Multi-output technical efficiency of production of western Kenya agricultural households: an econometric approach

Tom Owiyo

C50/7074/2006

A Research Paper Submitted to the School of Economics, in Partial Fulfillment of the Requirements for the Award of Master of Arts (Economic Policy and Management) of the University of Nairobi.

Supervisors:

Dr. Wilfred Nyangena

Dr. Seth O. Gor

Declaration

This research paper is my original work and has not been presented for a degree award in any other University.

12.08.2011

Tom Owiyo

Date

This research paper has been submitted for examination with our approval as University Supervisors.

30-8-2011

Dr. Wilfred Nyangena

Date

16-09-2011

Dr. Seth O. Gor

Date

Table of Contents

CHAPTER ONE

1. INTRODUCTION

1. Background

Agriculture can work in concert with other sectors to produce faster growth, reduce poverty, and sustain the environment (World Bank, 2008). In many countries in Sub-Saharan Africa (SSA), the role of agriculture can be enhanced as a lead sector for overall growth and development and as an effective instrument for poverty reduction and improvement of livelihoods (Barrett, et. al., 2005; World Bank, 2008). According the World Bank (2008), two main reasons support the view that agriculture can be a leading sector of a growth strategy for the largely agriculture-based economies in SSA. First, in many of these countries, food remains imperfectly tradable because of the high transaction costs and the prevalence of staple foods that are only partially traded, such as roots and tubers and local cereals. This implies that the countries largely rely on own agricultural production for food security. In addition, agricultural productivity determines the price of food, which in turn determines wage costs and competitiveness of the tradable sectors. Second, comparative advantage in the tradable subsectors will still lie in primary activities (agriculture and mining) and agroprocessing for many years due to resource endowments and the difficult investment climate for manufacturing. Development interventions therefore need to target the agricultural sector even as economies diversify to exploit potential in other sectors. In many of the SSA countries however, agriculture is still largely smallholder-based, driven by rural households as a livelihood source and as an economic activity.

Productivity of agricultural households in rural areas has acquired a central focus in the recent past, particularly in the context of poverty reduction and improvement of livelihoods of communities in the rural areas. Many developing countries have recently developed and implemented Poverty Reduction Strategy Papers (PRSP) as blueprints to guide efforts to spur growth and reduce poverty, reduce income inequality and as part of broader economic development agenda. Targeting poverty in rural areas imply addressing the challenges that confront the agricultural sector, particularly the smallholder crop and livestock production, the predominant economic activity of majority of rural households. World Bank (2008) estimates that in Sub-Saharan Africa (SSA), 86% of rural households derive their livelihood from agriculture. To these households, agriculture is a source of livelihood, an economic activity and a provider of environmental services.

Although smallholder agricultural production systems are closely integrated with the national economies, farm households are generally price takers and are hardly prepared for the competition that market liberalization has exposed them to (World Bank, 2008), let alone the distortions in the market. Evidence shows that majority of smalholder producers in SSA operate at suboptimal production levels due to many challenges that they face. In this study, an assessment will be made to determine the levels of efficiency of farm households with a view towards identifying the critical household attributes that influence production efficiency.

2. The Production Systems and Analysis

The economic efficiency of households has been widely researched with majority of studies focusing on the efficiency of farm activities as opposed to household level activities (Chavas *et. al.*, 2005). To a large extent, such analysis often ignore off-farm activities in spite the substantial evidence that demonstrate the significant contributions that off-farm activities have made to the welfare of agricultural households. In the context of Africa, Reardon *et. al.* (1992) demonstrated the significance of off-farm earnings in the African rural households. Furthermore, considerable income diversification between farm and off farm activities in Africa may be seen as a response to the poorly functioning capital markets, with the cash from non-farm earnings helping to stimulate agricultural productivity through farm investments (Haggblade *et. al.*, 1989; Hazel and Hojjati, 1995). As Reardon *et. al.* (1997) noted, very poor households often lack access to non-farm income as a result of which any imperfections in the labor market can contribute both to inefficient labor allocation in rural households and to more unequal income distribution. This necessitates the inclusion of off-farm income in efficiency analysis particularly for poor African rural households where incomes are low and small inefficiencies may have large impacts in income and welfare (Chavas *et. al.*, 2005).

Singh *et. al.* (1986) have shown that under efficiency, competitive markets for commodities and labor, and perfect substitution between family and wage labor, farm decisions are separable from other household decisions. However, in SSA, the commodity markets, farmer support institutions and related agricultural policies are largely dysfunctional. As such, family wage labour and household decisions are inseparable. As Chavas *et. al.* (2005) pointed out, several reasons exist why a narrow focus on farm level analysis may be inappropriate. First, the assumption of separability between farm and household activities does not hold. It is an approach that neglects possible inefficiency in the allocation of labor between farm and off-farm activities, particularly for those households who rely significantly on off-farm income. Secondly, the technology supporting off-farm activities may be joint with farm activities. It may be the case that new skills acquired by the households while engaged in off farm activities are applied on farm to improve production and general farm management. Finally, where credit rationing exists, access to off-farm income may affect the use of farm inputs and thus affect allocative efficiency. This implies that market imperfections can lead to quite significant interactions between farm and off-farm activities in the analysis of efficiency. In order to capture these interactions, Chavas *et. al.* (2005) proposes an approach to economic analysis that captures the household activities and accounts for the efficiency of both farm and off farm activities.

3. Statement of the Problem

The agricultural sector is of great importance to Kenya's economy. The sector contributes significantly to the GDP, foreign exchange earnings and employment amongst other benefits. Agriculture in Kenya employs nearly 80% of the rural population and ensures a large share of the country's food security. In 2006, agriculture contributed about 24% of the GDP and 60% in the foreign export earnings (GOK, Economic Review of the Agricultural Sector, 2007). Households in most rural parts in developing countries produce at sub-optimal levels due to several factors that include poor access to external resources, high levels of poverty, low managerial ability and the prevailing policy environment. Many governments in Sub Saharan Africa have initiated specific programs aimed at supporting the rural communities increase productivity and improve their livelihoods. However, such interventions are commonly implemented without prerequisite assessment and understanding of the critical factors that limit the realization of the production potential and improvement of livelihoods by rural communities. Therefore, the success of these interventions requires a clear understanding of the prevailing level of production efficiency and factors that influence it at the household level. Such information would enable policy making process to target critical factors that impede production efficiency and with the use of well designed panel data, allow for multi-temporal monitoring of progress. This study will use data collected by the The Government of Kenya and the World Bank for an eight year rural development program in western Kenya.

4. Justification for the study

Policy environment may enhance or curtail the growth in the agricultural sector – as a livelihood and as economic activity. Understanding the prevailing economic, social and political environment is essential to stimulate debate on appropriate interventions to undertake to address productivity constraints. According to Ricker-Gilbert *et. al.* (2010), inappropriate policies often result from inadequate empirical economic evidence and adverse political considerations. Stakeholders involved in policy dialog often lack empirical evidence on local level policy interventions that are necessary to improve productivity of rural households in the agricultural sector. This study aims to determine the factors that influence the technical efficiency of household production in western Kenya to stimulate debate among stakeholders: rural farmers, policy makers, agricultural private sectors operators and civil society in the region and contribute to the design and the development of the interventions that address production constraints.

5. Overall Objective

The objective of this study is to provide empirical evidence on the levels of technical efficiency in household production in western Kenya and identify how it can be improved through rural development interventions.

6. Specific Objectives

The specific objectives are:

i. Estimate the technical efficiency of farm household production of rural agricultural households in western Kenya and determine its variability within the project intervention area.
ii. Identify the factors that influence the technical efficiency of household productions in the study area.
iii. Based on (ii) above, identify appropriate development policy interventions to increase the levels of technical efficiency of production of the farm households in western Kenya.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Production efficiency models

Many methods have been used in the analysis of efficiency. The concept of efficient frontier has been widely applied in production efficiency analysis mainly due to its consistency with the notion of maximization of profit and minimization of cost. This is evidenced by the proliferation of studies on frontier models over the last two decades (Battese, 1992; Bravo-Ureta and Pinheiro, 1993 and Gorton and Davidora, 2004). Production efficiency analysis dates back to early studies by Debrue (1951) and Koopman (1951). The original frontier function introduced by Farrel (1957) uses the efficient unit isoquant to measure economic efficiency and to decompose this measure into technical efficiency (TE) and allocative efficiency (AE). Frontier models can be classified into two basic categories: parametric and non-parametric, with the parametric group further separated into stochastic and deterministic models. While the stochastic models allows for statistic variation, the deterministic models assume that any deviation from the frontier is due to inefficiency in the production system. As such, the fundamental problem with the deterministic frontier models is that any measurement error and any other source of variation in the dependent variable is embedded in the one-sided component making the resulting efficiency analysis sensitive to outliers (Greene 1993).

Econometric analysis of efficiency has been approached from primal and dual aspects, depending on the underlying behavioral assumptions (Bravo-Ureta *et.al.*, 2006). Although the primal approach has been more common in frontier estimation, Kumbhakar (2001) noted that the dual cost and in particular the profit function has received increased attention in recent times. Using panel data to estimate stochastic frontier analysis was observed to overcome some of the limitations present in cross sectional studies (Schmidt and Sickles, 1984).

Non-parametric models for technical efficiency, also known as data envelopment analysis (DEA) and were pioneered by Färe (1996) based on the mathematical programming techniques (Bravo-Ureta *et. al.* 2006). While DEA approaches do not require the functional form to be specified, their major drawback arising from their deterministic nature is that extreme observations have the potential of affecting the analysis. In addition, the resulting efficiency scores may be sensitive to the number of observations in the data (Ramanathan, 2003).

The application of parametric approach in efficiency analysis involves estimating the production function by specifying a parametric form of the function which is fitted to the observed data by minimizing some measure of their distance from the estimated function (Llewelyn *et.al.,* 1996). Extending the stochastic frontier approach to deal with the multi-output technologies has received much attention in the recent past, with the main approach being the use of stochastic distance functions. The main advantage of the distance function approach is twofold; it obviates the need for price information and the need for assuming separability between inputs and outputs, i.e., seperability between farm and non-farm activities (Kumbhakar *et. al.* 2003).

2.2 Efficiency as a farm's economic performance measure

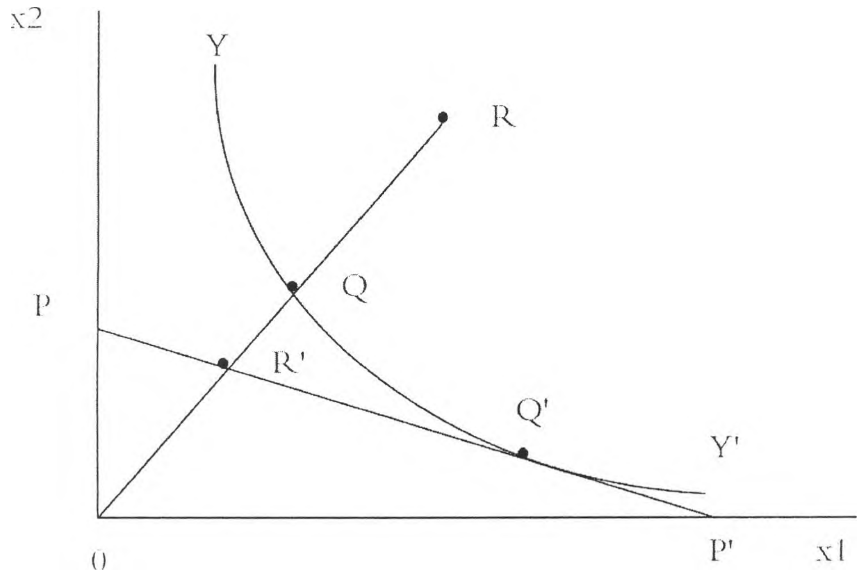
Whereas the economic performance of a farm can be measured using the traditional financial ratios analysis or cost-revenue analysis, efficiency approach is superior in that it allows for the farms to be evaluated comprehensively with all inputs and outputs considered at the same time (Coelli, 1995). The analysis of financial ratios and cost-revenue on the other hand compares only two aspects at a time. Farmers in their production process may have other goals apart from the cost minimization or revenue maximization. To be sustainable in the long run however, they need to at least give consideration to their production costs and revenues regardless of their production goals. Consequently, efficiency analysis is convenient in assessment of the level of performance of a farm.

Analysis of farm efficiency can be conducted from input or output perspectives. As an input measure, the focus is on the costs, i.e., how inputs or costs can be reduced while producing the same amounts of outputs. The output perspective on the other hand focuses on revenue and measures how much output or revenue can be increased given the same level of inputs.

In the output context therefore, the production frontier is viewed as a firm's locus of maximum outputs from various sets of input combinations. As such, it is plausible that some firms, within their scale of operation, are not close to the frontier while others may have outputs that are close to the frontier, given their input levels. A measure of how close a firm is to the maximum output level as defined by the frontier, given its level of inputs, is the measure of its technical efficiency (Kumbhakar and Lovell, 2003). This is further illustrated graphically in the next section.

2.3 Efficiency as input-oriented perspective

Allocative and economic efficiency are estimated when the isocost line is drawn as illustrated graphically in Figure 1 for a single output and two inputs.



Fig, 1. Allocative, Technical and Economic efficiency based on input orientation
Source: Coelli et al. 2005.

The isoquant YY' represents the technically efficient way to produce output Y. The economical optimal point is the tangency point between the isoquant and the isocost line, PP', where the technical rate of substitution between the two inputs, x1 and x2 equals the economic rate of substitution. An efficient farm represented by the point R and producing an amount Y, has its economic efficiency measured as OR'/OR, this is interpreted as potential cost reduction. The technical efficiency is measured as OQ/OR while the allocative efficiency is measured as OR'/OQ. In this context, the product of technical efficiency and allocative efficiency gives the overall allocative efficiency.

2.4 Efficiency as output-oriented perspective

In this perspective, efficiency is evaluated keeping the inputs constant. Fully efficient production possibility curve and isorevenue line is used to measure and interpret the economic output efficiency. The output oriented perspective is shown in Figure 2.

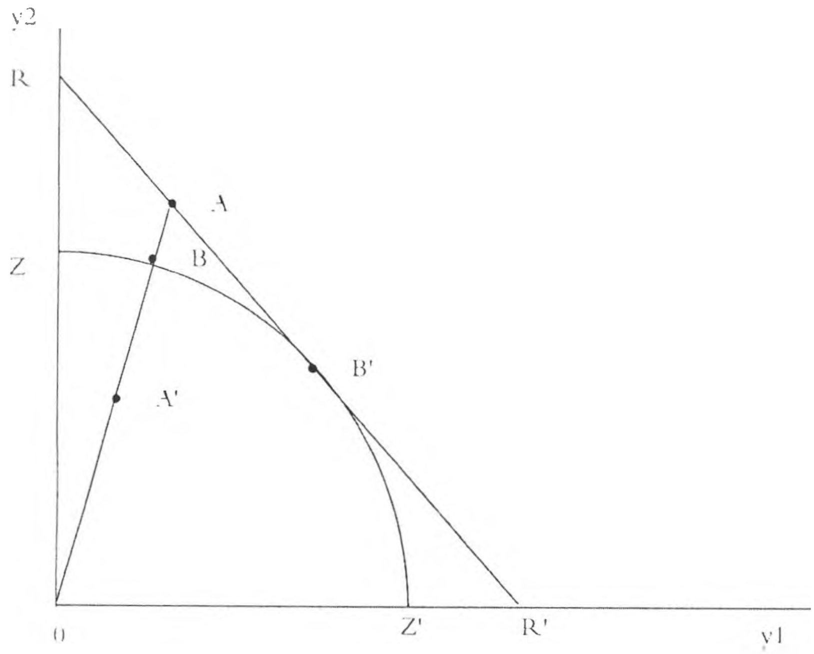


Fig. 2 Allocative, Technical and Economic efficiency based on output orientation
Source: Coelli *et al,* 2005

The production possibility curve is represented by the curve ZZ', this represents the technically efficient combination of outputs y1 and y2, given the firm's level of input endowments. The economically efficient point is B', where the marginal rate of product transformation equals the slope of the isorevenue line RR'. For a farm operating at point A', its economic output efficiency is OA'/OA. The technical efficiency of this farm is represented by OA'/0B and the allocative efficiency is OB/OA.

2.5 Farm versus household production efficiency

Many studies on economic efficiency of farm households have been conducted using parametric as well as non-parametric methods. Examples include Ray and Bhandra (1993) in

India; Adesina and Djato (1996) and Gurjand (1997) in Cote d'Ivore; Aguilar and Bigstein (1993) in Kenya; Olowofeso (1999) in Nigeria and Heshmati and Mulugetya (1996) in Uganda. Majority of these studies provide some evidence on the agricultural inefficiency and show heterogeneity across farm households in terms of access to technology and their ability to manage scarce resources. A number of studies also attribute the inefficiencies observed to imperfections in the credit and capital markets (Aguilar and Bigstein, 1993; Ray and Bhandra, 1993; Adesina and Djato, 1996). Whether or not efficiency studies should be undertaken at farm or household levels have also been a subject for many studies. However, evidence provided by among others, Chavas *et. al*. (2005), that demonstrated that labor rigidities, jointness of technologies of farm and nonfarm activities and jointness of labor decisions made on farm and off farm necessitate analysis of production efficiency at the household rather than the farm levels.

2.6 Study area description

Data used in this study is part of a household baseline survey that was collected for the Western Kenya Community Driven Development and Flood Mitigation (WKCDD&FM), a Government of Kenya project supported by the World Bank. The project covers all the districts in Western Province and two (Siaya and Bondo) in Nyanza province. WKCDD&FM is a rural development project that adopted a community driven development approach in the identification and implementation of income generating micro-projects. The project beneficiaries were identified based on the district poverty incidence according to the 2005 Government of Kenya statistics. Selection of the micro projects to be supported was done based on the potential of the projects to improve the household output and contribute towards achieving improved welfare and livelihoods for the participating households. The baseline data was collected during the first year of project implementation (2008).

The Study Area, Western Kenya is endowed with natural resources such as forests, rivers and lakes, with great potential to contribute to the local economy and improved livelihood for the local communities. However, the communities still experience high rates of poverty and vulnerability. Particular features that make communities in Western Kenya vulnerable include flooding, disease and degradation in natural resources, particularly land. According to Central Bureau of Statistics (2005), the poverty incidence in Western Province was 61 percent, and in Nyanza 64.6 percent. The major urban centers of Western Kenya have the highest incidence of poverty at 80 percent. The report identified perennial flooding, high incidence of HIV/AIDS and malaria as some of the poverty aggravating factors in the region. Women and children (particularly orphans and widows) are especially vulnerable.

Over the years, problems associated with flooding have been aggravated by poor land use practices that have lead to land and natural resource degradation. A combination of poor land-use practices, deforestation and pollution in the watershed catchment areas, and accumulation of silt in the lower sections of the main rivers, particularly river Nzoia are the main causes of frequent floods in areas such as Budalang'i and Bunyala of Busia district. Being the largest of the four water catchments in western Kenya that feed their waters into Lake Victoria, the Nzoia catchment is thus an important economic resource both to the local as well as the international community. Frequency and intensity of floods have similarly been on the rise thereby affecting further the productivity of the rural households in region. Such frequent flooding creates problems in water supply and sanitation, agriculture, health, education, communication, and transport.

The region has a relatively high population (estimated at over 4.5 million) and over 75% of the population lives in the rural areas where the predominant economic activity is smallholder agricultural production. Although the soils are relatively productive, the high levels of depletion of soil fertility have made the current agrarian practices quite unsustainable. Tree cover has been removed and land continuously fragmented, thanks to the relatively egalitarian access to land. The high population pressure and continuous land fragmentation has lead to increased population density with the resulting land sizes becoming too small that households cannot climb out of poverty solely through growth in farm productivity (Marenya, et. al. 2003. Hence the need to identify on-farm and off-farm attributes that influence productivity at the household level. Main sources of household livelihood in the area include crops cultivation, predominantly maize, groundnuts, vegetables and livestock production. Main cash crops grown in the area are coffee, tea and sugar cane.

Agricultural production in the region is mainly rain fed. The region is characterized by a bimodal rainfall pattern which although plentiful (1000 to 2400 mm pa) has been increasingly variable over time thereby interrupting the agricultural and livestock production patterns. The climate is generally suitable for a range of tropical and semi-tropical crops and temperatures vary in the range of 15-30 degrees centigrade, while elevation ranges from 1000 to 2000 m above sea level. The topography is generally rolling hills with scarps and a great potential for irrigated agricultural production.

Other challenges to agricultural production in the region include poor road conditions, leading to poor access to markets as a consequence of which farm households routinely oscillate between glut and scarcity with attendant price fluctuations. Incidences of post harvest crop losses are common in the region and agricultural production is constrained by lack of opportunity to diversify, lack of markets for cops in glut, few alternative avenues for value addition, and inefficient use of natural resources, i.e., land and water resources. As such, as the communities in the region embark on improving production and productivity, it is imperative to understand the how households may effectively respond to the production challenges. Decisions made at the household level could potentially provide insights into appropriate interventions to improve the productive capacity of Western Kenya region.

2.7 Sampling design and data collection

The study used primary household data collected by the Government of Kenya and World Bank as part of the baseline survey for the WKCDD&FM project – an eight year old rural development project. A two level randomization was adopted, first in the selection of the target (sampled) communities and secondly in the selection of target (sampled) households. The households were randomly selected using spatial randomization techniques implemented in Geographic Information Systems (GIS). Spatial randomization is a two dimensional randomization technique that applies two sets of random numbers to randomly define the geographical location of an object in space. Once the random household locations are generated in space, Global Positioning System (GPS) Coordinates of these households were generated and input in handheld GPS units. Enumerators then used the handheld GPS units to navigate to the selected household. Ten households were identified in each community. A total of 1800 households were included in the baseline survey.

CHAPTER THREE

3. STUDY METHODOLOGY

3.1 Measuring the production efficiency

Modeling and estimation of production efficiency of a firm relative to the 'best' practice in an industry has become an important area of economic study. As noted earlier, much empirical work focused on imperfect, partial measures of productivity, such as yield per hectare or output per unit of labour (Coelli and Battese, 1996). However, Farrell (1957) suggested a method of measuring technical efficiency of a firm in an industry by estimating the production function of firms, which are fully efficient (i.e., frontier production function). This was further improved and used by Battese and Coelli (1995).

This study adopted a stochastic frontier production function with multiplicative disturbance term following Aigner *et al.* (1977) and Meeusen and van de Broeck (1977) to analyze the data. The model used for the study is specified as follows:

$$Y = f(X_a; \beta)e\varepsilon \qquad (1)$$

where:

Y = the gross value of household agricultural output,

X_a= vector of input quantities,

β= vector of parameters and

e = error term

and where ε is a stochastic disturbance term consisting of two independent elements u and v, and thus:

$$E= u + v \qquad (2)$$

The symmetric component, v, accounts for random variation in output due to factors outside the farmer's control, such as weather and diseases. It is assumed to be normally, independently and identically distributed as $v \sim iidN(0, \sigma^2 v)$. A one-sided component $u \leq 0$ reflects technical inefficiency relative to the stochastic frontier, $Y = f(X_a; \beta) e\varepsilon$. Thus, $u = 0$ for a farm whose output lies on the frontier and $u < 0$ for one which is below the frontier as $| N \sim (0, \sigma^2 u) |$; which implies the distribution of u is half-normal.

For each farm, the measure of technical efficiency was estimated thus:

$$TE = \exp. [E \{U/\varepsilon\}] \tag{3}$$

The Battese and Coelli (1995) single-stage model was applied in the efficiency analysis. In this regard, u in equation 3 is a non-negative random variable, which is the efficiency associated with technical inefficiency factors in production by the sample farmers. It is assumed that the inefficiency factors are independently distributed and that u arises by the truncation (at zero) of the normal distribution with mean μ and variance σ^2, where u in equation 3 is defined as:

$$U = f(Z_b; \delta) \tag{4}$$

where: Z_b is the vector of farmer-specific factors, and δ is the vectors of parameters. The β- and δ- coefficients in equations 1 and 4 respectively are unknown parameters which are expressed in terms of:

$$\sigma^2 s = \sigma^2 v + \sigma^2 \tag{5}$$

and

$$\gamma = \sigma^2 / \sigma^2 s \tag{6}$$

where γ- parameter has a value between zero and one.

3.2 Empirical frontier model for the households in western Kenya

A Cobb-Douglas stochastic frontier production function was estimated and assumed to specify the technology of the farmers. The function was specified as:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{ij} + \beta_2 \ln X_{2ij} + \beta_3 \ln X_{3ij} + \beta_4 \ln X_{4ij} + \beta_5 \ln X_{5ij} + \beta_6 \ln X_{6ij} + \beta_7 \ln X_{7ij} + \beta_8 \ln X_{8ij} + V_{ij} - \mu_{ij} \tag{7}$$

where ln represents logarithm to base e; subscripts ij refers to the j^{th} observation of the i^{th} farmer; Y is the value of gross value of household agricultural output of the household in Kenya shillings (KSh); X_1 represents the total land size under cultivation (in hectares); X_2 represents imputed cost of family labour (in adult equivalent); X_3 is off- farm income (in Ksh); X_4 is the amount spent on livestock (in Ksh); X_5 represents the amount spent on other inputs (in Ksh); X_6 represents livestock (in tropical livestock unit); and X_7 represents cost of hired labor.

It is assumed that the technical inefficiency effects are independently distributed and μ_{ij} arises by truncation (at zero) of the normal distribution with mean μ_{ij} and variance, σ^2, where μ_{ij} is defined as:

$$\mu_{ij} = \delta_0 + \delta_1 \ln Z_{1ij} + \delta_2 \ln Z_{2ij} + \delta_3 \ln Z_{3ij} + \delta_4 \ln Z_{4ij} + \delta_5 \ln Z_{5ij} + \delta_6 \ln Z_{6ij} + \delta_7 \ln Z_{7ij} \quad (8)$$

where μ_{ij} represents the technical inefficiency of the i^{th} farmer; Z_1 represents access to credit by the household head; Z_2 denotes the gender of the household head; Z_3 denotes age of the household head; Z_4 is highest education of the household head; Z_5 denotes the distance to the nearest inputs market in kilometers; Z_6 the household size and Z_7 membership to community based organization.

The maximum–likelihood estimates of the β and δ coefficients in equations (7) and (8) respectively were estimated simultaneously using the computer program FRONTIER 4.1 (see Coelli 1996)

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Demographic and Socio-Economic Characteristics of the farmers

The analysis of technical efficiency of the households in the study area was done based on 243 households that were found to have complete data entries out of the 997, the total number in the sample. All the households grow maize, which often grown together with other cereals, fruits and vegetables. The farms are generally small, averaging about 6.7 acres, out of which maize is grown on about 78 percent. Livestock is kept by about 73 percent of the households with the main types being cattle, sheep and goats. Farm households also engage in off farm activities and about 43 percent reported to receive income from such activities. For these households, the average contribution of off farm income to their total income is about 14 percent. Access to credit was determined based on ease of the household obtaining KSh 300 in case of an emergency and about 46 percent could easily obtain this amount.

Technical efficiency was estimated using the gross value of annual farm output and 7 inputs as reported in Equations 7 and 8 (Table 3.1). Maize total production was measured in kilograms while the production of the other crops was aggregated using farm prices where these were available. Total revenues from livestock and livestock products such as meat, milk, eggs, honey were estimated for each household. Amount of off farm income was computed for all the households who reported availability of the off farm income. The inputs used included number of male and female adults which were computed using the equivalence scale proposed by Deere and Janvry (1981)[1]. Land represents the total surface devoted to farming activities while hired labor is measured using the total amount spent on hired workers in both crops and livestock activities. The cost of inputs includes the cost of hired land, seeds, fertilizers and costs due to

---

[1] This procedure assigns a weight of 0 to members aged below 3, 0.1 to children aged between 3 and 5, 0.3 to members aged between 5 and 8 and over 75, 0.5 to those aged between 8 and 12 and between 65 and 75, 0.8 to those aged between 13 and 17 and between 59 and 65 and 1 to the remaining members aged between 17 and 59.

livestock (feeds and veterinary expenses). Finally livestock was measured in tropical livestock unit (TLU), a standard procedure used to aggregate across different species[2].

[2] Cattle correspond to 1 TLU while sheep and goats correspond to 0.7 TLU.

4.2 Descriptive statistics of the model variables

Table 3.1 presents the variables used in the two models, for the estimation of the stochastic production frontier and the estimation of the factors that influence the technical efficiency of the households in the region. The average value of household gross output ranged from KSh 0 to KSh 285,800 with a mean of KSh 59,209. Thus there is a wide disparity in the value of gross output among households in the region. Average household land holding was 6.7 acres but ranging from 0.1 acres to 56.4 acres. Not all households kept livestock, but average tropical livestock units per household was 3.6. The estimated cost of household labor was KSh 16,507 slightly lower than the average cost of hired labor which was KSh 18,132. The significant proportion of hired labor is expected given the acreage of the farms (average 6.7 acres). Indeed the average cost of hired labor was higher than the average cost of other inputs purchased by the households (KSh 14,609) for farm production. .

For the technical efficiency influencing variables, majority of the households are female headed (54 percent) while the average age for the household head is 49.59 years, with the youngest household heads being 20 years while the oldest ones were 74 years old. The longest distance to input source for the households was 9 km. On average, the input sources were located some 1.97 km from the households. Only 27 percent of the households had access to extension services while 77.7 percent of the household heads had any formal education. About one third of all the households were members of community based organizations, some of which were farmer support institutions.

Table 3.1 Descriptive statistics for the variables used in the model

Variable	Mean	Minimum	Maximum	S.D.
Variables for estimation of SPF				
Value of Household gross output	59,209.10	0.00	285,800	4638.23
Land Size (Acres)	6.7	0.1	56.4	3.6
Livestock holding units	3.60	0.00	16.60	3.84
Livestock cost (Ksh)	1,870.63	0.00	5,697	641.49
Household Labour Cost (Ksh)	16,507	0.00	23,870	176.54
Hired labour Cost(Ksh)	18,132	0.00	36,600	1231.65
Other inputs Costs (Ksh)	14,609	3,005	28,320	2309.32
Household off-farm income (Ksh)	10,891.68	0.00	180,000	135.99
Variables for estimation of TE				
Age of Respondent	49.59	20.00	74.00	12.72
Male headed Households (%)	46.00	0.00	1.00	0.50
Household seize	5.83	1	20	3.16
Input market distance (Km)	1.97	0.00	9.00	1.70
Access to credit (Percentage)	15.00	0.00	1.00	0.30
Access to formal education (%)	77.70	0.00	1.00	0.42
Access to extension services (%)	27.40	0.00	1.00	0.45
Percent of household CBOs members`	33.5	0.00	1.0	0.32

4.3 Maximum likelihood estimates of the stochastic frontier production model

Results of the stochastic frontier production model (equation 7) and the technical efficiency estimates (equation 8) are shown in Table 3.2. All the variables of the production model except hired labor cost have positive coefficients as expected. The coefficients of family labor cost, input cost and livestock units were all significant at five percent level, while coefficient of elasticity of substitution for livestock cost was significant at one percent. Cost of inputs appears to be the most important significant variable with an elasticity of substitution of 0.97. This implies that reducing the cost of input by, for example, ten percent would result in increase in input by 9.7 percent. Evidently, the cost of the production inputs is a major limitation to household production. Number of livestock units has an elasticity of 0.44 implying that a reduction in number of livestock units by ten percent would result in a 4.4 percent increase in production. Whether this observation is attributable to the generally small farm sizes and the fact that many livestock keepers in the study area tend to keep the less productive local breeds of livestock that are traditionally less productive compared to improved breeds clearly requires further investigation.

The elasticity of the cost of family labor was 0.27 implying too, that an increase in cost of family labor by 10 percent would result in a decrease in production by 2.7 percent. However, this observation needs to be viewed in terms of the rigidities in the labor market in the western Kenya. Studies on labor allocative efficiency by Kamau *et. al.* (2009) observed that households that participate in labor markets have appeared to have higher shadow wages than non-participating households, which suggested that participation in labor market made them more productive. Given the scarcity of off farm employment in the region, especially for skilled and semi skilled workers, it is plausible to conclude that a large majority of the labor sold off farm is unskilled. Intuitively therefore, when the shadow price of labor increases, labor supply also increases, resulting in less labor available as input in household production, although the wages earned are considered as off farm income, hence part of gross household income.. Although land size had a positive elasticity of substitution, it was not significant at five percent, an observation that is inconsistent with other previous studies including Fitzgerald, *et. al.*, (1996) and Idiong (2007).

The parameter estimate for gamma was 0.92 which indicates that the specified model explains 92 percent of the variation in technical efficiency of household production in the study area. The estimate for sigma square was 0.56, again illustrating the correctness of the specified assumptions of the distribution of the composite error term.

Table 3.2. Maximum Likelihood Estimates for the parameters in the frontier model

Determinants	Coeff	S.E.	t-Value
intercept	0.2246	0.6612	0.3400**
Land size	0.8572	0.4942	0.1734
Family Labour cost	0.2710	0.4307	0.6311*
Off farm income	0.7537	0.4609	0.1635
Livestock Cost	0.1747	0.4732	0.3692**
Input cost	0.9738	0.4362	0.2232*
Livestock Units	0.4421	0.3154	0.1401*
Hired Labour cost	-0.1617	0.3710	0.4359
Sigma squared	0.5614	0.6309	0.8898
Gamma	0.9219	0.2586	0.3564
Logliklihood	0.9626	0.9626	
N	243		

Note **: Significant at 1 percent, *: Significant at 5 percent

4.4 Estimates of household technical efficiency

Table 3.3 shows the summary statistics for the estimates of technical efficiency for the 243 households used in the model. It can clearly be seen that the estimates of efficiency are generally low, with an average of 54 percent. The values of potential efficiency increase (PEI) were also computed for all the districts according to Saha and Jain (2004). This shows the potential increase of technical efficiency be households given highest technical efficiency observed in the sample. The lowest efficiency estimates of 28 percent were in Vihiga district while the highest of 81 percent were observed in Butere Mumias district. Low levels of production efficiency, like those in Teso district (49 percent), imply that the households could, broadly speaking, increase their output by up to 39 percent without changing the bundle of inputs employed in the production process. And given that the analysis considered off farm income simultaneously with conventional farm outputs, high levels of inefficiencies may signal the presence of barriers to non-farm employment.

Labor rigidities in the wake of high levels of technical production inefficiencies often contribute to poor labor allocation as well as increased inequality in income distribution as was observed by Reardon (1992) . However, given too that the farm households had a significant off farm income, almost one fifth of the average gross household income, further investigation is clearly warranted to determine the exact sources of the reported off farm income.

Table 3.3 Estimates of technical efficiency estimates by district

District	Obs	Technical efficiency		Potential increase in Efficiency (PEI)	
		Mean	Std dev.	Mean	Least
Lugari	28	59.39	0.134	26.7	63.0
Kakamega	23	59.96	0.146	26.0	63.0
Vihiga	21	52.10	0.108	35.7	65.4
Butere/Mumius	24	50.96	0.112	37.1	64.2
Bungoma	32	54.09	0.101	33.3	53.1
Busia	26	56.35	0.119	30.5	56.8
Teso	27	49.33	0.089	39.1	60.3
Mt Elgon	21	51.80	0.085	36.1	60.3
Siaya	18	55.67	0.127	31.5	61.8
Bondo	23	52.43	0.148	35.3	64.2
Total Observ.	**243**	**54.25**	**0.121**	**33.1**	**65.4**
Nyanza	41	54.62	0.135		
Western	202	54.18	0.118		

PEI is calculated using Saha and Jain (2004) formulae (1-TEy/TEmax) x 100

4.5 Analysis of factors affecting technical efficiency

This was done using a set of key factors usually considered in literature such as human capital, assets indicators and household characteristics. Table 3.1 shows the variables considered in this study as well as their descriptive statistics. Human capital endowments are represented by the age and education level of the head of the household and also by the ratio of the skilled members to over all adult family members. Off farm earnings provide a good source of liquidity to households which may at times obviate the lack of access to credit to increase households' ability to acquire efficiency enhancing inputs. Consequently, the share of off farm to total household income was used as an explanatory variable. Two health factors, whether a member of the household was suffering from a chronic illness or had been sick over the last four weeks were also used as explanatory variables.

It has been documented in literature that soil degradation is a severe cause of falling yields in the study area (Ngoze, et. al., 2009) and as such, soil and water conservation factors, i.e., whether the household practiced and whether it experienced any negative effects of soil and water conservation from neighboring farms were also used as explanatory variables. Therefore, the baseline model for the analysis of technical efficiency is specified as follows:

$$TE_i = \alpha + \beta X_i + \delta P_i + \gamma O_i + \varepsilon_i,$$

where TE_i indicates technical efficiency, X_i is a vector of household characteristics including human capital (gender, age and highest level of education of household), ratio of skilled over adult household members, and physical capital (negative impact of soil and water erosion, distance to fertilizer and seed market, access to credit proxy, membership to a community-based organization); O_i represents the share of off farm earnings to total income and P_i is a vector of health indicators chronic illness and sickness over the four weeks preceding the interview.

Table 3.3 Summary statistics for the technical inefficiency model

Determinants	Coeff	S.E	t-Value
intercept	0.8092	0.3343	0.2420*
Access to credit	-0.3918	0.1784	0.2196
Gender of household head	0.3639	0.1839	0.1978
Household head age	0.9196	0.4188	-0.2187***
Access to education	-02884	0.2982	0.9669
Distance to input market	-0.5074	0.4254	0.1192**
Household size	-0.3008	0.2956	0.4301
Membership to CBO	0.5017	0.1097	-0.1120*
N	243		

Note **: Significant at 1 percent, *: Significant at 5 percent

CHAPTER FIVE

4.1 Recommandations and |Conclusions

5.1 Policy recommandations

The study shows that there are gains linked to improvements in technical efficiency among the farmers in Western Kenya. The years of schooling, access to credit and system of cultivation are some of the instruments that can be manipulated within the agricultural policy framework in order to improve technical efficiency of coffee farmers. This might involve government allocating more credit facility and availing affordable credit and agricultural extension agents to the farmers. The farmers need to adopt best practices while growing agricultural crops on the farms. This might involve the government subsidizing the cost of the inputs and availing affordable credit and extension services to the farmers.

5.2 Conclusions

Given the findings of the study, it can be concluded that there are opportunities for farmers in Western Kenya to increase their level of output by increasing their current level of technical efficiency. This will enhance the productivity of the farm house sub-sector so that it can to cope with declining crop productivity in Kenya. This will also lead to increased household income earnings through sale of surplus crop production. The study recommends that for productivity to improve there is need for more emphasis to be laid on the improvement of socio-economic characteristics of the farmers. Since education level significantly influenced output, focus should be on better training of farmers. On access to credit, the agricultural finance institutions should focus on provision of credit for purchase of farm inputs. This can be done through farmers co-operative unions at the local level. The availability of fertilizer and pesticides and at affordable rates should be guaranteed. These farmers attributed the high costs of fertilizer and pesticides as a major limitation to their productivity. With reduced technical inefficiencies, farmers yield can significantly be increased.

4.34.2

References

Aigner D. J., C. A. K. Lovell and P. Schmidt (1977). *Formulation and estimation of stochastic frontier production function models.* Journal of Econometrics 6:21-37

Ali, F. and J. Flinn, (1989). *Profit efficiency among basmati rice production in Pakistan, Punjab.* Am. J. Agric. Econ., 71:303-310.

Ali, F., A. Parikh and M. K. Shah (1994). *Measurement of profit efficiency using behavioral and stochastic frontier approaches*. Appl. Econ, 26: 181 -188.

Barrett, C. B., B. Mesfin, D. C. Clay, and T. Reardon. (2005). *Heterogeneous Constraints, Incentives and Income Diversifi cation Strategies in Rural Africa.* Quarterly Journal of International Agriculture 44(1):37–60.

Batteese, G. E. and T. J. Coelli (1995). *A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data.* Empirical Economics 20:325-332

Bravo-Ureta, B. E. and A. Pinhero (1993). *Efficiency analysis of developing country agriculture: a review of frontier function literature.* Agric Resour Econ Rev 22:88-101

Coelli, T. J. (1996). *A Guide to Frontier Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation. Australia:* CEPA Working Paper 96/7, Department of Econometrics, University of New England, Armidale NSW Australia.

Coelli, T. J., Prasada, R. D. S., O'Donnel, C. J. and Battesse, G. E. 2005. *An introduction to Efficiency and Production Analysis*. Springer + Business Media, LLC. New York, USA.

Debreu, G. (1951) *The Coefficient of Resource Utilization.* Econometrica 19:273–92.

Dibertin, D. L. 2002. "*Agricultural Production Economics*" New York, Macmillian Publishing Company.

Fare, R., S. Grosskopf, and C. A. K. Lovell (1996). *The Measurement of Efficiency of Production*. Boston: Kluwer-Nijhoff Publication, 1985. Production Frontiers. Cambridge UK: Cambridge University Press, 1994.

Farrell, M. J. (1957). *The Measurement of Productive Efficiency.* Journal of the Royal Statistical Society, Series A 120:253–90.

Farrell, M. J. and M. Fieldhouse (1962). *Estimating Efficient Production under Increasing Return to Scale.* Journal of the Royal Statistical Society, Series A 125:252–67.

Forsund, F.R., C.A.K. Lovell, and P. Schmidt (1980). *A Survey of Frontier Production Functions and their Relationship to Efficiency Measurement.* Journal of Econometrics 13:5–25.

Gardner, B. L. (2002). *American Agriculture in the Twentieth Century* (2002). Cambridge MA: Harvard University Press.

Greene, W. (2002). *Econometric analysis.* 5th Edn. Pearson education.

Haggblade, S., P. Hazell, and J. Brown (1989). *Farm-Nonfarm Linkages in Rural Sub-Saharan Africa.* World Development 17:1173–201

Hansson, H. (2007). *Driving and Restraining forces for Economic Efficiency in DairyFarms- What are the Effects of Technology and Management.* Doctorial Thesis, Swedish University of Agricultural Sciences, Faculty of Natural Resource and Agricultural Science, Department of Economics, Uppsala.

Heshmati, A., and Y. Mulugetya (1996) *Technical Efficiency of the Ugandan Matoke Farms. Applied Economics Letters* 3:491–4.

Huang, Y. and K. P. Kalirajan (1997). *Potential of China's grain production: evidence from the household data.* Agricultural Economics 17: 191-199

Kioko, U. M. (2008). *The Economic Burden of Malaria in Kenya: A Household-Level Investigation.* Ph.D. Thesis. Department of Economics, University of Nairobi. Nairobi.

Kumbhakar, S. C. and A. Bhattacharyya (1992). Price distortions and resource-use inefficiency in Indian Agriculture: a resticted profit function approach. Rev. Econ. Stat. 74:231-239.

Meeusen W. and J. van den Broeck (1977). *Efficiency estimation from Cobb-Douglas production functions with composed error.* International Economic Review 18:435-444

Olowofeso, O. E. (1999). *On Maximum Likelihood Estimation of Frontier Production Functions: Empirical Application to Small-Scale Rice Framers in Ondo State, Nigeria.* Indian Journal of Applied Economics 8 (1999):121–36.

Ramanathan, R. (2003). An Introduction to data envelopment analysis: a tool for performance management. SAGE Publication.

Ray, S.C., and D. Bhadra (1993). *Nonparametric Tests of Cost Minimizing Behavior: A Study of Indian Farms.* American Journal of Agricultural Economics. 75(1993):990–99.

Reardon, T., C. Delgado, and P. Matlon (1992) *Determinants and Effects of Income Diversification amongst Farm Households in Burkina Faso.* Journal of Development Studies 28(1992):264–96.

Henning T. J., S. Robinson, and F. Tarp (2010) *Measuring Agricultural Policy Bias: General Equilibrium Analysis of Fifteen Developing Countries*. Am. J. Agr. Econ. (2010) 92(4): 1136-1148

Saha, A. K. and Jain, D. K. (2004). *Technical Efficiency of Dairy Farms in Developing Countries: A Case Study of Hayana State, India.* Indian Journal Agricultural Economics, 59, (3) 114-135.

World Bank (2008). *Agriculture for Development.* The World Development Report. Washington DC.