In the low potential areas of Kieni, population density is low and mean landholding is higher. Table 4.6 shows mean landholdings in Nyeri by division.

Table 4-6 Land Ownership in Acres by Division

Division	Mean	Std Dev.	Min.	Max.
Municipality	1.30	1.20	0.10	5
Mathira	1.50	1.33	0.10	5
Mukuruwe-ini	1.94	1.43	0.25	5
Othaya	1.29	1.13	0.08	5
Tetu	1.49	1.11	0.25	5
Kieni West	3.24	3.60	0.25	15
Kieni East	1.98	1.82	0.25	11
District	2.28	3.01	0.08	23

Kieni West has the largest land holding at 3.24 acres. Othaya has the least at 1.29 acres.

In Kieni the farmers are migrants from the other divisions of the district. Some farmers in the densely populated areas try to augment their land holdings by renting free plots but such plots are few. Others take advantage of road reserves where they cultivate Napier grass or graze animals. Forestlands are often exploited for pastures and crop cultivation.

Table 4.7 shows that the main method of land acquisition in the district is via inheritance. Parents allocate land to their children but often retain the title deed in their names. Many household heads only possess partial rights for their plots.

Table 4-7 Land Tenure and Tenure Rights

	Mean	Std. Dev
Mode of Land Acquisition		
Purchased	0.10	0.30
Inherited	0.80	0.38
Rented	0.10	0.07
Registration of Land		
Father	0.47	0.50
Head	0.36	0.48
Brother of Head	0.01	0.12
Mother of Head	0.05	0.21
Landlord	0.01	0.10
Spouse	0.07	0.26
Relative	0.02	0.15
Tenure Rights		
Land sale	0.44	0.50
Bequeathing the land	0.40	0.50
Renting the land	0.14	0.35
Other land transactions	0.02	0.15
Security of Rights		
Unlikely to lose land ownership	0.80	0.40
Other stakeholders on land	0.20	0.45

In inherited lands, tenure rights are weak, particularly when the beneficiary has no title deed. For instance, sale of the land may be restricted by custom or parents. The Land Control Boards enforce sale restrictions. Tenure rights can have major effects on demand for inputs and on investments in land and soil conservation (Kabubo-Mariara *et al.*, 2010).

(iv) Selected Inputs in Smallholder Agriculture

Table 4.8 shows the relative importance of selected farm inputs. Livestock and capital equipment are the main production inputs in smallholder agriculture. The market value of manure used in small farms is high compared to the value of the fertilizers applied.

Table 4-8 Selected Inputs in Smallholder Agriculture

Variable	Mean	Std. Dev.	Min.	Max.
Value of farm equipments in Ksh	3,761	4,956	50	39,350
Value of external inputs in Ksh	1,078	1,903	0	25,740
Value of livestock inputs in Ksh	5,972	12,517	20	200,000
Family labor, person-days	137	154	0	954
Hired labor, person-days	22.5	64.3	0	587
Manure, kilograms	1,597	2,530	0	21,000
Agricultural chemicals, kilograms	0.25	1.79	0	40
Fertilizer, kilograms	45.9	72.6	0	600

Usage of farm equipment (e.g., hoes, spray pumps) and external inputs (e.g., animal feeds, and seeds) in the district is modest. Table 4.8 shows that family labor is more widely used than hired labor. Animal manure usage is greater than that of fertilizer. The mean amount of manure usage is 1,597 kilograms compared with the fertilizer use that has a mean of 46 kilograms.

Livestock inputs account for the largest share of external inputs on small farms, and are relatively expensive. Extension services, though important in agriculture are virtually non-existent in study area. Of the sampled farmers, only three had been visited by an extension agent. Table 4.9 shows little investments in soil conservation in the district.

Table 4-9 Proportion of Households Investing in Soil Conservation

Variable	Mean	Std Dev.
Plots with some conservation	0.60	0.49
Erosion control practices		
Terraces	0.03	0.17
Planted trees	0.03	0.16
Ridging	0.19	0.39
Grass strips	0.28	0.45
Other practices (e.g., mulch, fallow)	0.07	0.25
Nature of the practices		
Short term investments	0.46	0.50
Long term investments	0.54	0.50
Mineral addition practices		
Fertilizer use	0.17	0.37
Manure use	0.17	0.38

The data indicates that 60 percent of the plots practiced some form of soil conservation. Grass stripping is the most common erosion control practice at 28 percent. In addition to erosion control practices, some farmers use fertilizers and manure to increase soil fertility on their plots.

(v) Village Characteristics

Input usage is influenced by village level characteristics, such as access to markets, population density, social institutions, and access to social services (Kabubo-Mariara *et al.*, 2010, Kabubo-Mariara, 2007; 2010). Table 4.10 shows extents of access to various infrastructural facilities.

Table 4-10 Distances to Infrastructural Facilities (kilometers)

Type of Infrastructure	Mean	Std. Dev.	Min.	Max.
Market centre	3.09	2.89	0.01	25
Primary school	1.44	0.89	0.01	5
Secondary school	2.05	1.24	0.01	7
College	11.8	11.03	0.09	60
Health facility	2.41	1.61	0.01	10
All-weather road	1.67	2.20	0	15
Tarmac road	4.18	4.89	0.01	30
Cooperative	4.34	4.26	0.01	20
Church	1.62	1.87	0.01	18

Table 4.10 shows that most households have access to schools, churches, and all-weather roads. However, most households are far from colleges, cooperative societies and tarmac roads.

Tea growing zones of Othaya and Mathira have a higher density of road network than other areas because the tea levy is used to construct and maintain roads. Non-cash crop growing areas especially in Kieni are particularly disadvantaged in terms of access to roads. Poor road maintenance denies many households participation in market activities.

Social infrastructures and institutions are important in so far as they facilitate access to information, farm inputs and markets. Information and access to markets not only shape a farmer's entrepreneurial attitudes but also determine the technology and management practices that the farmer adopts. Access to markets also opens up possibilities of overcoming liquidity and credit constraints (Kabubo-Mariara *et al.*, 2010).

In summary, this chapter has described the study area, with particular attention to its natural features and socioeconomic conditions. The district is suitable for farming, and agriculture is the main source of income for many households. In a bid to improve farm productivity and reverse the negative effects of land degradation, a majority of farmers in the district have invested in soil conservation. However, the performance of producer cooperative societies in the district is wanting, especially in the area of prompt payment of farmers for their produce.

CHAPTER 5 : ESTIMATION RESULTS

5.0 Introduction

This chapter analyses demand for farm inputs together with the associated returns, first in relation to crop output, and then in connection with livestock output. In farming, some inputs such as fertilizer and animal feeds are endogenously determined together with farm output. To assess the impact of these inputs without the common problem of endogeneity, each of the endogenous variables is instrumented. The procedure involves predicting demand for the endogenous input and then using the predicted measure to replace the actual measure of the input in the estimation of parameters of the farm output function (Greene, 1997). This two-stage procedure is done in one step by the commonly available statistical software (see Stata, 1990). The ensuing section presents and discusses regression results, starting with the first stage regressions.

5.1 Demand for Fertilizer

The parameter estimates of demand for fertilizer are presented in Tables 5.1 and 5.2. In Table 5.1 four specifications of fertilizer demand are presented. The characteristics of the household head and social interactions at the village level are the control variables. Social interactions relate to village averages of fertilizer usage, soil conservation efforts in areas of ridging, grass stripping, and the dominant type of property rights in a village. In Table 5.1, the distance to the nearest cooperative society is used as an instrument for fertilizer use. The effect of distance on fertilizer demand is assumed to be non-linear, which is the reason for inclusion of the square of distance in demand equation (Thori and Mehlum, 2010).

Table 5-1 First Stage Regression – Demand for Fertilizer (*t*-statistics in parentheses)

Variables	*OLS Parameter Estimates*			
Factor Inputs				
Capital, index	2.664(1.36)	2.081(1.03)	1.804(0.89)	1.805(0.90)
Labor, person days	.043(2.25)	.034(1.71)	.034(1.69)	.039(1.95)
Land, hectares	.268(0.23)	-.451(0.38)	.200(0.17)	-.228(0.19)
Farmer and Neighborhood Characteristics				
Age, years	.526(0.33)	-.203(0.12)	-.303(0.18)	-.409(0.25)
Age^2	.034(0.23)	-.735(0.00)	.001(0.03)	.002(0.11)
Education, level	3.632(0.76)	3.362(0.69)	3.167(0.64)	4.048(0.83)
Mean fertilizer usage in a village, kilograms	.675(5.42)	-	-	-
Mean of soil ridging practices (1= ridging)		55.781(2.30)	-	-
Mean of grass stripping practices (1=stripping)	-	-	31.474(1.37)	-
Property rights regime (1,2...*n*), where *n* = private	-	-		-17.214(2.68)
Exclusion Restrictions (instrumental variables excluded from the production functions)				
Distance to a cooperative society	-3.603(3.75)	-3.396(3.41)	-3.570(3.58)	-3.510(3.55)
Distance to a cooperative society squared	.097(4.55)	.095(4.35)	.098(4.45)	.093(4.23)
Constant	28.389(0.67)	45.529(1.04)	50.896(1.16)	111.047(2.35)
R^2	.125	0.0739	0.066	0.079
F-statistic [*p*-value]	6.550[0.000]	3.65[0.000]	3.25[0.001]	3.93[0.000]
Root MSE	68.619	70.644	70.933	70.404
Observations	423	423	423	423

The estimates in Table 5.1 indicate that labor and social interaction variables, represented by means of fertilizer usage, soil conservation efforts and property rights within a village are the main determinants of fertilizer demand. An increase in distance to the nearest cooperative society is shown to reduce demand for fertilizer.

The estimates indicate that a one person-day increase in labor endowment at the household increases fertilizer application on a plot by 0.043 kilograms. The social effects of fertilizer usage and soil ridging are positive. If the mean fertilizer usage at the village level were to increase by one kilogram, an observing farmer within the village would increase his own fertilizer usage by close to 0.7 of a kilogram. This finding is suggestive of social learning among farmers and of positive social information externalities within the village.

For every kilometer increase in distance to a cooperative society, a farmer reduces his annual demand for fertilizer by 3 kilograms. Long distances to cooperative societies discourage fertilizer usage.

Likewise, a unit change in the property rights regime in the direction of private ownership reduces fertilizer demand by 17 kilograms. In smallholder agriculture farmers may opt to use organic manure rather than inorganic fertilizer when they are certain of using their own plots for a long period. Use of manure may be advantageous in that soil fertility lasts for a longer period. However, manure application is laborious and perhaps more expensive than fertilizer if sourced from outside the farm. The results suggest that private rights regimes may reduce plot level application of fertilizers.

Apart from labor, social interaction variables and distances to cooperative society, all other variables in Table 5.1 are statistically insignificant. Note that the R^2 values in Table 5.1, as well as in the other tables that report on this statistic in this chapter, are low. R^2 is commonly low in estimations using cross-sectional data. This is because of the effect of confounding factors on input demand and on output. The control function deals with this effect. In cross-sectional econometric analysis, the F-statistic is a better measure of goodness-of-fit than the R^2.

In Table 5.2, the same analysis is performed, as in Table 5.1, but entering the basic farm inputs into the fertilizer demand equation separately. The separation is in attempt to control for multicollinearity among the basic inputs.

Table 5-2 Demand for Fertilizer by Main Factor Inputs with Controls for Neighborhood Effects (*t*-statistics in parentheses)

Variables	*Capital*				*Labor*				*Land*			
	OLS Estimates				*OLS Estimates*				*OLS Estimates*			
Factor Inputs												
Capital, index	3.573 (1.91)	2.544 (1.33)	2.386 (1.24)	2.43 (1.28)	-	-	-	-	-	-	-	-
Labor, person days	-	-	-	-	.049 (2.60)	.037 (1.92)	.037 (1.90)	0.042 (2.16)	-	-	-	-
Land, hectares	-	-	-	-	-	-	-	-	1.003 (0.90)	0.164 (0.14)	.384 (0.34)	.374 (0.33)
Farmer and Neighborhood Characteristics												
Age, years	-.439 (0.28)	-.148 (0.09)	-.249 (0.15)	-.343 (0.21)	-.424 (0.27)	-.151 (0.09)	-.249 (0.15)	-.355 (0.22)	-.334 (0.21)	-.062 (0.04)	-.172 (0.10)	-.262 (0.16)
$Age^2 * 10^{-2}$	.357 (0.24)	.003 (0.00)	.056 (0.04)	.172 (0.11)	.287 (0.20)	-.041 (0.03)	.013 (0.01)	.124 (0.08)	.274 (0.19)	-.041 (0.03)	.009 (0.01)	.121 (0.08)
Education, level	4.471 (0.94)	3.802 (0.78)	3.661 (0.75)	4.635 (0.95)	4.736 (1.01)	3.923 (0.81)	3.749 (0.77)	4.619 (0.96)	5.440 (1.15)	4.791 (0.99)	4.473 (0.92)	5.474 (1.13)
Mean fertilizer used by neighbors, Kg	.651 (5.24)	-	-	-	.650 (5.28)	-	-	-	.633 (5.09)	-	-	-
Mean of soil ridging (1=ridging)	-	57.991 (2.39)	-	-	-	53.402 (2.21)	-	-	-	55.363 (2.28)	-	-
Mean of grass stripping (1=stripping)	-	-	35.408 (1.56)	-	-	-	30.150 (1.33)	-	-	-	34.306 (1.50)	-
Bundles of property rights in a village (1, 2…), n = private	-	-	-	16.744 (2.61)	-	-	-	17.058 (2.66)	-	-	-	16.488 (2.56)
Exclusion Restrictions												
Distance to a cooperative society	-3.45 (3.58)	-3.27 (3.30)	-3.45 (3.47)	-3.38 (3.43)	-3.55 (3.69)	-3.37 (3.39)	-3.54 (3.56)	-3.48 (3.53)	-3.39 (3.51)	-3.22 (3.23)	-3.40 (3.41)	-3.33 (3.37)
Distance to a cooperative society squared	.097 (4.54)	.095 (4.32)	.098 (4.45)	.092 (4.22)	.097 (4.48)	.095 (4.35)	.098 (4.45)	.093 (4.24)	.096 (4.49)	.095 (4.31)	.098 (4.43)	.092 (4.20)
Constant	32.79 (0.77)	47.23 (1.08)	52.29 (1.19)	112.32 (2.37)	23.63 (0.56)	41.77 (0.96)	47.37 (1.09)	106.72 (2.27)	26.39 (0.62)	42.53 (0.98)	47.63 (1.09)	106.49 (2.25)
R^2	0.114	0.067	0.060	0.070	0.120	0.072	0.065	0.077	0.108	0.063	0.057	0.067
F-statistic *p*-value	7.61 0.000	4.26 0.000	3.77 0.001	4.48 0.000	8.11 0.000	4.55 0.000	4.08 0.000	4.95 0.000	7.16 0.000	3.99 0.000	3.55 0.001	4.25 0.002
Root MSE	68.88	70.72	71.00	70.56	68.63	70.56	70.83	70.30	69.12	70.87	71.12	70.69
Observations	423	423	423	423	423	423	423	423	423	423	423	423

The results in Table 5.2 show that the key determinants of fertilizer demand are labor, social interactions and distances to the nearest cooperative societies, just as in Table 5.1. A unit increase in capital index increases fertilizer usage by 3.6 kilograms. Household capital endowment reflects the level of household wealth, an increase of which raises demand for fertilizer.

Characteristics of household heads do not influence demand for fertilizer in a systematic way. This result is consistent with Akwasi's (2010) finding that household characteristics, including basic education do not affect fertilizer demand. It has been known since the work of T. W. Schultz (1963) that in static agricultural settings with limited technological changes, farmer education has no effect on farm yields.

5.2 Returns to Farm Inputs in Crop Production

(i) Crop Production Functions

In crop production, it will be appreciated that some inputs are basic to all farmers, while others are not. Every farmer applies some form of capital, labor and land in production, so that these factors are basic inputs in crop and livestock production. In contrast, only some of the farmers use fertilizers and animal feeds.

Table 5.3 presents estimates of returns to farm inputs. The dependent variable is log of crop output in kilograms. The production function is estimated using OLS, IV-2SLS and the control function methods.

Table 5-3 Crop Production (Fertilizer is Endogenous), *t*-statistics in parentheses

Variables	*Dependent Variable is Log Crop Output*			
	OLS Estimates	*IV-2SLS Estimates*	*Control Function Estimates*	
Factor Inputs				
Capital, index	.056(3.21)	.046(2.39)	.046(2.58)	.046(2.55)
Labor*10^{-1}, person days	.004(2.09)	.002(1.00)	.002(1.08)	.002(1.18)
Land	.024(2.39)	.022(2.04)	.022(2.20)	.023(2.26)
Fertilizer*10^{-1}, Kg	.006(1.38)	.040(1.93)	.040(2.08)	.045(2.27)
Farmer and Neighborhood Characteristics				
Age, years	-.012(0.82)	-.010(0.65)	-.010(0.70)	-.009(0.67)
Age^2*10^{-1}	.001(0.85)	.001(0.71)	.001(0.77)	.001(0.73)
Education, level	.013(0.31)	-.006(0.13)	-.006(0.14)	-.008(0.19)
Mean fertilizer usage by neighbors within a village, Kg	.005(4.54)	.003(2.00)	.003(1.70)	.003(1.68)
Controls for Unobservables				
Reduced-form fertilizer Residual	-	-	-.004 (1.82)	-.004 (1.75)
Fertilizer*reduced-form residual*10^{-3}	-	-	-	-.003 (1.02)
Constant	9.061 (24.39)	9.017 (22.53)	9.017 (24.29)	8.996 (24.20)
R^2	0.1152	.	0.1222	0.1244
F-statistic *p*-value	6.74 0.000	6.09 0.000	6.39 0.000	5.86 0.000
Root MSE	.607	.652	.605	.605
Observations	423	423	423	423

The OLS estimates show that controlling for neighborhood effects in fertilizer usage, returns to factor inputs with the exception of returns to fertilizer are statistically significant at the 5 percent level. The relevant peer effects are estimated in Appendix 2 Table A2-1. In IV-2SLS estimation, capital, land, fertilizer and mean fertilizer usage are the most important determinants of crop production. The significance of returns to capital in smallholder agriculture is also evident in pineapple and maize-cassava growing in Ghana. Using the accounting approach of internal rate of return, Udry and Anagol (2006) find high average returns to capital investments in pineapple and maize-cassava growing among smallholder farmers in Ghana.

In the IV-2SLS estimation, the coefficient on fertilizer is larger in magnitude than the OLS estimate. The coefficient is also statistically significant, indicating that controlling for endogeneity matters in estimation of returns to farm inputs. When endogeneity and the effects of village level fertilizer usage are controlled for, returns to fertilizer are estimated at 0.4 percent. The coefficient on reduced-form residual is statistically significant confirming that fertilizer is endogenous to crop production, and thus OLS estimates of factor returns are biased.

Since the coefficient on the reduced form fertilizer residual interacted with fertilizer variable is not statistically significant, heterogeneity is not a problem in this particular specification (see Terza, Basu and Rathouz, 2007 for heterogeneity tests). The control function estimates are thus not an improvement over the IV estimates. Table 5.4 presents parameter estimates from a specification that minimizes multicollinearity among basic farm inputs.

Table 5-4 Crop Production by Main Farm Inputs (*t*-statistics in parentheses)

Variables	*Capital*			*Labor*			*Land*		
	OLS	*Control Function*		*OLS*	*Control Function*		*OLS*	*Control Function*	
Factor Inputs									
Capital, index	.073 (4.40)	.060 (3.30)	.060 (3.31)	-	-	-	-	-	-
Labor/10, days	-	-	-	.005 (3.07)	.003 (1.73)	.003 (1.81)	-	-	-
Land, acres	-	-	-	-	-	-	.036 (3.63)	.032 (3.08)	.032 (3.14)
Fertilizer* 10^{-1}, Kg	.007 (1.70)	.042 (2.22)	.045 (2.29)	.007 (1.70)	.043 (2.24)	.048 (2.39)	.008 (1.90)	.040 (2.07)	.044 (2.22)
Farmer and Neighborhood Characteristics									
Age, years	-.011 (0.74)	-.009 (0.64)	-.009 (0.62)	-.009 (0.62)	-.008 (0.52)	-.007 (0.5)	-.009 (0.62)	-.008 (0.55)	-.008 (0.53)
Age^2*10^{-1}	.001 (0.88)	.001 (0.79)	.001 (0.77)	.001 (0.76)	.001 (0.68)	.001 (0.65)	.001 (0.74)	.001 (0.67)	.001 (0.64)
Education, level	.026 (0.61)	.003 (0.06)	.002 (0.04)	.043 (1.02)	.018 (0.41)	.016 (0.36)	.036 (0.86)	.013 (0.29)	.011 (0.25)
Mean fertilizer, Kg	.005 (4.04)	.002 (1.42)	.002 (1.41)	.004 (3.71)	.002 (1.16)	.002 (1.14)	.004 (3.87)	.002 (1.47)	.002 (1.47)
Controls for Unobservables									
Fertilizer residual	-	-.004 (1.88)	-.004 (1.83)	-	-.004 (1.90)	-.004 (1.84)	-	-.003 (1.69)	-.003 (1.62)
Fertilizer* residual* 10^{-3}	-	-	-0.002 (0.59)	-	-	-.002 (0.92)	-	-	-.002 (0.87)
Constant	9.136 (24.4)	9.069 (24.2)	9.060 (24.1)	8.979 (23.7)	8.948 (23.7)	8.930 (23.6)	9.002 (23.9)	8.960 (23.8)	8.947 (23.7)
R^2	0.091	0.099	0.010	0.070	0.078	0.080	.078	0.078	0.086
F-statistic *p*-value	6.97 0.000	6.52 0.000	5.74 0.000	5.23 0.000	5.03 0.000	4.50 0.000	5.89 0.000	5.89 0.000	4.89 0.000
Root MSE	.613	.611	.612	.620	.618	.619	.618	.618	.616
Observations	423	423	423	423	423	423	423	423	423

After controlling for endogeneity and multicollinearity land, capital and fertilizer are shown to be significant determinants of crop production. The coefficients on labor, village level fertilizer usage and household characteristics are not statistically significant. The results suggest two things. First, multicollinearity among farm inputs is not a problem. Second, fertilizer usage at the village level influences fertilizer demand but not crop output.

The estimated coefficients show that returns to capital are the highest at 6 percent, followed by returns to land at 3.2 percent. Returns to fertilizer are at

0.42 percent implying that when a farmer increases annual fertilizer usage by one kilogram, crop output increases by 0.42 percent, ceteris paribus. Of the three inputs, fertilizer is the most flexible in usage. For smallholder farmers, increasing acreage is not an option because of intense land fragmentation in the study district. The ensuing sections assess impacts of social interactions on returns to farm inputs.

(ii) Soil Conservation and Returns

Village level soil conservation efforts have mixed effects on returns. While average soil ridging in a village has a positive effect on returns, grass stripping has a negative effect. In either case, the coefficients on social interaction variables are significant, indicating evidence of social externalities. The results on this issue are presented in Tables 5.5 and 5.6.

Table 5-5 Crop Production Effects of Soil Ridging (*t*-statistics in parentheses)

Variables	*Dependent Variable is Log Crop Output*	
	OLS Estimates	*IV-2SLS Estimates*
Factor Inputs		
Capital	.052 (3.00)	.046(2.40)
Labor* 10^{-2}	.028(1.60)	.016(0.84)
Land	.018(1.77)	.019(1.78)
Fertilizer* 10^{-1}	-.007(1.86)	.039(1.90)
Farmer and Neighborhood Characteristics		
Age	-.009(0.64)	-.008(0.55)
Age^2* 10^{-3}	.083(0.63)	.083(0.59)
Education	.001(0.03)	-.008(0.18)
Mean of soil ridging effort by neighbors within a village (1=soil ridging)	.595(2.80)	.431(1.74)
Constant	9.153(24.33)	9.059(22.43)
R^2	0.089	.
F-statistic [*p*-value]	5.040[0.000]	4.380[0.000]
Root MSE	.616	.652
Observations	423	423

The estimates in Table 5.5 show that soil ridging efforts in a village are positively associated with crop production. The coefficient on soil ridging indicates that a 10% increase in the proportion of farmers engaged in this practice would raise crop output by 4.31 percent. This result suggests that there are positive production social externalities in the village stemming from farmers that are practicing soil ridging. This finding contrasts with the case of grass stripping, where estimates show that when grass stripping efforts by neighbors increase, crop output on individual plots declines (Table 5.6).

Table 5-6 Crop Production and Grass Stripping (*t*-statistics in parentheses)

Variables	*Dependent Variable is Log Crop Output*	
	OLS Estimates	*IV-2SLS Estimates*
Factor Inputs		
Capital	.043(2.49)	.038(2.12)
Labor* 10^{-2}	.038(2.23)	.028(1.50)
Land	.014(1.35)	.013(1.23)
Fertilizer* 10^{-1}	.011(2.55)	.029(1.53)
Farmer and Neighborhood Characteristics		
Age	-.010(0.70)	-.009(0.60)
$Age^{2}*10^{-3}$	.100(0.77)	.097(0.73)
Education	.009(0.22)	.008(0.19)
Mean of grass stripping efforts by neighbors within a village	-.952(4.86)	-.958(4.78)
Constant	9.573(25.65)	9.407(24.43)
R^2	0.127	0.080
F-statistic [*p*-value]	6.010 [0.000]	6.080[0. 000]
Root MSE	.604	.619
Observations	423	423

Soil ridging by neighbor farmers leads to positive externalities to non-conserving farmers, raising plot level productivity. In contrast, depending on how they are constructed, grass strips may not be effective in controlling soil erosion, and may worsen erosion downstream during heavy rains.

Further, if a farmer observes his neighbors' grass strips and plants the same in his farm, the strips may compete for space with crops and reduce yields. This however might be a short-run result because in the long run, the grass strips would control erosion and increase crop output. However, due to data limitations, testing for long run impacts of grass strips on crop output is beyond the scope of this study. Existing studies show that soil conservation is a boost to crop production (Kabubo-Mariara, 2010; Kabubo-Mariara *et al.*, 2010)

(iii) Property Rights and Returns

When farmers have secure property rights, they invest more in land. Thus, secure property rights influence inputs use and affect yields (Kabubo-Mariara, 2007; 2010; Kabubo-Mariara *et al.*, 2010).

According to estimates in Table 5.8, as the property rights held by neighbors tend to private ownership of land, crop output at plot levels increases. The social effect of property rights on demand for farm inputs may be negative but positive in the case of crop production.

Investments in soil improvement are linked to property rights. Households with "full" or "complete" land rights bundle (i.e., right of access, right of withdrawal, right of management, right of exclusion and right of alienation) on plots they cultivate can be expected to invest more in them than the tenants would. Put differently, farm owners can be expected to make long-term investments in land. The social effects of village level property rights may be felt in long-term investments in land and the associated returns.

Given the positive relationship between neighborhood property rights and crop output, neighborhood property rights can be expected to improve plot level productivity. Estimates in Table 5.7 confirm this externality.

Table 5-7 Crop Production and Property Rights (*t*-statistics in parentheses)

Variables	*Dependent Variable is Log Crop Output*	
	OLS Estimates	*IV-2SLS Estimates*
Factor Inputs		
Capital	.047(2.67)	.040(2.09)
Labor*10^{-2}	.028(1.63)	.013(0.69)
Land	.018(1.75)	.018(1.66)
Fertilizer*10^{-1}	.010(2.43)	.044(2.01)
Farmer and Neighborhood Characteristics		
Age	-.009(0.64)	-.008(0.50)
Age^2*10^{-3}	.085(0.64)	.079(0.56)
Education	-.002(0.06)	-.014(0.30)
Property rights held by neighbors in a village	.117(2.06)	.176(2.40)
Constant	8.984(21.50)	8.586(17.35)
R^2	.087	.
F-statistic [*p*-value]	3.91[0.000]	3.59[0.001]
Root MSE	.618	.661
Observations	423	423

Information on responsiveness of crop output to changes in factor inputs is important in policy formulation. It is useful in making decisions regarding optimal factor inputs. The section that follows looks at the issue of the elasticity of crop output with respect to factor inputs, highlighting the policy value of the relationship.

5.3 Crop Production, Output Demand and Output Elasticities

(i) The Elasticity of Crop Output with Respect to Factor Inputs

Table 5.8 presents estimates of the responsiveness of crop output to changes in factor inputs based on results reported in Table 5.3, combined with responsiveness of crop output to changes in mean neighborhood variables (see Tables 5.5, 5.6 and 5.7).

Table 5-8 Absolute Elasticities of Crop Output with Respect to Factor Inputs and Village Level Variables (*t*-statistics in parentheses)

Variable	Elasticity
Capital*10^{-5}	0.081 (2.550)
Labor	0.048 (1.180)
Land	0.060 (2.260)
Fertilizer	0.206 (2.270)
Mean fertilizer used by neighbors within a village	0.131 (1.680)
Mean of grass stripping by neighbors within a village	0.272 (4.760)
Mean of soil ridging efforts by neighbors within a village	0.078 (1.710)
Bundles of property rights held by neighbors in a village	0.508 (2.360)

According to Table 5.8, crop output is inelastic with respect to changes in the factor inputs and to variations in neighborhood variables. This has implications on demand for inputs at the farm level. With regard to land, the results suggest that soils may be over cultivated leading to low crop yields. Crop response to changes in capital, labor, fertilizer and soil conservation is also low due to a myriad of factors, including the farming technology. In smallholder agriculture in the study district family labor, traditional seeds and farming methods (e.g., hand digging) dominate. Timely land preparation and weeding using a hand hoe is difficult. The quantities of fertilizer used particularly on food crops may be below optimum (Kelly, 2005; Akwasi, 2010). Agriculture in smallholder farms is largely rain-dependent and crop response can be low in the case of rain failure. But as to how smallholder farmers could adopt modern technologies remains an issue of major policy concern (Mwabu, 2005; Mwabu *et al.*, 2002; 2008; Nafula *et al.*, 2005).

Due to low response of output to changes in inputs, a decline in, say, wage rate relative to crop output price will not attract significant labor on the farm (Hayami, 1969). Low crop response discourages increased input usage at the farm level.

Table 5.8 indicates that crop output is affected by neighborhood variables such as property rights, grass stripping and fertilizer usage. According to the estimates in Table 8, if fertilizer application on a plot were, for instance, to increase by ten percent, output would increase by 2.06 percent. In smallholder agriculture, as land becomes scarce, and as the price of fertilizer relative to price of land continues to decline, the use of fertilizer and of fertilizer-responsive crops particularly the high breed varieties can be expected to increase. Factor substitution can be expected along the isoquant of a meta-production function as happened in Japan (Hayami, 1969).

With a fixed supply of land, opportunities for higher yields from land lie in combining it with factors that push up crop and livestock production functions, such as fertilizer or animal feeds. This is a prudent farming strategy because crop elasticity with respect to land is 0.06, compared with a fertilizer elasticity of 0.206 percent. Crop increments are highest for investments in grass strips, but their productivity benefits seem to lie in the future. Crop expansion also responds strongly to property rights that give farmers complete control of their plots.

(ii) Meta-Production Function and Elasticity of Price with Respect to Output

Table 5.9 presents parameter estimates for best crop production practice. The dependent variable is crop output in kilograms while the regressors of interest are input prices in shillings, with farmers' characteristics being treated as control variables. This is a special type of production function, known in the literature as a meta production function. It is used to analyze indirect effects of input prices on output, as transmitted through inputs usage (Hayami, 1969; Pitt, 1983). Input prices influence output indirectly via their direct effects on demand for inputs. In the meta production function estimated in Table 5.9, wage is treated as the price of labor in the crops production function.

In estimating the effect of output price on crop output, the endogeneity of crop output in the price equation should be recognized. The price equation is nothing but the inverse demand for crops by the population. Before estimating the price equation, crop output must be endogenized. Table 5.9 reports results of a meta crop production function in which wage, the price of labor is treated as the exclusion restriction. That is, wage rate is omitted from the second stage regression, where the responsiveness of output price to output expansion is estimated.

Table 5-9 First Stage Regression – Meta Production Function (Dependent Variable is Crop Output in Kilograms), *t*-statistics in parentheses

Variables	*OLS Estimates*
Wage	69.519 (3.05)
Wage squared	-.372 (2.84)
Age	127.637 (0.58)
Age^2	-1.343 (0.65)
Education	-184.256 (0.28)
Constant	-362.649 (0.06)
R^2	0.023
F-statistic [*p*-value]	1.960 [0.083]
Root MSE	9582.200
Observations	423

It should be noted that in Table 5.9, the meta production function for crops is non-linear in wage rate. The coefficient on the wage rate is positive, whereas that on wage squared is negative. Thus, the derivative of the meta production function with respect to the wage rate is 69.519 - 2(mean wage)*.372, which is negative 33 because the mean wage rate for persons in wage employment is Ksh 138. Thus, as expected, output declines as the wage rate rises because demand for labor is falling.

The wage rate is a valid instrument for crop output in the wage equation that is estimated in the second stage regression because it affects crop output without directly affecting prices at which crops are sold. The second stage regression equation is an inverse demand function for crops, whose parameter estimates are presented in Table 5.10. The results in Table 5.10 show that IV parameter estimates are an improvement over the OLS estimates.

Table 5-10 Second Stage Regression – Inverse Demand Function for Crop Output (t-statistics in parentheses)

Variables	*Dependent variable is average price per kilogram of crop output*	
	OLS Estimates	*IV-2SLS Estimates*
Independent Variables		
Crop output	-.001(3.44)	-.004(2.04)
Age	1.620(1.29)	1.941(1.30)
Age squared	-.008(0.64)	-.011(0.78)
Education	-.911(0.25)	-.543(0.13)
Constant	18.055(0.55)	21.069(0.54)
F-statistic [*p*-value]	7.960[0.000]	4.650[0.001]
R^2	0.071	.
Root MSE	54.420	64.129
Observations	423	423

In this inverse demand function, the dependent variable is average price of crop output, while the independent variable of interest (the treatment variable) is crop output. In a direct demand function, the price of a commodity drives the quantity purchased by consumers. In an inverse demand function the price consumers pay (and hence the revenue received by farmers) is driven by the quantity on sale in the crop market.

When farmers produce more of a given farm product, they compete to sell by offering lower prices for their products. From the estimates in Table 5.10, when crop output increases by one kilogram, price falls by 0.004 shillings. This shows that price decreases with output available in the market. The relationship between agricultural output and its price is well captured by the Cobweb theorem (Kaldor, 1934; Nerlove, 1958).

The inverse price elasticity of demand for crops, say Ø, calculated from Table 5.10 is 0.177. Therefore, the direct price elasticity of demand for crops, η, is arithmetically equal to 1/0.177 =5.6. As can be seen, the elasticity of price with respect to crop output, Ø, is less than unity (.018), implying that the corresponding elasticity of output with respect to price, η is greater than one (5.6). When η is elastic, it means that a percentage change in crop output attracts a smaller percentage change in price, whereas, a unit percentage change in product price leads to a percentage change in output that is greater than unity.

Besides crops, smallholder farmers also produce livestock products, the main ones being milk and eggs. To produce these products, the farmers demand basic and output-enhancing inputs, the most important of which is animal feeds. The next section analyzes demand for animal feeds.

5.4 Demand for Animal Feeds

Parameter estimates of demand functions for animal feeds are presented in Tables 5.11 and 5.12. In these tables, the dependent variable is animal feeds in kilograms.

The effect of distance to the nearest cooperative society on demand is assumed to be non-linear, making it necessary to consider demand effects of distance together with its square term. As before, the mean of animal feeds usage by neighbors within a village captures social interactions among farmers.

Table 5-11 First Stage Regression – Demand for Animal Feeds (*t*-statistics in parentheses)

Variables	*OLS Estimates*
Factor Inputs	
Capital, index	1673.133(4.06)
Labor, person days	15.564(3.82)
Land, hectares	-297.623(1.20)
Farmer and Neighborhood Characteristics	
Age, years	589.671(1.76)
Age^2	-5.140(1.65)
Education, level	-735.273(0.73)
Mean of animal feeds used by neighbors within a village, kilograms	0.231(3.20)
Exclusion Restrictions	
Distance to a cooperative society, kilometers	-386.073(1.83)
Distance to a cooperative squared	16.349(3.60)
Constant	-8170.64(0.91)
R^2	0.192
F-statistic [*p*-value]	10.90[0. 000]
Root MSE	14521
Observations	423

The parameter estimates in Table 5.11 show that capital, labor, mean of animal feeds usage by neighbors, and distances to the nearest cooperative society are the main determinants of demand for animal feeds. While the influence of capital, labor and neighborhood variables are positive, the influence of distance is negative. In Table 5.12, the estimated parameters show the same results suggesting that multicollinearity among the basic factor inputs is not a problem.

Table 5-12 First Stage Regression – Demand for Animal Feeds by Factor Inputs (*t*-statistics in parentheses)

Variables	*OLS Estimates*		
Factor Inputs	*(1) Capital*	*(2) Labor*	*(3) Land*
Capital, index	1834.529(4.58)	-	-
Labor, person days	-	18.09(4.45)	-
Land, hectares	-	-	63.00(0.25)
Farmer and Neighborhood Characteristics			
Age, years	611.839(1.79)	636.96(1.87)	680.05 (1.95)
Age^2	-5.128(1.62)	-5.482(1.73)	-5.46(1.69)
Education, level	-557.583(0.55)	-233.69(0.23)	214.36(0.21)
Mean of animal feeds used by neighbors within a village, kg	0.235(3.30)	0.245(3.45)	0.276(3.70)
Exclusion Restrictions			
Distance to cooperative society, km	-341.153(1.59)	-372.36(1.73)	-328.29(1.49)
Distance to a cooperative squared	16.082 (3.50)	16.34 (3.55)	16.44 (3.48)
Constant	-7260.783 (0.80)	-11887.02 (1.32)	-11663.39 (1.26)
R^2	0.1618	0.1595	0.1196
F-statistic [*p*-value]	11.44[0.000]	11.25 [0.000]	8.05[0. 000]
Root MSE	14753	14773	15120
Observations	423	423	423

Based on OLS estimates in Table 5.11, a unit increase in household capital raises demand for animal feeds by 1,673 kilograms. Capital may be a proxy for household wealth which is positively associated with demand for animal feeds. Wealthy households are able to adopt better animal husbandry practices, including use of animal feeds and acquisition of improved breeds of livestock. Labor employment is associated with higher demand for animal feeds. As labor employment is raised by one person-day, demand for animal feeds increases by 16 kilograms.

When average animal feeds usage by neighbors within a village increases by one kilogram, demand for feeds rises by over 0.2 kilograms. This is evidence of positive social externalities in livestock rearing.

Farmers far off from a cooperative society have lower demand for animal feeds. The cooperative society is a source of farm inputs so that if it is located far away from farmers, transportation costs discourage usage of the inputs. For every kilometer increase in distance to a cooperative society, demand for animal feeds drops by -341.150 + 2(mean distance of 5.4)*16.08 which is 168 kilograms.

Age of the household head affects demand for animal feeds but the education level has no statistically significant effect. Although the demand effect of education is statistically insignificant the sign and magnitude of this variable could still have policy value (McCloskey and Ziliak, 1996). For instance, the negative sign of the coefficient on education may suggest that highly educated farmers use less animal feeds probably because they do not engage in livestock activity. Livestock farming is quite involving, and educated farmers may probably shun the activity as it can conflict with their non-farming activities.

5.5 Returns to Farm Inputs in Livestock Activities

(i) Livestock Output Function

Table 5.13 presents estimates of the livestock output model, using animal feeds as the treatment variable. The OLS estimates show the returns to capital, labor and animal feeds are statistically significant at the 5 percent level. However, in the IV-2SLS and control function estimates, only the return to capital is statistically significant.

Table 5-13 Livestock Output Function (Dependent Variable is Log of Livestock Output), *t*-statistics in parentheses

Variables	*OLS Function Estimates*	*IV-2SLS Estimates*	*Control Function Estimates*
Factor Inputs			
Capital, index	.273(3.03)	.292(2.42)	.292(2.45)
Labor*10^{-1}, person days	.002(1.95)	.002(1.62)	.002(1.79)
Land, hectares	.071(1.34)	.069(1.27)	.060(1.11)
Animal feeds*10^{-3}, kg	.060(5.83)	.049(1.04)	.057(1.22)
Farmer and Neighborhood Characteristics			
Age, years	-.013(0.18)	-.007(0.09)	.018(0.23)
Age^2*10^{-2}	.012(0.17)	.007(0.09)	-.015(0.21)
Education, level	.010(0.05)	.005(0.02)	.006(0.03)
Mean of animal feeds used by neighbors within a village*10^{-3}, kg	.016(1.07)	.019(0.96)	.021(1.11)
Controls for Unobservables			
Reduced form animal feeds residual* 10^{-3}	-	.011(0.23)	.049(0.97)
Animal feeds*reduced-form residual* 10^{-8}	-	-	-.106(2.75)
Constant	1.438(0.75)	1.332(0.68)	.746(0.38)
R^2	0.183	0.181	0.198
F-statistic [*p*-value]	11.59[0.000]	7.46[0.000]	10.16[0.000]
Root MSE	3.116	3.12	3.095
Observations	423	423	423

In Table 5.14, the livestock output function is re-specified to avoid potential multicollinearity among basic inputs.

Table 5-14 Livestock Output Function by Factor Inputs (Dependent Variable is Log of Livestock Output), *t*-statistics in parentheses

Variables	*Capital*			*Labor*			*Land*		
	OLS Estimates	*Control Fn Estimates*		*OLS Estimates*	*Control Fn Estimates*		*OLS Estimates*	*Control Fn Estimates*	
Factor inputs									
Capital, index	.312 (3.22)	.219 (1.08)	.350 (1.78)	-	-	-	-	-	-
Labor10^{-1}, days	-	-	-	.003 (3.35)	.003 (2.76)	.003 (2.66)	-	-	-
Land, hectares	-	-	-	-	-	-	.096 (1.78)	.086 (1.34)	.094 (1.47)
Animal feeds*10^{-3}, kg	.022 (3.38)	.037 (1.27)	.055 (1.96)	.028 (4.75)	.033 (1.24)	.047 (1.78)	.029 (4.90)	.037 (1.37)	.047 (1.74)
Farmer and Neighborhood Characteristics									
Age, years	.023 (0.31)	.020 (0.27)	-.008 (0.11)	.025 (0.34)	.023 (0.30)	-.007 (0.10)	.028 (0.38)	.025 (0.33)	.017 (0.23)
Age^2/100	-.012 (0.17)	-.009 (0.13)	.017 (0.25)	-.016 (0.23)	-.015 (0.21)	.013 (0.19)	-.017 (0.24)	-.014 (0.20)	-.007 (0.10)
Education, level	.118 (0.53)	.160 (0.68)	.014 (0.06)	.177 (0.81)	.180 (0.82)	.103 (0.48)	.200 (0.90)	.207 (0.92)	.188 (0.84)
Village level an. feeds/1000	.031 (2.13)	.024 (1.21)	.029 (1.50)	.028 (1.90)	.025 (1.15)	.036 (1.70)	.028 (1.83)	.023 (1.10)	.001 (0.45)
Controls for Unobservables									
Feeds residual*10^{-3}	-	-.015 (0.52)	.023 (0.80)	-	.001 (0.19)	.031 (1.12)	-	.001 (0.30)	.016 (0.56)
Animal feeds* residual*10^{-3}	-	-	-.004 (5.61)	-	-	.003 (5.04)	-	-	.013 (2.62)
Constant	.860 (0.43)	.781 (0.39)	1.596 (0.83)	.122 (0.06)	.174 (0.09)	.931 (0.48)	.317 (0.16)	.380 (0.19)	.653 (0.33)
R^2	0.117	0.118	0.180	0.119	0.119	0.170	0.102	0.102	0.117
F-statistic *p*-value	9.21 0.000	7.92 0.000	11.37 0.000	9.37 0.000	8.02 0.000	10.61 0.000	7.89 0.000	6.76 0.000	6.85 0.000
Root MSE	3.231	3.234	3.121	3.228	3.232	3.140	3.259	3.262	3.240
Observations	423	423	423	423	423	423	423	423	423

According to the OLS results in Table 5.14, capital, labor and animal feeds are statistically significant determinants of livestock output at the 5 percent level. Animal feeds usage at the village level may positively influence livestock output and the relevant peer effects are estimated in Appendix 2 Table A2-2. In livestock farming, it can be seen that a person day engaged in livestock activity increases livestock output by 0.03 percent. A kilogram of animal feeds increases output by 0.002 percent, while a unit increase in capital index increases livestock output by 31 percent.

The signs on the parameters of factor inputs are positive as postulated by economic theory. A unit rise in average animal feeds usage in the neighborhood increases output of an individual farmer by 0.003 percent. This indicates existence of social externalities in animal feeds.

(ii) Soil Conservation and Factor Returns in Livestock Activities

Table 5.15 presents parameter estimates of the livestock output function controlling for village level conservation efforts. Soil conservation by neighbors has a negative impact on livestock output. The marginal effect of neighbors' conservation efforts on livestock output is minus 2.8 kilograms.

This finding may arise from demonstration effects that motivate individual farmers to adopt soil conservation practices in farmland that was previously used as pasture areas. The result could alternatively reflect use of resources for conservation, resources that were previously used to buy animal feeds. In either of these cases, average conservation effort at the village level has the effect of reducing output from livestock activities.

Table 5-15 Production of Livestock Output Controlling for Village Level Conservation Effort (Animal Feeds is the Endogenous Input), *t*-statistics in parentheses

Variables	*Dependent Variable is Log Livestock Output*	
	OLS Estimates	*IV-2SLS Estimates*
Factor Inputs		
Capital	.254(2.86)	.302(2. 59)
Labor* 10^{-1}	.023(2.59)	.028(2.33)
Land	.074(1.45)	.074(1.43)
Animal feeds* 10^{-3}	.058(5.84)	.031(0.72)
Farmer and Neighborhood Characteristics		
Age	-.033(0.46)	-.019(0.26)
Age^2* 10^{-2}	.033(0.49)	.020(0.29)
Education	-.014(0.07)	-.039(0.18)
Mean of conservation effort by neighbors within a village	-2.750(4.06)	-2.924(3.98)
Constant	3.664(1.91)	3.662(1.89)
R^2	0.212	0.198
F-statistic [*p*-value]	13.930[0.000]	9.560[0.000]
Root MSE	3.060	3.088
Observations	423	423

Table 5.16 shows the impact of soil ridging practice on livestock output. As in Table 5.15, village level conservation (soil ridging by neighbors) is negatively correlated with livestock output.

Table 5-16 Livestock Output Function Controlling for Effects of Soil Ridging at the Village Level (Animal Feeds is the Endogenous Input), *t*-statistics in parentheses

Variables	*Dependent Variable is Log Livestock Output*	
	OLS Estimates	*IV-2SLS Estimates*
Factor Inputs		
Capital	.253(2.81)	.280(2.40)
Labor*10^{-1}	.018(2.09)	.021(1.86)
Land	.086(1.67)	.086(1.67)
Animal feeds*10^{-3}	.064(6.32)	.050(1.27)
Farmer and Neighborhood Characteristics		
Age	-.020(0.28)	-.012(0.17)
Age^2*10^{-2}	.016(0.25)	.009(0.13)
Education*10^{-2}	-.017(0.00)	-1.312(0.06)
Mean of soil ridging efforts by neighbors within a village	-2.495(2.37)	-2.408(2.22)
Constant	2.263(1.19)	2.18(1.14)
R^2	0.192	0.188
F-statistic [*p*-value]	12.27 [0.000]	7.450[0.000]
Root MSE	3.099	3.106
Observations	423	423

5.6 Effects of Fertilizer on Animal Feeds

Table 5.17 presents parameter estimates of animal feeds production function with fertilizer as an endogenous regressor. The dependent variable is animal feeds in kilograms, while the independent variables are capital, labor, land and fertilizer. Fertilizer is the explanatory variable of policy interest.

The OLS estimates show that capital and average fertilizer usage by neighbors within a village are important determinants of demand for animal feeds. In the IV-2SLS estimates, fertilizer comes out as a strong determinant of the amount of animal feeds produced.

Table 5-17 The Effect of Fertilizer on Animal Feeds (Dependent Variable is Animal Feeds in Kilograms), *t*-statistics in parentheses

Variables	*OLS Estimates*	*IV-2SLS Estimates*
Factor Inputs		
Capital, index	1744.946(4.19)	1566.584(2.88)
Labor, person days	16.145(3.91)	12.095(2.12)
Land, hectares	-123.180(0.50)	32.270(0.10)
Fertilizer, kg	8.666(0.85)	172.318(2.86)
Farmer Characteristics		
Age, years	575.885(1.70)	594.606(1.36)
Age^2	-5.223(1.66)	-5.256(1.30)
Education, level	-1005.800(0.99)	-1871.110(1.40)
Exclusion Restrictions		
Distance to the nearest cooperative society	-170.701(0.82)	-
Distance to the cooperative squared	13.926(2.99)	-
Constant	-5567.542(0.62)	-12065.120(1.03)
R^2	0.173	.
F-statistic [p-value]	9.620[0.000]	6.290[0.000]
Root MSE	14687	18866
Observations	423	423

The IV-2SLS estimates show fertilizer usage is positively correlated with animal feeds at the plot level. As is readily appreciated, fertilizer affects the output of crops, and the by-products of crops are turned into fodder and into commercial animal feeds. The output of animal feeds increases in tandem with increases in crop output. As this happens, the price of animal feeds declines thus encouraging their demand by farmers. As a result, livestock output would increase, ceteris paribus. Thus, fertilizer is an important determinant of livestock output, albeit indirectly via animal feeds, including fodder.

5.7 Livestock Output, Demand for Livestock Products and Price Elasticities

(i) *Elasticity of Livestock Output with respect to Factor Inputs*

Table 5.18 presents elasticities of livestock output with respect to factor inputs, based on OLS estimates in Table 5.14. The table further shows elasticities of livestock output with respect to village level conservation efforts, based on OLS estimates reported in Tables 5.15 and 5.16.

Table 5-18 Elasticity of Livestock Output with respect to Factor Inputs and Soil Conservation by Neighbors

Variable	Elasticity
Capital, index	0.13(3.68)
Labor, person days*10^{-2}	.087(2.53)
Land, hectares	.047(2.35)
Animal feeds*10^{-3}, kg	.025(6.04)
Mean of conservation efforts by neighbors within a village	-1.05(3.96)
Mean of soil ridging efforts by neighbors within a village	-.955(2.35)

The estimates indicate that livestock output is inelastic with respect to changes in factor inputs but elastic in the average conservation efforts by neighbors. The output response to changes in factor inputs is positive in all cases. With regard to animal feeds, the table shows that if the usage of this input were to increase by 10 percent, livestock output would increase by 0.003 percent.

Livestock output serves subsistence as well as cash needs of households. In producing for the market, farmers have a price at which they expect to sell their products. From the expected price and the output they produce, they further form expectations of the amount of revenue to be earned. By comparing the expected revenue to the costs of inputs, farmers decide whether to engage in livestock activities or not.

The revenue received by farmers is determined by consumers' expenditure on livestock products. The amount spent on livestock output is determined by the price elasticity of demand for that output. The next section deals with these issues.

(ii) Price Elasticity of Demand for Livestock Output

Table 5.19 shows the relationship between livestock output and input prices. The link between livestock output and distances to markets is also shown. The input prices and distances to markets are augments of meta-production function for livestock. The log of wage and log of distance to the nearest market are the independent variables of policy interest in the meta production function, with household characteristics serving as control variables.

Table 5-19 First Stage Regression – Livestock Output Function (Dependent Variable is Livestock Output in Kilograms), *t*-statistics in parentheses

Variables	*OLS Estimates*
Inputs Prices	
Log wage	-78.471(1.62)
Log distance to the nearest market	-180.877(1.78)
Distance to market*wage	1.278(2.97)
Age	50.730(1.37)
Age^2	-.379(1.11)
Education	156.023(1.43)
Constant	-940.049(0.97)
R^2	.036
F-statistic [*p*-value]	2.590[0.018]
Root MSE	1597.900
Observations	423

The estimates show that livestock output is negatively associated with the price of labor and with distance to the nearest market center. One shilling increase in wage reduces livestock output by (marginal effect of log wage on output*mean wage which is arithmetically -78.47/138= -0.57) 0.57 kilograms. The wage rate and distance to the market serve as instrumental variables for livestock output in an equation of price for livestock output. This equation can be interpreted as the inverse demand for livestock output. Table 5.20 presents estimates of an inverse demand for livestock output.

Table 5-20 Inverse Demand Function for Livestock Output (*t*-statistics in parentheses)

Variables	Dependent variable is average price of livestock products	
	OLS Estimates	*IV-2SLS Estimates*
Independent Variables		
Livestock output, kg	.003(2.06)	-.012(1.23)
Age, years	-.314(0.33)	.409(0.35)
Age squared	.002(0.27)	-.003(0.28)
Education, level	.532(0.19)	2.876(0.82)
Constant	24.995(1.03)	10.033(0.34)
F-statistic [*p*-value]	1.130[0.34]	0.43[0.78]
R^2	.011	.
Root MSE	40.765	46.655
Observations	423	423

The OLS estimates show that demand for livestock output is positively correlated with own price. However, this finding is not reliable because livestock output and price are jointly determined. The IV estimates show that livestock output is negatively correlated with own price, as predicted by theory of demand. Moreover, the instrumental variables for livestock output (see Table 5.19) are valid.

The inverse price elasticity of demand for livestock products calculated from the estimates reported in Table 5.20 is 0.46. Since this responsiveness of price to quantity offered to consumers is inelastic, it follows that quantity demanded is elastic. That is, the direct demand for livestock output is elastic[1]. This means that a one percentage increase in livestock output leads to a percentage decrease in price that is smaller than unity.

5.8 Elasticities of Fertilizer and Animal Feeds

Table 5.21 shows the elasticity of fertilizer and animal feeds to changes in selected variables. Elasticities of fertilizer are based on estimates of fertilizer

[1] If the inverse price elasticity of demand is 0.46, the direct absolute price elasticity of demand is $\frac{1}{0.46} = 2.17$

demand in Table 5.1. Elasticities of animal feeds are based on estimates of demand for animal feeds in Table 5.12.

Table 5-21 Elasticities of Fertilizer and Animal Feeds (*t*-statistics in parentheses)

Variables	Fertilizer Elasticity	Animal Feeds Elasticity
Labor	.205(2.25)	.286(3.72)
Capital*10^{-3}	.010(1.35)	.025(3.94)
Education	.101(0.75)	-.081(0.73)
Mean fertilizer usage at the village level	.653(5.41)	-
Mean animal feeds at the village level	-	.275(3.14)
Distance to cooperative society	-.421(3.75)	-.176(1.81)
Distance to cooperative squared	.183(4.54)	.120(3.52)

According to the estimates, fertilizer responds positively to changes in labor and to the mean fertilizer usage. Distance is negatively correlated with demand for fertilizer. Animal feeds respond positively to labor, capital and mean animal feeds usage. As with fertilizer, distance is negatively correlated with demand for animal feeds. However, the responses are less than unitary in all the cases considered. The two inputs respond positively to social interaction variables, suggesting existence of social externalities in usage of both fertilizer and animal feeds.

CHAPTER 6 : POLICY SIMULATIONS

6.0 Introduction

In its Economic Recovery Strategy Paper (ERS), the government identified agriculture as the sector most likely to play a central role in reducing poverty and increasing food security (Republic of Kenya, 2004a). For the agricultural sector to play this role effectively, the government should design interventions to increase farm productivity, particularly in small farms where yields are below potential, despite their dominance in marketed agricultural production. The government had projected that if average yields of major crops from smallholder farmers could have risen by 5 percent by 2007, poverty could have been reduced substantially. The target was, however, not realized.

Fertilizer's role as a productivity-enhancing input is being expanded as donors and governments seek to use it as an instrument for achieving diverse goals of GDP growth, poverty alleviation, soil fertility replenishment, soil conservation and food security. Combined with improved land husbandry practices, fertilizer has the potential to contribute to these different goals (Kelly, 2005). With declining land holdings and productivity in smallholder agriculture, farmers can gain a lot by using inputs that are known to raise output, a prime example being fertilizer.

Chapter five shows that fertilizer and animal feeds are important in raising crop and livestock outputs, respectively. However, demand for farm produce is elastic with respect to consumer prices. This implies that a unit percentage increase in farm output leads to a percentage drop in price that is smaller than one. Under this circumstance, farmers' revenue responds in a particular way to increases in quantity produced. Moreover, the connection between this change in revenue and the household poverty status can be readily established.

This chapter simulates the impact of changes in demand for fertilizer on smallholder production. Specifically, the simulations relate to the effect of a change in fertilizer demand on crop revenue, and to the effect of a change in demand for animal feeds on livestock revenue. The simulations are extended to analyze welfare impacts of different policy scenarios.

The information on demand elasticities is important in determining whether an increase in farm output (due to either greater usage of fertilizer or animal feeds) would increase farm revenue. Moreover, by expressing the revenues in per capita adult equivalent terms and relating to poverty measures, it is possible to gauge the potential of the revenue in poverty reduction. The simulation results can help establish whether raising farm yields can reduce poverty as envisaged in government policy documents.

6.1 Simulated Effects of Increased Fertilizer usage on Farm Revenue and Poverty Gap

Table 6.1 presents simulated results of increasing fertilizer usage on crop output. With a base crop output of 999,604 kilograms (Table 4.6 in chapter 4) and crop output elasticity with respect to fertilizer of 0.206 (Table 5.9 in chapter 5), a 10 percent increase in fertilizer application would increase the base crop output by 2.06 percent or by 20,592 kilograms. Assuming that all the output is sold in the market, the existing output price would have to fall by a certain percentage for the market to absorb this extra output.

Table 6-1 Increase in Fertilizer Usage and Associated Revenue

Percentage increase in fertilizer usage	10%	20%	25%	30%
Base crop output in kilograms	999,604	999,604	999,604	999,604
Base price of 1 kilogram of crop output in Ksh	55	55	55	55
Percentage increase in crop output	2.06	4.12	5.15	6.18
Level of output increase in kilograms	20,592	41,184	51,480	61,776
Total crop output after the increase in fertilizer usage in kilograms	1,020,196	1,040,788	1,051,084	1,061,380
New price per 1 kilogram in Ksh	44	33	27.8	22
Increase in crop output per adult equivalent in kilograms	12.91	25.82	38.5	38.7
Revenue from the extra crop output per adult equivalent (Ksh/year)	568	852	1070	852

The absolute elasticity of price with respect to crop output, Ø, was earlier estimated at 0.177. Suppose that the average price of one kilogram of crop output is Ksh 55, as is the case in this study. If the fertilizer usage were to increase by 10 percent and as a consequence crop output increase by 20,592 kilograms, price would have to drop by 20 percent[2], i.e., from Ksh 55 to Ksh 44 for the market to clear. At the new price, the increase in revenue to the farmers from the sale of the 20,592 kilograms of crop output is Ksh 906,048 (Ksh 44 x 20,592 kilograms). However, if the fertilizer usage were to increase by 20 percent instead of 10 percent, output would rise by 41,184 kilograms. This output would drive the price down by 40 percent, i.e., from Ksh 55 to Ksh 33. At this price, revenue to farmers would increase by close to Ksh 1.4 million. Similarly, a 25 percent increase in fertilizer demand would increase output by 51,480 kilograms, and revenue would increase by slightly over Ksh1.4 million.

Apparently, if fertilizer usage were to increase by 30 percent instead, crop output would increase by a much higher amount of 61,776 kilograms, but the

[2] Given $Ø = \frac{dp}{dq}.\frac{q}{p}$; substituting with figures, $0.177 = \frac{dp}{20592}.\frac{999604}{55}$ and working out the equation gives $dp = 0.2$; the price drop would be 20%.

increase in revenue to farmers would be the same as from the sale of 51,480 kilograms of crop produce arising from a 25 percent increase in fertilizer usage. The price drop when 61,776 kilograms are placed in the market is higher eroding the gains from increasing fertilizer usage beyond 25 percent.

Actually, if the fertilizer usage were to increase by, say, 40 percent, crop output would increase by 82,267 kilograms but the price would drop to Ksh11 and this would lead to a lower revenue, of only Ksh 904,937. The optimal decision in this case is to increase fertilizer application by 25 percent.

If the population in the sample can be expressed in adult equivalent terms by assigning persons in age category 0-5 years a weight of 0.24; age category 6-14 a weight of 0.65; and age category 15+ years a weight of 1 (as in Mwabu *et al.*, 2000), the additional revenue would be shared by a population of 1595 adult equivalents. The increases in fertilizer and the corresponding increase in output and revenue, expressed in per adult equivalent terms are shown in Table 6.1.

If fertilizer usage was to increase by 25 percent, total crop output would rise by 5.15 percent. The annual revenue from selling the output in the market at an average price of Ksh 33 per kilogram would amount to Ksh 1,070 per adult equivalent in the district.

The impact of the increased revenue on poverty alleviation can be assessed by estimating the proportion of the poverty gap closed by the revenue. This is done by first estimating the monetary value of a change in output resulting from increased fertilizer usage.

The Kenya National Bureau of Statistics has estimated that to meet the minimum nutritional requirements, a household in the rural areas needs to spend Ksh 1,562 per month per adult equivalent (Republic of Kenya, 2007a). This expenditure is the national poverty line for rural areas. In annual terms, this expenditure is equal to Ksh 18,744 per adult equivalent.

Expenditure on minimum nutritional requirements by poor rural households in Nyeri district falls below the poverty line by 11.8 percent (Republic of Kenya, 2007a). As such, the district has a poverty gap of Ksh184 per month or Ksh 2,208 per annum. A 25 percent increase in fertilizer application would generate enough revenue (Ksh 1,070) to close 48.5 percent of this gap. This means the absolute poverty gap can be reduced by almost 50 percent through increases in fertilizer usage. As already noted, the optimal percentage increase in fertilizer application is 25 percent (see Table 6.2).

Table 6-2 The Impact of Fertilizer Applications on Poverty Alleviation

Projected percentage increase in fertilizer usage (%)	Monetary value of the increase in crop output per adult equivalent (Ksh/year)	Poverty gap closed by additional revenue (%)
10	568	25.7
20	852	38.6
25	1070	48.5

To eliminate poverty would require a combination of interventions that go beyond increasing crop output. For example, increasing other farm and non-farm incomes would boost household income, and reduce poverty.

The discussion now turns to simulations of the effects of increasing animal feeds on farm revenue and poverty reduction.

6.2 Simulated Effects of Increased Animal Feeds on Farm Revenue and Poverty Gap

Table 6.3 presents simulated results of increasing animal feeds usage on livestock output. Starting with a base livestock output of 304,373 kilograms

(Table 4.6) and livestock output elasticity with respect to animal feeds of 0.64 (Table 5.19), an increase in animal feeds of say, 3 percent, would increase livestock output by 1.9 percent or 5,844 kilograms. Starting with a base price of Ksh 27 per kilogram of livestock output, if all the 5,844 kilograms of livestock output were put on the market, sales competition among farmers would drive the price down to Ksh 20.60. At the new price, revenue to farmers would increase by Ksh 120,386.40. But this increase is not optimal since revenue can be increased through higher usage of animal feeds as shown in Table 6.3.

The optimal increase in animal feeds usage is estimated at 7 percent. With this increase, output would increase by 4.48 percent or by 13,636 kilograms. With an inverse absolute price elasticity of demand for livestock output of 0.461 (estimated from Table 5.20), an annual increase of 13,636 kilograms in livestock output would cause the price to drop by 56 percent[3]. The new price would be Ksh 11.90 per kilogram of livestock output. At the new price, annual revenue to the farmers would increase by Ksh 162, 268. Considering a population of 1,595 adult equivalents, the increase in revenue would be only Ksh 101.7 per adult equivalent.

[3] Given $\emptyset = \frac{dp}{dq} \cdot \frac{q}{p}$, substituting figures, $0.461 = \frac{dp}{13636} \cdot \frac{304373}{27}$ and working out the equation gives $dp = .56$

Table 6-3 The Effect of Increasing Animal Feeds on Livestock Output and Farm Revenue

Percentage increase in animal feeds usage	3%	5%	7%	10%
Base Livestock output in kilograms	304,373	304,373	304,373	304,373
Base price per 1 kilogram in Ksh	27	27	27	27
Percentage increase in livestock output	1.9	3.2	4.48	6.4
Level of output increase in kilograms	5,844	9,740	13,636	19,480
Total livestock output after the increase in animal feeds, kilograms	310,217	314,113	318,009	323,853
Per capita increase in livestock output per adult equivalent in kilograms	3.7	6	8.55	12
New price per 1 kilogram in Ksh	20.6	16.2	11.9	5.50
Farm revenue due to an increase in livestock output per adult equivalent (Ksh)	76.2	97.2	101.7	67

If usage of animal feeds in the district were to rise by 7 percent, annual gains from sales of the extra livestock output would be equal to Ksh 102 for every adult equivalent in the district. This amount can bridge poverty gap in the area by 4.6 percent. Moreover, additional output would become available to consumers at lower prices, raising their welfare.

An increase in animal feeds above 10 percent would collapse the market price for livestock products in the district. Unlike the crop market, the market for livestock products is fragile due to perishability of its commodities.

In Kenya, the market for milk more often than not gets into a state of disarray whenever milk production registers a substantial increase. This is particularly the case during prolonged rainy seasons when pastures become abundant, with considerable increases in milk. The consequence of this is a significant drop in milk prices. The findings reported here can be used to design policies that would avoid the collapse of milk prices during periods of abundant pasture.

CHAPTER 7 : SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

This thesis has investigated the extent to which village-level variables influence farm decisions regarding inputs usage, and how social interactions affect returns to inputs in smallholder agriculture. Towards this end, parameters of farm input demand functions and farm production functions have been estimated controlling for the effects of social interactions. Several econometric techniques, notably, the OLS, IV and control function approaches were used for estimation. The study has examined the ability of smallholder agriculture to reduce poverty in farming communities.

7.1 Summary and Conclusions

Smallholder farming activities are conducted in a social context. Using fertilizer and animal feeds as special cases of more general situations, the study has shown that social interactions matter in smallholder agriculture. Social interactions directly influence demand for inputs and have large impacts on returns to inputs at the plot level. The effects of the social interactions on individual farmers may be through social learning or peer pressure, but due to data limitations, this study was unable to distinguish between these channels. If social externalities are ignored in estimating parameters of input demands or production functions, the estimated parameters would be biased.

Unlike in some literatures where externalities are mostly thought of as negative quantities, this study has found positive and negative externalities in smallholder agriculture. The externalities emanate from social interactions of farmers with neighbors. Positive externalities relate to social learning and peer effects that emanate from social interactions. They influence usage of inputs in a farm. This influence has been found to be largely positive.

Usage of farm inputs was found to be positively correlated with property rights regime at the village level. The dominant property rights regime in a village has an influence on crop output. Negative externalities are associated with the nature of neighborhood conservation efforts. Soil conservation at the village level could negatively influence farm output of individual farmers in the short term. Should a farmer adopt prevailing conservation practices, the benefits of adoption may not be forthcoming until sometime later. Since conservation investments consume resources that would otherwise have gone into production of crop or livestock products, conservation practices can be negatively correlated with crop and livestock production in the short run.

Crop production is one source of household income, and a means to reduce poverty. The study has investigated whether poverty can be alleviated by increasing output from smallholder agriculture as recommended in government policy documents. The results show that this can be achieved through application of output-increasing technologies such as fertilizer and animal feeds up to a point. Fertilizer can only be increased by 25 percent and animal feeds by 7 percent without lowering farm revenues below levels that farmers would find unprofitable to expand production due to unacceptably low supply prices.

The revenue from increased usage of fertilizers and animal feeds has been shown to reduce poverty gap by sizeable margins indicating that smallholder agriculture is important in Kenya's development process. However, agricultural income alone cannot eliminate poverty among small farmers. Additional income support measures are required to close poverty gap. Off-farm employment would go a long way towards poverty reduction. Thus, poverty reduction in smallholder agriculture requires a multi-faceted approach that combines technologies that enhance farm yields with interventions that give farmers access to off-farm income.

The study has established that farm output is responsive to changes in new technologies. Agricultural productivity in smallholder agriculture can be improved if farmers were to apply modern technologies to grow crops and to produce high value livestock products. Fertilizers and animal feeds have been shown to be associated with increased levels of smallholder farm outputs. However, adoption of these technologies without due consideration to market structure, particularly price elasticities of demand for farm produce can ruin farmers.

The gains from increasing fertilizer usage go beyond increasing crop output. A part of the crop harvest resulting from intensification of fertilizer application can be used to feed livestock, thus saving farmers the high costs of buying animal feeds. Thus, livestock output increases in tandem with crop production. As farm outputs increase, prices of farm produce decline in accordance with the law of demand.

7.2 Policy Implications

Agricultural productivity in smallholder farms can be improved if farmers could apply modern technologies in agriculture. At the policy level, the challenge is how to make farmers adopt these technologies.

The thesis has shown that application of fertilizer and animal feeds have potential to increase farm productivity and reduce household poverty. However, usage of these technologies is currently below optimal levels. To boost their usage, several options can be explored.

The first option is to increase the number of cooperative societies so as to improve accessibility to fertilizer and animal feeds. By increasing accessibility to cooperative societies, marketing of agricultural products can be expanded, further encouraging production. Membership into cooperative societies can strengthen farmers' negotiating power with corporate buyers or enable them to form cereal banks and warehouses that can enable them to wait for better prices. Through cooperatives, farmers can develop new products and output processing industries and be able to place high value farm produce on the market as envisaged in Kenya's Vision 2030.

Another policy option is to increase the density of all-weather feeder roads so that transport costs to the markets and cooperative societies are brought down. Reduction of fuel taxes would bring transport costs down and hopefully marketed output would increase.

The thesis has found that the marginal effect of an increase in distance to a cooperative society on fertilizer demand is to reduce it by 3.6 percent. To raise the current mean fertilizer usage from 45.9 to 57.4 kilograms representing a 25 percent increase, mean distance to the nearest cooperative society would have to be reduced by 3.2 kilometers. That is, the mean distance to the nearest cooperative society in the district would have to drop from 5.4 to 2.2 kilometers.

A further option for increasing farm production is to use extension officers to popularize fertilizer usage in smallholder farming as is done in India. This study found extension services to be virtually absent in the study area. Extension services can be strengthened through private sector provisioning as currently there is no credible public extension system in Kenya.

Agricultural markets are erratic and this has discouraged investments in agricultural production. To deal with the problem, some reform of markets for farm inputs is recommended in order to increase competition in the distribution of inputs and marketing, and to curb fraudulent practices of input suppliers and marketing agents.

The study has found that property rights that give farmers ownership of their plots are associated with increases in crop production. Although property rights go beyond mere possession of title deeds, these documents are necessary for long-term investments in soil conservation. Easing the legal and regulatory framework to enable households acquire strong property rights would improve soil conservation practices.

Farm output in smallholder agriculture is inelastic with respect to changes in farm inputs. This finding suggests that farm inputs would have to increase considerably before appreciable increase in farm output to be noticed.

The more fundamental policy issue to consider is whether the gains from increasing farm output move farmers out of poverty. Although the inverse demand for farm output in the study area is price inelastic, the room to increase crop production without the need to support falling prices through production subsidies is limited.

7.3 Areas for Further Research

The study has looked at social externalities in smallholder agriculture. Average neighborhood variables of inputs and of property rights regimes were used as proxies for social interactions. While social interactions generate externalities in form of social learning or peer effects, this study was not able to distinguish between the two outcomes. Distinguishing social learning from peer effects in agriculture is a research agenda worth pursuing.

Improved farm management technologies have the promise of increasing output in smallholder agriculture and therefore deserve close attention. This study found negative effects of grass stripping conservation efforts on farm produce. There is need for further research to establish whether in the long run the effects turn positive.

REFERENCES

Akwasi M. (2010), "Price and Non-price Determinants of Farm Household Demand for Purchased Inputs: Evidence from Northern Ghana", *Journal of Development and Agricultural Economics*, 2(22):054-064.

Argys L. M. and Rees D. I. (2008), "Searching for Peer Group Effects: A Test of the Contagion Hypothesis", *The Review of Economics and Statistics*, 90(3): 442-458.

Banerjee A.V. (1992), "A Simple Model of Herd Behavior", *The Quarterly Journal of Economics*, 117(3):797-817.

Bandiera O. and Rasul I. (2006), "Social Networks and Technology Adoption in Northern Mozambique", *Economic Journal*, 116(October):869-902.

Baumol W.J. and Oates W.E. (1988), *The Theory of Environmental Policy*, Cambridge University Press.

Becker G. S. (1974), "A Theory of Social Interactions", *The Journal of Political Economy*, 82(6): 1063-1093.

Bobonis G. J. and Finan F. (2009), "Neighborhood Peer Effects in Secondary School Enrollment Decisions", *The Review of Economics and Statistics*, 91(4):695-716.

Borelli S. (2009), "Social Aspects of Drug Use in Djibouti: The Case of the Leaf of Allah", *Journal of African Economies*, 18(4): 555-591.

Bureau of Agricultural Economics (1976), "Farm Production in Japan. Determinants, Performance and Prospects", *Occasional Paper* 35, Canberra.

Chaudhary M., Khan M. and Naqvi K. (1998), "Estimates of Farm Output Supply and Input Demand Elasticities: The Translog Profit Function Approach", *The Pakistan Development Review*, 37(4):1031-1050.

Coase R.H. (1960), "The Problem of Social Cost", *Journal of Law and Economics*, 3:1-44.

Conley T. and Udry C. (2001), "Social Learning through Networks: The Adoption on New Agricultural Technologies in Ghana", *American Journal of Agricultural Economics*, 83(3):668-673.

Conley T. and Udry C. (2008), "Learning About a New Technology: Pineapple in Ghana", IDEAS, http://ideas.repec.org/a/fip/fedfpr/y2005x27.html.

Debertin, D. (1986), *Agricultural Production Economics*, New York, McMillan Publishing Company.

DeGiorgi G., Pellizzari M. and Redaelli S. (2009), "Be as Careful of the Company You Keep as of the Books You Read: Peer Effects in Education and on the Labor Market", *NBER Working Paper Series*, Working Paper 14948.

Demsetz H. (1967), "Towards a Theory of Property Rights", *American Economic Review, Papers and Proceedings*, 57(2):347-359.

Eisenkopf G. (2010), "Peer Effects, Motivation, and Learning", *Economics of Education Review*, 29:364-374.

Ekbom A. and Sterner T. (2008), "Production Function Analysis of Soil Properties and Soil Conservation Investments in Tropical Agriculture", *Environment for Development*, Discussion Paper Series 08-20.

Ellison G. and Fudenberg D. (1995), "Rules of Thumb of Social Learning", *Quarterly Journal of Economics*, 110:93-125.

Farquharson R. J. (2006), "Production Response and Input Demand in Decision Making: Nitrogen Fertilizer and Wheat growers", Australasia Agribusiness Review 14(5).

Feder G., Just R.E. and Zilberman D. (1985), "Adoption of Agricultural Innovations in Developing Countries: A Survey", *Economic Development and Cultural Change*, 33(January):255-298.

Fenske J. (2010), "Land Tenure and Investment Incentives: Evidence from West Africa", *Journal of Development Economics*, (forthcoming).

Fletcher J. (2010), "Social Interactions in Smoking: Evidence using Multiple Student Cohorts, Instrumental Variables, and School Fixed Effects", *Health Economics*, 19(April):466-484.

Foster A.D. and Rosenzweig M.R. (1995), "Learning by Doing and Learning form Others: Human Capital and Technical Change in Agriculture", *Journal of Political Economy*, 103(6):1176-1209.

French M.T. and Popovici I. (2009), "That Instrument is Lousy! In Search of Agreement when Using Instrumental Variables Estimation in Substance Use Research", *Health Economics*, www.interscience.wiley.com

Fulginiti L. E. and Perrin R. K. (1998), "Agricultural productivity in developing countries", University of Nebraska Faculty Publications, Agricultural Economics.

Gaviria A. and Raphael S. (2001), "School-based Peer Effects and Juvenile Behavior", *The Review of Economics and Statistics*, 83(2):257-268.

Goldstein M. and Udry C. (2008), "The Profits of Power: Land Rights and Agricultural Investments in Ghana", *Journal of Political Economy*, 116(6):981-1022.

Greene W.H. (1997), *Econometric Analysis*, Prentice-Hall Inc., New Delhi.

Halliday T.J. and Kwak S. (2007), "Bad Apples, Goody Two Shoes and Average Joes: The Role of Peer Group Definitions in Estimation of Peer Groups", *Journal of Economic Literature*, I: 12-120.

Hartmann W.R., Manchanda P., Nair H., Bothner M., Dodds P., Godes D. and Hosanagar K. (2008), "Modeling Social Interactions: Identification, Empirical Methods and Policy Implications", *Market Lett* 19:287-304.

Hayami Y. (1969), "Resource Endowments and Technological Change in Agriculture: United States and Japanese Experiences in International Perspectives", *American Journal of Agricultural Economics*, 51(5):1293-1303.

Hayami Y. and Ruttan V.W., (1970), "Factor Prices and Technical Change in Agricultural Development: The United States and Japan, 1880-1960", *Journal of Political Economy*, 78(5):1115-1141.

Heyer J., Maitha J.K. and Senga W.M., (Eds) (1976), *Agricultural Development in Kenya. An Economic Assessment*, Oxford University Press, Nairobi.

Heyer J. and Waweru J. (1976), "The Development of Small Farm Areas" in Heyer J., Maitha J.K. and Senga W.M., (eds), *Agricultural Development in Kenya. An Economic Assessment*, Oxford University Press, Nairobi.

Hogset H. and Barret C. (2008), "Social Learning, Social Influence and Projection Bias: A Caution on Inferences Based on Proxy-reporting of Peer Behavior", Research Paper.

Huesch M. D. and Sakakibara M. (2009), "Forgetting the Learning Curve for a Moment: How Much Performance is Unrelated to Own Experience?", *Health Economics*, 18: 855–862

Jansen H., Pender J., Damon A. and Schipper R. (2006), "Rural Development Policies and Sustainable Land Use in the Hillside Areas of Honduras. A Quantitative Livelihoods Approach", International Food Policy Research Institute Research Report, 147.

Jha D., Hojjati B. (1993), "Fertilizer Use on Smallholder Farms in Eastern Province, Zambia", Research Report 94, IFPRI, Washington.

Kabubo-Mariara J. (2007), "Land Conservation and Tenure Security in Kenya: Boserup's Hypothesis Revisited", *Ecological Economics*, 64:25-35.

Kabubo-Mariara J., Mwabu D. K. and Ndenge G. (2009), "Analyzing the Correlates of Poverty in Kenya: An Institutional Approach", *African Journal of Economic Policy*, 16(1):1-35.

Kabubo-Mariara J. (2010), *Agricultural Productivity and Environmental Conservation in Kenya. Implications for Poverty Reduction*, Lambert, Berlin.

Kabubo-Mariara J., Linderhof V., Kruseman G., Atieno R. and Mwabu G. (2010), "Poverty-Environmental Links: The Impact of Soil and Water Conservation and Tenure Security on Household Welfare in Kenya", *Journal of Development and Agricultural Economics*, 2(1):041-053.

Kaldor N. (1934), "A Classificatory Note on the Determination of Equilibrium", *Review of Economic Studies*, 1:133-135.

Katleen B. and Dercon S. (2007), "Social Interactions in Growing Bananas: Evidence from a Tanzanian Village", CSAE WPS/2007-05.

Kelly V. A. (2005), "Fertilizer Demand in Sub-Saharan Africa: Realizing the Potential", Policy Synthesis for Cooperating USAID Offices and Country Missions, No.77.

Kimenyi M.S., Mwabu G. and Manda D.K. (2006), "Human Capital Externalities and Private Returns to Education in Kenya", *Eastern Economic Journal*, 32(3):1-21.

Kohler H., Behrman J.R. and Watkins S.C. (2001), "The Density of Social Networks and Fertility Decisions: Evidence from South Nyanza District, Kenya". *Demography*, 38(1):43-58.

Lalive R. and Cattaneo A. (2009), "Social Interactions and Schooling Decisions", *The Review of Economics and Statistics*, 91(3): 457-477.

Lamb G.R. (1972), "Peasants, Capitalists and Agricultural Development in Kenya", Conference Paper, Nairobi.

Levin J. (undated), "Poverty Impact of Rising Maize Prices in Kenya", Department of Economics, Orebro University.

Libecap G. and Hansen Z. (2002), "Small Farms, Externalities and the Dust Bowl of the 1930s", University of Arizona and University of Washington, htt://www.isnie.org/ISNIE02/Papers02/libecap.pdf

Lipton M. (2005), "The Family Farm in a Globalizing World. The Role of Crop Science in Alleviating Poverty", IFPRI Discussion Paper, 40 Washington D.C.

Lofgren K. (2000), "Markets and Externalities" in Folmer H. and Gabel H.L. (eds) (2000), *Principles of Environmentai and Resource Economics. A Guide to Students and Decision-makers*, Edward Elgar, Cheltenham.

Manski, C. (1993), "Identification of Endogenous Social Effects: The Reflection Problem," *Review of Economic Studies*, 60(3):531-542.

__________ (2000), "Economic Analysis of Social Interactions", *Journal of Economic Perspectives* 14(3):115-136.

McCloskey D.N. and Ziliak S.T. (1996), "The Standard Error of Regressions", *Journal of Economic Literature*, 34(March):97-114.

Meade J. (1952), "External Economies and Diseconomies in a Competitive Situation", *Economic Journal*, 62:54-67.

Munshi K. (2004), "Social Learning in a Heterogeneous Population: Technology Diffusion in the Indian Green Revolution", *Journal of Development Economics*, 73(2):185-213.

Mwabu G., Masai W., Gesami R., Kirimi J., Ndeng'e G., Kiriti T., Munene F., Chemengich M. and Mariara J. (2000), "Poverty in Kenya: Profiles and Determinants", Report of a Collaborative Research Between University of Nairobi and Ministry of Planning entitled, "Poverty in Kenya: Measurement, Identification and Profiles", Nairobi.

Mwabu G., Kimenyi M.S., Kimalu P., Nafula N. and Manda D.K. (2002), "Predicting Household Poverty: A Methodological Note with a Kenyan Example", KIPPRA Discussion Paper Series No.12, Nairobi.

Mwabu G. (2005), "Quantitative Poverty Analysis", in Odhiambo W., Omiti J.M. and Muthaka D.I. (eds), *Quantitative and Qualitative Methods for Poverty Analysis*, KIPPRA, Nairobi.

Mwabu G., Mwangi W. and Nyangito H. (2008), "Does Adoption of Improved Maize Varieties Reduce Poverty?" KIPPRA Discussion Paper Series No.71, Nairobi.

Nafula N., Onsomu E. N., Mwabu G. and Muiruri S. (2005), "Review of Policy Options for Poverty Reduction in Kenya", KIPPRA Discussion Paper Series No. 49, Nairobi.

Nagayets O. (2005), "Small Farms: Current Status and Key Trends", *Information Brief*, Wye College.

Nerlove M. (1958), "Adaptive Expectations and Cobweb Phenomena", *Quarterly Journal of Economics*, 1(:227-240.

Nicholson W. (1985), *Microeconomic Theory. Basic Principles and Extensions*, The Dryden Press, Chicago.

Nyangena W. and Kohlin G. (2008), "Estimating Returns to Water and Soil Conservation Investments. An Application to Crop Yield in Kenya", *Environment for Development* Discussion Paper 08-32.

Ogundari K. (2008), "Resource-Productivity, Allocative Efficiency and Determinants of Technical Efficiency of Rainfed Rice Farmers: A Guide for Food Security Policy in Nigeria", *Journal of Sustainable Development in Agriculture and Environment*, 3(2):20-33.

Pigou A.C. (1946), *The Economics of Welfare*, Macmillan, London.

Pitt M.M. (1983), "Farm-Level Fertilizer Demand in Java: A Meta-Production Function Approach", *American Journal of Agricultural Economics*, 65(3):502-8.

Randrianarisoa T. C. and Minten B. (2001), "Agricultural Production, Agricultural Land and Rural Poverty in Madagascar", USAID-funded Research Paper, Madagascar.

Republic of Kenya (1994), "Kenya Forest Master Plan", Ministry of Environment and Natural Resources, Nairobi.

______________ (1997), "Nyeri District Development Plan, 1997-2001", Government Printers, Nairobi.

______________ (2002), "Nyeri District Development Plan 2002-08", Government Printers, Nairobi.

______________ (2004a), "Investment Programme for the Economic Recovery Strategy for Wealth and Employment Creation, 2003-2007", Ministry of Planning and National Development, Nairobi.

______________ (2004b), "Strategy for Revitalizing Agriculture 2004-2014", Ministry of Agriculture and Ministry of Livestock and Fisheries Development, Mimeo.

______________ (2006) Farm Management Handbook of Kenya, Volume II, Ministry of Agriculture, Nairobi. (Mimeo)

_______________ (2007a), Kenya National Bureau of Statistics, "Basic Report on Well-Being in Kenya Based on Kenya Integrated Household Budget Survey-2005/06" (Mimeo), The Regal Press Limited, Nairobi.

____________ (2007b), "Draft Land Policy", Government Printers, Nairobi.

____________ (2007c) "Kenya Vision 2030", Government Printers, Nairobi.

____________ (2009), "Economic Survey", Government Printers, Nairobi.

____________ (2010), "Economic Survey", Government Printers, Nairobi.

Rosset P. (2000) "Small Farms are more Efficient and Sustainable", interview with *Multinational Monitor*, July/August, 21 no. 788.

Schultz T. W. (1963), *The Economic Value of Education*, Columbia University Press, New York.

Senga W.M. (1976), "Kenya's Agricultural Sector" in Heyer J., Maitha J.K. and Senga W.M., (eds), *Agricultural Development in Kenya. An Economic Assessment*, Oxford University Press, Nairobi.

Sindhu S. and Baanante A. (1981), "Estimating Farm-level demand and Wheat Supply in the Indian Punjab using a Translog Profit Function", *American Journal of Agricultural Economics*, 63(2):237-246.

Singh I., Squirre L. and Strauss J. (1986), *Agricultural Household Models: Extensions, Applications and Policy*, The John Hopkins University Press, Baltimore.

Silberberg E. (1978), *The Structure of Economics. A Mathematical Analysis*, McGraw-Hill, New York.

Spencer D., (2001), "Will they Survive? Prospects for Small Farmers in Sub-Saharan Africa", IFPRI Discussion Paper, September, Bonn.

StataCorp (1990), *Data Analysis and Statistical Software: Release 10.0*, Stata Corporation, Texas.

Terza J. V., Basu A. and Rathouz P. J. (2007), "Two-stage Residual Inclusion Estimation: Addressing Endogeneity in Health Econometric Modeling", *Journal of Health Economics*, 27:531–543.

Thori L. J. and Mehlum H. (2010), "With or Without U? The Appropriate Test for a U-Shaped Relationship", *Oxford Bulletin of Economics and Statistics*, 72(1):109-119.

Udry C. and Anagol S. (2006), "The Return to Capital in Ghana", Yale University, Economic Growth Center Discussion Paper No. 932.

Varian H. (1984), *Intermediate Microeconomics. A Modern Approach*, W.W. Norton, New York.

_________ (1992), *Microeconomic Analysis* (3rd ed.), W.W. Norton, New York.

Yamane, T. (1967), *Statistics. An Introductory Analysis*, 2nd Ed., Harper and Row, New York.

Yao S. (1996), "The Determinants of Cereal Crop Productivity of the Peasant Farm Sector in Ethiopia, 1981-87", *Journal of International Development*, 8(1):69-82.

Yeung P. and Roe T., (1971), "Induced Innovation: A CES-Type Meta-Production Function", University of Minnesota, Institute of Agriculture, Staff Paper P71-27.

Yotopoulos P. A. (1972), "Profit, Supply and Factor Demand Function", *American Journal of Agricultural Economics*, 54:11-18.

Yotopoulos P. A., Lau L. J. and Lin W. (1976), "Micro-economic Output Supply and Factor Demand Functions in the Agriculture of the Province of Taiwan", *American Journal of Agricultural Economics*, 58:333-40.

APPENDIX 1 VARIABLE DEFINITIONS, SAMPLE STATISTICS AND CHARACTERISTICS

Table A1-1 Variables and their Measurement

Variables	Definition	Units of Measurement
Dependent variables		
Log crop output	Log of annual household crop output during survey year	Log of kilograms
Log livestock output	Log of annual household output of milk and eggs during survey year	Log of kilograms
Fertilizer	Amount of inorganic fertilizer used by a household during survey year	Kilograms
Animal feeds	Amount of animal feeds used by a household during survey year	Kilograms
Explanatory variables		
Capital	Household farm equipments	Principal Component Analysis index of farm equipments
Labor	Family and hired labor used by a household during survey year	Person-days. 1 person-day equals 8 day-time hours
Land	Area cultivated or used for livestock activity	Acres
Log wage	Log of annual household payments to hired labor during survey year	Kenya shillings (Ksh). Ksh 82=1USD currently
Household Characteristics		
Age of household head	Years of household head	Number
Education of household head	Education level attained by household head	Categorical (0=none 1=primary 2=secondary 3=post-secondary)

Neighborhood Factors		
Average fertilizer used by neighbors within a village	Annual mean of fertilizer used by farmers in a village excluding the focus farmer during survey year	Kilograms
Average animal feeds used by neighbors within a village	Annual mean of animal feeds used by farmers in a village excluding the focus farmer during survey year	Kilograms
Average conservation efforts by neighbors within a village	Mean of dummies assigned to whether a farmer in a village engages in conservation efforts, excluding the focus farmer	Dummy average (1=yes, 0= no)
Average grass stripping efforts by neighbors within a village	Mean of dummies assigned to grass stripping efforts in a village, excluding the focus farmer	Dummy average (1=yes, 0=no)
Average soil ridging efforts by neighbors within a village	Mean of dummies assigned to soil ridging efforts in a village excluding the focus farmer	Dummy average (1=yes, 0=no)
Property rights bundles relating to land utilized by neighbors within a village	Mean of dummies assigned to property rights over lands utilized by farmers in a village, excluding the focus farmer	Mean of these categories (1=rent with permission 2=rent without permission 3=bequeath with permission 4=bequeath without permission 5=sell with permission 6=sell without permission)
Instrumental variables		
Distance to the nearest cooperative society	Distance from the household to the nearest cooperative society	Kilometers
Log distance to the nearest market	Log of distance from the household to the nearest market center	Log of kilometers
Distance to market*wage	Interaction term of distance to the nearest market center and annual wage paid to workers.	

Table A1-2 Sample Statistics for all Variables Included in Regressions

Variables	Mean	Std. Dev.	Min.	Max.
Log crop output	9.2	0.64	4.28	12
Log livestock output	2.6	3.42	0	8.9
Capital*10^{-3}	0. 2	1.86	-2.76	22.07
Labor	216.7	183.31	8	1002
Land	2.6	3.14	.12	23
Fertilizer	45.9	72.57	0	600
Animal Feeds	11785.2	15979.64	0	94900
Age of household head	51.3	13.90	16	90
Education of household head	1.3	0.78	0	4
Average fertilizer usage by neighbors within a cluster	46.0	27.45	2.31	130.06
Average animal feeds usage by neighbors within a cluster	14043.2	11217.02	1273.25	57823.63
Average conservation efforts by neighbors within a village	0.593	0.226	0	1
Average grass stripping efforts by neighbors within a village	0.287	0.157	0	0.5
Average soil ridging efforts by neighbors within a village	0.185	0.145	0	0.5
Average property rights to land utilized by neighbors within a village	2.955	0.537	1.438	4.2
Distance to the nearest cooperative	5.4	7.62	.01	60
Distance to the nearest market	3.0	2.44	.01	16
Wage	62.0	73.62	0	250
Log wage	2.19	2.446	0	5.525
Sample size	423			

Table A1-3 Sample Clusters and their Characteristics

Cluster name	Cluster no.	Sub-location	Location	Division
Kangiri	0091	Amboni	Mweiga	Kieni West
Ngano-ini	0092	Embaringo	Gatarakwa	Kieni West
Manyatta	0093	Kamburaini	Naromoru	Kieni East
Ragati/Guara	0094	Gathiuru	Gakawa	Kieni East
Mbogoini	0095	Ndathi	Kabaru	Kieni East
Gachiura	0096	Karindundu	Konyu	Mathira
Unjiru	0097	Ichuga	Konyu	Mathira
Umbui	0098	Kiaguthu	Iria-ini	Mathira
Kiamucheru	0099	Gaikuyu	Magutu	Mathira
Giagachucha	0100	Ruturu	Ruguru	Mathira
Rathithi	0101	Gachuiro	Kirimukuyu	Mathira
Gaithumbi	0102	Njiru-ini	Gakindu	Mukuruwe-ini
Gitura	0103	Kiharo	Githi	Mukuruwe-ini
Gatongu/ Karigu-ini	0104	Karaba	Thanu	Mukuruwe-ini
Gitumbi	0105	Mutundu	Rutune	Mukuruwe-ini
Gikira 'A'&'B'	0106	Gichiche	Chinga	Othaya
Mugumo-ini	0107	Kairuthi	Iria-ini	Othaya
Nduyi/ Gachami	0108	Rukira	Mumwe	Othaya
Nyakirutu	0109	Huhoini	Gaaki	Tetu
Karigu-ini	0110	Karangia	Thegenge	Tetu
Itare	0111	Kanjora	Muhoya	Tetu
Gathugu/ Chiara-ini	0112	Karia	Mukaro	Municipality
Maharu	0113	Mathari	Mukaro	Municipality
Kanuna 'A'	0114	Kirichu	Kiganjo	Municipality
Thunguma	1400	Mukaro	Thunguma	Municipality

APPENDIX 2 PEER EFFECTS, FARM INPUTS AND OUTPUTS

Table A2-1 Parameter Estimates of Crop Production Controlling for Peer Effects (t-statistics in parentheses)

Variables	*Capital*		*Labor*		*Land*	
	First Stage Regression: Fertilizer Demand in Log Kg.	Second Stage Regression: Crop Output in Log Kg.	First Stage Regression: Fertilizer Demand in Log Kg.	Second Stage Regression: Crop Output in Log Kg.	First Stage Regression: Fertilizer Demand in Log Kg.	Second Stage Regression: Crop Output in Log Kg.
Factor Inputs						
Log Fertilizer	-	.096(0.97)	-	.108(1.12)	-	.094(0.90)
Log Capital index	.501(3.65)	.067(1.11)	-	-	-	-
Log Labor	-	-	.253(2.71)	.042(1.28)	-	-
Log Land	-	-	-	-	0.096 (1.01)	.022 (0.83)
Farmer and Neighborhood Characteristics						
Log Age	-.331(1.03)	.173(1.92)	-.346(1.06)	.169(1.85)	-.283(0.85)	.171(1.88)
Education level	.139 (1.18)	.011 (0.31)	.190 (1.64)	.014 (0.37)	.207 (1.77)	.019 (0.48)
Log Mean Crop Output of neighbors	-.141 (0.78)	.982 (19.82)	-.125 (0.69)	.985 (19.80)	-.132 (0.71)	.980 (19.57)
Log Mean Fertilizer used by neighbors	.727 (6.68)	-.088 (1.11)	.708 (6.47)	-.098 (1.29)	.670 (6.21)	-.088 (1.09)
Exclusion Restrictions						
Distance to a cooperative society	-.065 (2.67)	-	-.068 (2.77)	-	-.061 (2.50)	-
Distance to a cooperative society squared	.001 (2.21)	-	.001 (2.32)	-	.001 (2.13)	-
Constant	2.138 (0.99)	-.587 (1.00)	1.260 (0.57)	-.742 (1.27)	2.278 (1.01)	-.516 (0.85)
R^2	0.142	0.491	0.130	0.476	0.117	0.490
F-statistic *p*-value	9.84 0.000	73.04 0.000	8.88 0.000	70.64 0.000	7.86 0.000	71.54 0.000
Root MSE	1.722	.459	1.734	.466	1.747	.459
Observations	423	423	423	423	423	423

Table A2-2 Parameter Estimates of Livestock Output Function Controlling for Peer Effects (*t*-statistics in parentheses)

Variables	*Capital*		*Labor*		*Land*	
	First Stage Regression: Demand for Animal Feeds in Kg.	Second Stage Regression: Livestock Output in Log Kg.	First Stage Regression: Demand for Animal Feeds in Kg.	Second Stage Regression: Livestock Output in Log Kg.	First Stage Regression: Demand for Animal Feeds in Kg	Second Stage Regression: Livestock Output in Log Kg.
Factor Inputs						
Animal Feeds $*10^{-3}$, kg	-	.030 (1.22)		.031(1.27)	-	.031 (1.21)
Log Capital index	7861.36 (3.84)	.859(2.62)	-	-	-	
Log Labor	-	-	3468.98 (2.46)	.615 (3.18)	-	-
Log Land	-	-	-	-	4059.664 (2.90)	.343 (1.64)
Farmer and Neighborhood Characteristics						
Log Age	4495.10 (0.93)	.522 (0.87)	4547.95 (0.92)	.386 (0.64)	3023.30 (0.60)	.444 (0.73)
Education, level	-2045.96 (1.16)	.134 (0.62)	-1141.64 (0.65)	.208 (0.99)	-1261.102 (0.72)	.231 (1.08)
Log Mean Livestock Output of neighbors	64.50 (0.08)	.417 (4.28)	206.52 (0.26)	.426 (4.38)	400.015 (0.50)	.451 (4.55)
Log Mean Animal Feeds used by neighbors	7801.94 (3.92)	.308 (0.92)	7537.65 (3.73)	.224 (0.68)	6808.625 (3.32)	.236 (0.72)
Exclusion Restrictions						
Distance to a cooperative society	-257.23 (0.70)	-	-286.71 (0.77)	-	-194.034 (0.52)	-
Distance to a cooperative society squared	23.30 (2.90)	-	24.27 (2.99)	-	22.014 (2.72)	-
Constant	-81801.73 (2.99)	-6.15 (1.49)	-91548.59 (3.32)	-7.28 (1.71)	-64768.51 (2.25)	-4.888 (1.21)
R^2	.156	0.165	0.138	0.167	0.1429	0.1491
F-statistic *p*-value	10.92 0.000	10.81 0.000	9.50 0.000	10.63 0.000	9.88 0.000	8.67 0.000
Root MSE	25833	3.143	26099	3.138	26026	3.172
Observations	423	423	423	423	423	423

APPENDIX 3 FIELD QUESTIONNAIRE

Questionnaire No_____________ Date administered_________________________________

Division_______________________ Location_________________________________

Sub-location_____________________Cluster name_________________________________

Cluster No._____________________Interviewer's Name _____________________________

Respondent's Name____

A: Household characteristics

No.	Name of household member A1	Sex *1= male* *0=female* A2	Relationship to household head *see codes* A3	Age *years* A4	Marital status *see codes* A5	Highest level of education attained *see codes* A6	Occupation *see codes* A7
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Codes and notes

A1: serial no. 1 is always household (h/h) head

A3: 1= husband; 2= wife; 3= son; 4= daughter; 5= other (specify)

A5: 1= single; 2= married monogamous; 3= married polygamous; 4= separated; 5= widow/widower; 6= other (specify)

A6: 0= none; 1= primary; 2= secondary; 3= post secondary; 4= other (specify)

A7: 0= none; 1= farmer; 2= general business; 3=casual labor; 4=employed; 5=student; 6=other (specify)

A8. Has the household head ever attended agricultural training? *Yes__(1) No__(2)*

A9. If Yes, specify where attended_______________,
name of course______________________duration___________________

A10. Has any other member of the family ever attended agricultural training? *Yes_ (1) No____(2)*

A11. If Yes, specify where attended_______________,
name of course______________________duration___________________

B: Land status

Land currently owned and farmed by household

plot code	How many acres of land do you have in this site	How did you acquire this land? *1=bought 2=gift 3=inherit 4= rent 5=allotted 6=other specify*	For how long have you had this land? *years*	In whose name is this land regist-ered? *see codes below*	How many acres of land do you have else-where?	How did you acquire land elsewhere? *1=bought 2=gift 3=inherit 4= rent 5=allotted 6=other specify*	For how long have you had land else-where? *years*	In whose name is elsewhere land regist-ered? *See codes below*
	B1	B2	B3	B4	B5	B6	B7	B8
1								
2								
3								
4								
5								

Expected land rights in own land

What rights does the hh hold over this land? *see codes*	Is there anyone else with a stake on this land e.g. shared ownership? *Yes=1 No=0*	If yes, who? *see codes*	Can this land be taken away from you? *Yes=1 No=0*	If yes, by who? *see codes*	If yes, how likely is such a take-over? *1=not likely 2=slight chance 3=highly likely*
B9	B10	B11	B12	B13	B14

B4, B8, B11, B13 codes: 1= head; 2= spouse; 3= father; 4= mother; 5= brother; 6= other relative (specify) ________; 7= landlord; 8= institution (specify) __________; 9= other (specify)

B9 codes: 1= sell without permission; 2= sell with permission from (specify) ________;

3= bequeath without permission; 4= bequeath with permission from (specify) _______; 5= rent out without permission; 6= rent with permission from (specify) ___________; other (specify)

Expected rights in land rented out or lent out –skip if hh has no such land

how many acres are: a)rent-ed? b) lent out?		How far is such land from home?		How was this land acqui-red? *1=bou-ght 2=gift 3=inhe-rited 4=other specify*		how many yrs have you had the plots?		What rights does the hh hold over such plots? *see codes*		Who is regist-red in those plots? *see codes*		Is there anyone else with a stake on such plots e.g. shared ownership? *Yes=1 No=0*	If yes, who? *see codes*	Can those plots be taken away from you? *Yes =1 No =0*	If yes, by who? *see co des in B4 abo-ve*	If yes, how likely is such a take-over? *1=not likely 2=slig-ht cha-nce 3=hig-hly likely*
B15		B16		B17		B18		B19		B20		B21	B22	B23	B24	B25
a	b	a	b	a	b	a	b	a	b	a	b					

B20 codes: 1=head; 2= spouse; 3= father; 4= mother; 5= brother; 6= other relative (specify) ________________; 7= landlord; 8= institution (specify) ______________; 9= other (specify)
B19 codes: 1= sell without permission; 2= sell with permission from (specify)_______;
3= bequeath without permission; 4= bequeath with permission from (specify)___________;
5= rent out without permission; 6= rent with permission from (specify)_______;
other (specify)_______

Expected land rights in rented or borrowed land

What rights does the hh hold over this land? *see codes*	What arrangement do you have with the landlord to use his/her land?	For how long will the arrangement hold?	Please indicate total money paid for use of this plot last 2 seasons *(Ksh)*	Please indicate amount of payment in kind for use of land *units?*
B26	B27	B28	B29	B30

B26 codes: 1= grow whatever I wish; 2= grow agreed crops only (specify which) _________;
3= bequeath without permission; 4= bequeath with permission from owner; 5= sub-let without permission; 6= sub-let with permission from owner; other (specify)
B27 codes: 1= paid rent of x (specify) __ yrs; 2= sharecropping; 3= free use; 4= other (specify)
B28 codes: 1= indefinite; 2= definite years ≥ 5; 3= definite years < 5

Economic Activities

C: Major crops produced in own land during last 12 months

	Crops grown by household (h/h) in own land C1	Area planted *Acres* C2	Mono cropped? *1= yes; 0= no* C3	Experience in years growing each crop? C4	Total crop output *specify Units* C5	Quant-ity of output set aside as seeds *specify units* C6	Output consumed within h/h *specify units* C7	Who in the h/h cares for each crop in C1? *See names in A1 above* C8
1	Maize							
2	Beans							
3	Irish potatoes							
4	Sweet potatoes							
5	Bananas							
6	Cassava							
7	Cabbages							
8	Kale/ Sukuma wiki							
9	Spinach							
10	Carrots							
11	Peas							
12	Tomatoes							
13	Millet							
14	Sorghum							
15	Wheat							
16	Coffee							
17	Tea							
18	Tobacco							
19	Flowers							
20	Other *(specify)*							

D Major crops grown on rented and forestlands (last 12 months) *–skip if no rented or forest plots;*

Crops grown by h/h	1=in rent-ed plots, 2=in forest land		Area planted each crop in acres		Mono cropped ? *1=yes* *0=no*		Output by crop from 1=rent-ed 2=forest plots *specify units*		No. of forest land plots aban-doned last 10 yrs	Appr-oxim-ate sizes of aban-don-ed plots	Crops that were grown in aband oned plots	Inputs that were used in Aban-doned plots	Cons-ervat-ion pract-ices of aban-don-ed plots?
	D2		D2		D4		D5						
D1	1	2	1	2	1	2	1	2	D6	D7	D8	D9	D10
Maize													
Beans													
Irish potato													
Sweet potato													
Banana													
Cabba-ge													
Cassa-va													
Kale													
Spin-ach													
Carrots													
Peas													
Tomato													
Millet													
Sorgh-um													
Wheat													
Coffee													
Tea													
Tobac-co													
Other *specify*													

D11. Please explain reasons for any difference in crops grown in own plots and rented/ forest plots if any. ____

E: Farm inputs used in the growing of crops in year 2006 and 2007

Inputs *specify type* E1	Source of input *1=bought 2=own 3=donated 4=other specify* E2	Quantity (Qty) used on own plots *specify units* E3		Qty used on rented plots *specify units* E4		Qty used on forest plots *specify units* E5		Price of each input *Ksh* E6	Constraints in sourcing inputs *0=none 1=high cost 2=unavailability 3=other specify* E7	Proposals to solve cited constraints *1=sellers reduce price 2=govt subsidy 3=other specify* E8	Who decides on sourcing and use of inputs in E1? *see A1* E9
		06	07	06	07	06	07				
Seeds											
e.g Maize 614											
Fertilizers											
eg DAP											
Urea											
Herbicides											
eg Roundup											
Fungicides											
eg Dithane											
Pesticides											
Manure											
Cow dung											
Sheep dung											
Poultry dung											
Others											
Water											
Extension service											

F: Constraints in crop production

Constraints in crop production F1	Is it a problem? *1=Yes & serious* *2=Yes sometimes* *3=no* F2	If F2=1, how is it a serious problem? F3	Suggest a solution to the problem F4
Labor			
Seeds			
Fertilizer			
Rainfall			
Extension service			
Pests			
Weeds			
Diseases *(specify)*			
Erosion			
Others *(specify)*			

G: Crop marketing

Output by type G1	Qty Sold to middlemen *units?* G2	Middlemen price per unit *Ksh* G3	Qty sold in market *units?* G4	Market Price per unit *Ksh* G5	Qty Sold to co-op *unit?* G6	Co-op. Price per unit *Ksh* G7	Qty sold to Board *units?* G8	Board price per unit *Ksh* G9	Qty Sold to others *units?* G10	Others price per unit *Ksh* G11	Who *(seeA1)* decides on marketing of each in G1? G12	Most preferred marketing channel for each crop? G13
Maize												
Beans												
Irish potatoes												
Sweet potatoes												
Bananas												
Cabbages												
Cassava												
Kales												
Spinach												
Carrots												
Peas												
Tomatoes												
Millet												
Sorghum												
Wheat												
Coffee												
Tea												
Tobacco												

G14. Please give reasons for your choice of a marketing channel________________

____

G15. For how many years have you sold your output to each channel?
Middlemen?______Open-market?_____Co-operative?_______ Board?_________
Other (specify)?_______________

H: Constraints in crop marketing

Constraints in crop marketing H1	Is it a problem? *1=Yes & serious* *2=Yes sometimes* *3=no* H2	If H2=1, how is it a serious problem? H3	Suggest solutions to the problem H4
Low prices			
Delayed payments			
Non-payment			
Low demand			
Lack of transport			
Expensive transport			
Poor roads			
Lack of credit			
Poor/lack of market information			

J: Livestock owned by household last 12 months

Animal by type J1	Method of rearing? *1=zero grazing* *2=open grazing* J2	No. owned by h/h last 12 months J3	No. Owned now J4	Who in the h/h is "owner" of each in J1? J5	Experience in years raising animals in J1 J6	Names of market outlets J7	Expected market price per unit *Ksh* J8	Please specify "owner" decisions that affect J1? *1=sales* *2=slaughter* *3=feeding* *4=other specify* J9
Dairy cow								
Oxen								
Sheep								
Goat								
Chicken								
Duck								
Turkey								
Rabbit								
Pig								
Donkey								
Other *specify*								

K: Farm inputs into livestock output in year 2006 and 2007

Input by type K1	Qty used last 12 months specify units K2 06	07	Source of input see codes below K3	Years of using input K1? K4	Price of inputs used last 12 months Ksh K5	Who in the h/h decides on each input use? see A1 K6	Constraints in sourcing each input? *0=none 1=high cost 2=unavai-lable 3=other specify* K7	Proposals to solve each constraint *0=none 1=sellers reduce price 2=govt subsidy 3=other specify* K8
Napier								
Water								
Hay								
A.I. services								
Vet services								
Drugs								
Concent-rates								
Acaricides								
Labor *(person days)*								
Chaff-cutter services *(Ksh)*								
Extension visits *(no.)*								
Milking-machine services *(Ksh)*								
Transport Services *(Kshs)*								
Grazing pasture								

Codes for K3: 1= own plot; 2= rented plot; 3= forestland; 4= co-operative society; 5= government department; 6= private retailers; 7= neighborhood; 8= other (specify)

L: Constraints in livestock output

Type of constraint L1	Is the problem *1=always serious* *2=serious sometimes* L2	How serious is the problem? L3	Suggest solutions to the problem L4
Labor			
Feeds			
Pastures			
Water			
Veterinary service			
Extension service			
Animal breed			
Diseases *(specify)*			
Lack of credit			
Others *(specify)*			

M: Livestock output and marketing during last 12 months

Farm Output by type M1	Out-put last 12 mon-ths *units* M2	Total sold to mid-dle men *units* M3	Price per unit *Ksh* M4	Total sold to mar-ket *units* M5	Price per unit *Ksh* M6	Total Sold to co-op *units* M7	Price per Unit *Ksh* M8	Total sold to othe r *units* M9	Price per unit *Ksh* M10	Who owns sales of M1? M11	Who in A1 above deci-des on sales in M1? M12
Milk											
Hides/ skins											
Mutton											
Eggs											
Beef											
Chick-en											
Wool											
Pork											
Wax											
Chevon											
Other *(specify)*											

N: Constraints in marketing of livestock products

Constraint N1	Is it a problem? *1=Yes & serious* *2=Yes sometimes* N2	How is it a serious problem? N3	Suggest solutions to the problem N4
Middlemen			
Government regulations			
Quality/ standards			
Competition from imports			
Credit			
Transport			
Poor/lack of market information			
Others *(specify)*			

P: Farm capital endowments

Capital equipment by type P1	Quantity currently owned P2	Approximate value of each *Ksh* P4	Constraints in procurement *0=none* *1=high cost* *2=unavailabe* *3=other (specify)* P5	Proposals to solve constraints P6	Who decides how items in P1 are acquired and/or used? P7
Panga					
Wheel-barrow					
Spray pump					
Fork jembe					
Jembe					
Axe					
Animal-drawn cart					
Bicycle					
Plough					
Milk cans					
Milking machine					
Others *(specify)*					

Q: Other household assets

Asset Q1	Does the HH have/own/use each? *Yes=1* *No=0* Q2	Year acquired Q3	Approximate current value *Ksh* Q4	Who decides on the acquisition and/or use of items in Q1? *see table A column A1* Q5
Electricity				
Radio				
Telephone				
Television				
Motorbike				
Motor vehicle				

R: Household time allocated to farm activities last Season *(probe for all seasons)*

Activity	Family labor days R2		Hired labor days R3	
R.1	Men *R2a*	Women *R2b*	Men *R3a*	Women R3b
Livestock management				
Farming activities				
Planting crops				
Weeding				
Harvesting				
Sorting and drying				
Marketing				
Education Meetings				
Co-op meetings				
Other groups meetings				
Forest work				
Erosion control				
Other *(specify)*				

S: Infrastructural facilities serving household

Facility nearest home S1	Name of facility S2	Distance from home *(kms)* S2	Impact on economic activity S3
Prim. school			
High school			
Polytechnic			
Market center			
Tarmac road			
All-weather road			
Dispensary			
Church			
Cattle dip			
College			
Co-op			
Other *(specify)*			

T: Village institutions

T1. Is your household a member of a village grouping? *Yes=1*____, *No=2*____

If yes, please provide the following information.

	Group type *see codes* T2	Type of membership *see codes* T3	Who in your household is/are members of the group? *see table A column A1* T4	Indicate primary purpose/ benefit of group T5	Monthly fee paid by household T6	Annual proceeds from group last 12 months T7
1						
2						
3						
4						

T2 Codes: *1= Merry go round; 2= Benevolent; 3= Income generation; 4= Labor group; 5= church; 6= other (specify)*
T3 Codes: *1= Men only; 2= Women only; 3= Both men & women; 4= Elders; 5 = Other (specify)*

T8. If no, why?

U: Soil conservation practices

Do you Pract-ice soil conser-vation? *Yes=1* *No=0* U1	If yes, what conser-vation do you practice? *see codes* U2	Structure of conser-vation? *1=perma-nent* *2=during long rains only* *3=occa-sional as per need* U3	When (year) was the struc-tures done? U4	Qty of conser-vation (if pos-sible) U5	Cost of Pract-ice in Ksh? U6	Do you practice same conser-vation in rented/ forest plots? *Yes=1* *No=0* U7	If no, why ? U8	Common Conserv-ation practice in locality U9

U2 Codes: *1= grass strips, 2= mulching, 3= ridging, 4= fallowing, 5= stone terracing, 6= soil terracing, 7= terracing with hedges, 8= terracing with grass strips, 9= tree planting 10= other (specify)*