TECHNICAL EFFICIENCY AMONGST COFFEE FARMERS IN KENYA: A CASE STUDY OF GITHUNGURI DIVISION, KIAMBU DISTRICT

BY

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DECLARATION AND RECOMMENDATION

DECLARATION

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

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RECOMMENDATION

This research paper has been submitted for examination with our approval as university supervisors.

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DEDICATION

I dedicate this research work to my ever loving, motivating and supporting parents; Peter Runo and Susan Runo, my brother; Kahuha, my sisters; Ruth and Rose, my nieces; Marion and Imelda, my nephew; Ian and all my friends.

You are all great.

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Last but not least, I thank God for giving me the grace, good health and strength to do this research paper.

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ACRONYMS

CBK	Coffee Board of Kenya
CD	Cobb Douglas
CDF	Coffee Development Fund
CRF	Coffee Research Foundation
CES	Constant Elasticity Substitution
DEA	Data Envelopment Approach
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GOK	Government of Kenya
ICO	International Coffee Organization
KPCU	Kenya Planters Co-operative Union
KBS	Kenya Bureau of Statistics
MLE	Maximum Likelihood Estimation
MoA	Ministry of Agriculture
MT	Metric Tonnes
SFA	Stochastic Frontier Approach
SPF	Stochastic Production Frontier
TE	Technical Efficiency

ABSTRACT

It is argued that technical efficiency is determined by individual farm and farmer-specific characteristics. Such characteristics may be divided into two groups; demographic characteristics, which dominate the decision making, process of the farmer, and socioeconomic and institutional characteristics which influence a farmer's capacity to apply the decisions at the farm level.

The principal objective of this study is to analyze the factors influencing the technical efficiency of coffee farmers in Githunguri Division. Kiambu district. This study analyses the factors influencing the technical efficiency amongst coffee farmers using a translog stochastic production frontier function. The data used was collected from a sample of 100 small scale farmers and 40 coffee plantation farmers during the 2007 crop year. The estimated efficiencies are then explained by socioeconomic and demographic factors.

The mean technical efficiency index between the large-scale farms and small-scale farms is estimated at 97% and 93% respectively. The findings prove that that further productivity gains linked to improvement of technical efficiency may still be realized in coffee production in Githunguri Division. It is shown that education, credit accessibility, system of cultivation and household members contributes positively towards the improvement of efficiency. These results therefore suggest that if more resources are invested in these socioeconomic factors, then there will be an improvement in technical efficiency of farmers in Githunguri Division.

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Chapter One: Introduction

The agricultural sector is of great importance to the 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). The principal commodity exports of tea and coffee alone provided 21% of domestic exports revenue in 2005 while the combined revenue from coffee and tea was Kshs 51.993 billion compared to Kshs 43.016 billion in 2004 (Economic Review Survey, 2005). In addition, agricultural activity induces most of the spread effects in other sectors of the economy, thus contributing to job creation and poverty reduction. Agriculture contributes indirectly a further 27% of the country's GDP while about 45% of the government revenue is derived from the sector as well. The sector contributes over 75% of the industrial raw materials.

However, despite the important role the agricultural sector plays in the economy, the performance of the agricultural sector has been declining in the recent years, largely because of a continuous decline in output. Kenya's agricultural sector performed satisfactorily during the early post-independence period up to around 1974 when it declined as a result of the 1973 international oil crisis and the drought of 1973/74 (Economic Survey, 1975). This performance was reversed around 1976/77 when there was increase in both livestock and crop production performance, including coffee. The sector faces a number of challenges; among them is the decreasing production at the farm level which affects the agricultural income. The close relationship between agricultural performance and that of the economy imply that the agriculture must grow at a higher rate for it to spur economic growth (Nyoro, 2002). This situation similarly affects the coffee sub-sector. Coffee is important in the Kenyan agricultural sector and the economy in general. The importance of coffee as one of the main exported commodities in Kenya is measured by its contribution to foreign exchange earnings, farm incomes, employment opportunities and food security (CRF, 1999). Coffee currently ranks the fourth largest contributor to agricultural GDP after tea, horticultural and tourism (KBS, 2007). It provides direct and regular employment to about 600,000 workers and supports directly and indirectly about 6 million Kenyans (KBS, 2006).

1.0 Background of the study

Coffee was introduced in Kenya by Scotland missionaries in 1893. Kenya is famous globally for its high quality Arabica coffee which is largely attributed to inherent genetic characteristics of tree varieties, good agro-climatic and proper field and post harvest management practices. The major coffee growing areas in Kenya include Central and Eastern province. Kenya's early crop is harvested before July while the main crop is picked between July and December. The Coffee is grown from sea level to about 3,500 mm. It thrives in mean temperatures of 20^0 C or higher and requires 1,000 to 1,700 cm of rain annually and well-drained soils.

In 1963, coffee production stood at 43,778 metric tones from a total acreage of 45,538. The growth tempo accelerated in the 1970s and 1980s. There were however major reversals in 1990s on coffee production (KBS, 2007). Coffee is grown by approximately 600,000 small-holder farmers and 1,300 large-scale farmers spread across the country. Many households therefore depend on coffee for employment and income (CBK, 2008). It is recognized that growth in coffee income has contributed immensely to the development of the coffee producing areas. In these areas, income derived from coffee sales have been re-invested in other farm activities such as retail business and informal activities that have provided important link of agriculture to the rest of the economy.

1.1 Importance of coffee sub-sector

Historically, coffee has been an important agricultural commodity in Kenya because of its contribution to foreign exchange earnings, farm incomes and employment opportunities (Karanja and Nyoro, 2002). The coffee production has been decreasing over the years; 103,839 tones in 1989/90 to 53,368 tones in 2006/07 (CBK, 2008). Coffee sector has been a major employer, absorbing 400,000 permanent and 350,000 seasonal jobs but today, it can hardly afford only about 210,000 workers. The sector supports about 5 million Kenyan through its forward and backward linkages. At the household level, a large number of smallholder farmers directly engage in farm income in the coffee growing areas. These incomes have important multiplier effects in the national economy and especially in rural areas. The decline in coffee thus has a direct bearing on poverty in most coffee growing areas. In addition, coffee incomes are normally used to finance major household expenditures such as health care, school fees and investments which have both direct and indirect impact on child poverty.

Coffee is still considered a source of livelihood to many Kenyans as it plays a key role in the fight against poverty as a source of food security (The Economic Recovery Strategy for Wealth and Employment Creation, 2001-2003). The importance of coffee is further emphasized by the fact that the country's fiscal budget depends on its export earnings.

1.2 Coffee production trend

Official estimates indicate that the area under coffee is estimated at between 160,000 and 170,000 hectares (GOK, KBS, 2007). The smallholder accounts for around 128,000 hectares, equivalent to 75 per cent of the total area. There has been a decrease on coffee production for the last decade which can be attributed to farmers switching to other farm activities, mixed farming in coffee farms and the need to create room for human settlement. Nevertheless, limited coffee expansion has occurred in the recent past in some non-traditional coffee zones mainly in areas such as Uasin Gishu and Trans Nzoia districts (GOK, KBS, 2007). During the 1987/88 year, coffee production was at 130,000 Metric Tonnes. The decline in production has been more pronounced in smallholder farms where it declined by 47% during the period 1980 to 2005. The smallholder coffee production declined by 66 percent from 69,483 metric tones in 1990 to only 23,800 metric tones in 2000 (GOK, Economic Survey,2003), while in the same period, the estate production declined by 22 percent from 34,355 metric tones to only 26,743 metric tones. The sub-sector seems to be on the rebound. During the period 2005/2006, coffee production increased by 7% from 45,200 tonnes in 2005 to 48,303 tonnes in 2006. The increase was mainly attributed to smallholders whose share rose from 24,500 tonnes in 2005 to 27,046 in 2006 (GOK, Economic Review of Agriculture, 2007). During the same period, the exports of coffee increased by 6% from Kshs 8.225 billion in 2005 to Kshs 8.704 billion in 2006 representing the highest coffee export-earning over a 5-year period (GOK, Economic Review of Agriculture,2007). In the overall, increase in coffee production was attributed to improved crop husbandry following planned introduction of Coffee Development Fund (CDF) from where farmers can now access credit for coffee development.

Declines in production volume have been driven, in part, by declining crop yields as farmers stopped investing in fertilizers. Yields fell from 892 kilogram/hectare in 1980 to 284 kilogram/hectare in 2006 (Coffee Board of Kenya, 2008). These recent yields are very low compared to average yields for Arabica coffee worldwide of 698 kg/ha and yields of 1160 kg/ha in neighboring Rwanda and 995 kg/ha in neighboring Ethiopia.

Table 1: Coffee production trend in Kenya (1964-2007)

crop year	Production (tonnes) Estates	Production (tonnes) Small farms	Total Production (tones) Total	Value in Billion Kshs
1964/65	22,393	15,373	37,167	0.30
1989/70	26,521	26,275	52,796	0.40
1974/75	29,985	35,464	65,449	0.61
1979/80	39,109	51,900	91,009	2.26
1984/85	28,922	64,717	93,639	4.36
1989/90	34,356	69,483	103,839	4.00
1994/95	32,795	62,567	95,806	15.80
1999/00	38,585	62,265	100,850	10.50
2000/01	26,743	23,800	50,543	8.57
2001/02	23,073	28,822	51,895	6.76
2002/03	21,417	34,026	55,443	5.70
2003/04	18,473	29,958	48,431	6.70
2004/05	20,745	24,500	45,245	8.33
2005/06	21,251	27,046	48,297	8.70
2006/07	25,000	28,368	53,368	8.92

Source: Coffee Board of Kenya, 2008

Table 2: Area under coffee in Kenya: 2007

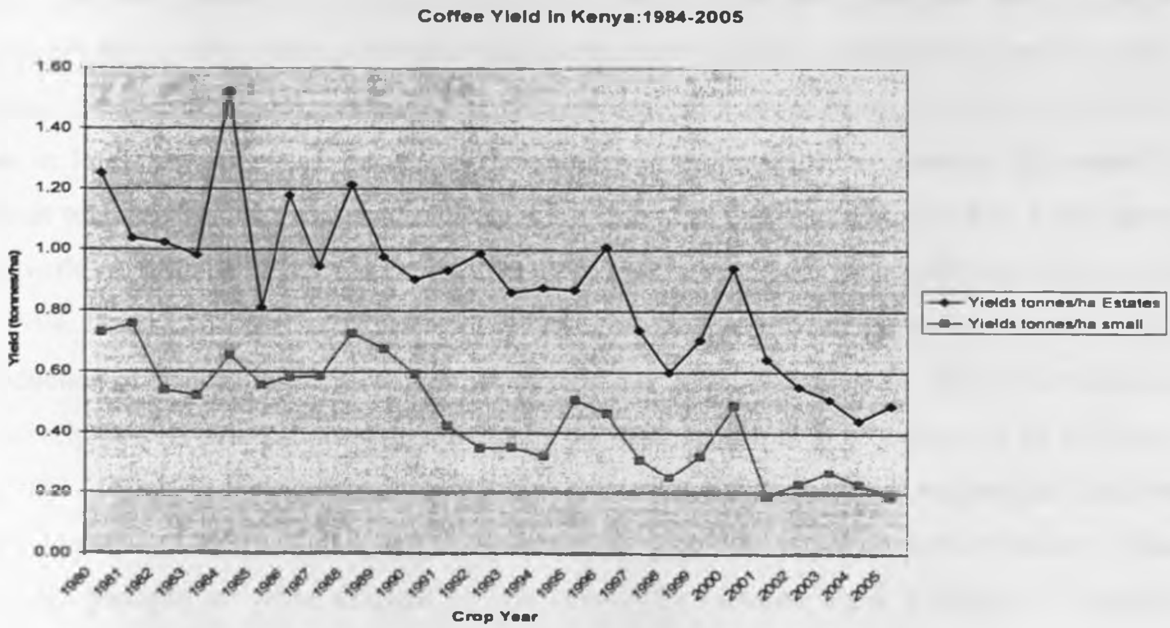
Crop year	Estates	Small farms	Total
2007	42,000	128,000	170,000

Source: Coffee Board of Kenya, 2008

1.3 Coffee yield

Coffee yield refers to the amount of production of cherry per coffee tree/hectare. In line with the trend in coffee production, coffee yields in Kenya have declined from 842 kg of clean coffee per ha in 1987/88 to an average of 475 kg per hectare during the last decade. The smallholder average yields during the last one-decade were only half those realized in 1987/88. The low productivity in smallholder farms remains a major challenge since coffee is a major contributor to the Kenyan economy.

Figure 1: Coffee Yield in Kenya (1984-2005)



Source: (Karanja et al, 2002)

1.4 Coffee Challenges and constraints

The escalating cost of production associated with high cost of inputs, labor, transport and energy had adversely affected the coffee sub-sector. Lack of affordable credit, including lapses of government programmes, negatively have impacted on coffee production due to the farmers' inability to afford inputs such as fertilizers, pesticides and also labor costs. Poor infrastructure is an important factor in coffee production and marketing. The coffee producing areas suffer from inadequate infrastructure in the form of electricity, clean water, roads and telephone among others. These infrastructures are vital to the efficiency in coffee production and marketing and without which, production and quality are adversely compromised.

The output of coffee has continued to suffer from low international commodity prices. As a result, the coffee auction price in Kenya has fallen from an average of Kshs 400 in 1997/98 to the 2002/03 level of Kshs 120 per kilo (Coffee Board of Kenya, 2007). This drop has been exacerbated by management problems that have plagued the industry for many years, with the result that some farmers have neglected their crops while others have abandoned them altogether, or uproot their coffee bushes, or replace them with more profitable enterprises. There has been a general downward trend in prices and all nations received a lower return of their coffee in 2002 than in 1994 (Coffee Board of Kenya, 2008). Kenya was amongst the countries that posted the lowest total production and average yield of the countries that produce more than 1 per cent of the world coffee. Kenya's coffee in 2002 fetched approximately 35 percent of the price that it did in 1994. Despite the steep price decrease, Peru for instance posted an impressive growth in total production of close to a 100 percent between 1994 and 2003. Kenya on the other hand which had relatively modest price decreases, witnessed a decrease in output to 65 percent of its 1994 level in 2002. The data provided by International Coffee Organization indeed suggest that declining world prices for coffee cannot fully explain the collapse of the Kenyan coffee industry. Other nations, similarly or worse affected by low prices (for instance, Peru, Ethiopia, El Salvador, Costa Rica and Honduras), were not only able to maintain their aggregate output and average yield, but were in most cases able to increase yields and boost production (Coffee Board of

Kenya, 2008) This indicates that additional circumstances specific to the Kenyan coffee industry must have amplified the negative consequences of the unfavorable international market.

Poor weather conditions have affected coffee production resulting to certain coffee diseases such as the coffee berry disease which not only reduce the yields but also destroy the bean quality. The effect of droughts and excessive rains reduces yields and bean quality as the coffee rust disease is more prevalent during the dry spells. Inadequate extension services are particularly a big challenge to coffee production among smallholders. Training of agricultural extension workers by the government has been inadequate and the training has not been specialized. In addition, the training has been focusing on general agricultural extension and not on coffee extension specifically.

Poor governance in the co-operative societies which provide the institutional infrastructure, especially for coffee marketing, is regarded as one of the major disincentives to coffee production in the recent years. Corruption among the management staff of such societies contributes to declining farmers' returns as unnecessary deductions are made on their savings while at the same time, reduced societies' capital base that affect credit availability for farmers to purchase inputs. High coffee indebtedness is another major challenge. The indebtedness is closely associated with the mismanagement in the coffee sector as individual societies accumulate debts arising from poor investment decisions and outright theft by management.

1.5 Measures to address coffee challenges

The coffee sector has also gone through a number of reforms since late eighties so as to improve coffee production and efficiency in Kenya. The reforms have been undertaken gradually in phases with an objective of having minimal disruption of coffee production, processing and marketing. The Coffee Act (Cap 333) is the overall legal framework guiding the coffee sector and which provides for its regulation and control over production process, marketing and export of coffee and associated issues through the supervision of the CBK. Reacting to pressure from international donors in the late eighties and early nineties, the government enacted a series of reforms aimed at the eventual liberalization of the Kenyan economy. For instance, in 1992, the government mandated CBK to undertake coffee auction at the Nairobi Coffee Exchange using dollars, which gradually gave way to payment of farmers in US dollars. Subsequent reforms led to the licensing of three more commercial millers in 1993 thereby dismantling the monopoly in the milling sector previously held by the KPCU. Implementation of such reforms has reduced the government role in the management of coffee co-operative societies through the enactment of the Co-operative Act (1998) and which has since been amended further through the Co-operative Act (2002).

The institutional reforms have led to the restructuring of the CBK to encourage all coffee beneficiary participation. For instance, the direct coffee sales were introduced to complement the central auction where coffee is sold to the highest bidder (as provided for in the Coffee Act, 2001). The direct coffee sales provided direct marketing where co-operatives societies and individual growers can sell their coffee directly to buyers abroad or exporters without going through the auction (MoA, 2006). It was anticipated that through this new arrangement cooperatives societies and estates would be able to realize better prices.

1.6 Statement of the Problem

Despite the challenges facing coffee farmers and the need for information on productive performance, empirical evidence on productive efficiency and factors that are associated with efficiency remain largely unexplored. The increases in costs of production when juxtaposed on the declining and low farm productivity, decline in coffee prices and performance risks have made returns to coffee production to dwindle in the recent past. As a coping mechanism most small-scale farmers have diversified from coffee to other farm enterprises such as dairy, horticulture and more so food crops. Others who are lucky enough have engaged in off farm activities such as small-scale trade and casual employment. As a result, coffee has been neglected, inter-cropped with all sorts of crops and in extreme cases uprooted. This has led to low coffee production as well as declining area under the crop.

Kenya wishes to realize rapid economic growth to fight high levels of poverty and unemployment (Vision 2030). This requires that all factor inputs be efficiently and effectively utilized to bridge the gap between actual and potential outputs. Further, because of inability of most developing countries such as Kenya to finance purchase of inputs especially those that are imported; and low levels of capital accumulation; today, focus on industrial growth is shifting to issues of efficiency in the use of the available productive inputs (Ajibefun and Daramola, 2003).

A large proportion of Kenyan population earns their living out of coffee sub-sector and a decline in coffee production is directly linked to under-employment, low incomes from the crop and low labor productivity. Despite the Kenyan government subsidizing the cost of coffee inputs, the coffee production has been on the decline. Thus there is need to explore other ways of increasing coffee production so as to improve the livelihood of coffee farmers. Realizing sources of inefficiency is one of the ways that coffee production could be increased. In this regard, empirical measures of efficiency are necessary in order to determine the maximum output of coffee that could be obtained given the fixed quantity inputs. A study on the factors that determine technical efficiency in coffee production is also important. A number of studies have been carried out on technical efficiency but so far no study has been done on coffee sector in Kenya. This study is thus a first attempt to the best of my knowledge.

Therefore, the research problem of this study can be stated by three questions. First, how do we improve productivity of the coffee farms so as to increase coffee production and increase income of the farmers and GDP of the country? Second, has there been any differential in technical efficiency among coffee farmers? Finally, what are the factors associated with technical inefficiency?

1.7 Objective of the Study

The general objective of the study is to establish the level of technical efficiency among coffee producing farms in Githunguri division in Kenya using a stochastic frontier production function. Specifically, the study aims to:

1. Estimate stochastic production frontier for the coffee farms in Githunguri division.
2. Estimate technical efficiency scores on the coffee farms in Githunguri division
3. To contribute to the technical efficiency literature as it relates to agriculture.

1.8 Hypothesis of the study

In order to guide the study in arriving at meaningful results, the following null hypothesis will be tested:

- The selected coffee farms are efficient and have no room for efficiency growth.
- There are no difference in technical efficiency among large-scale and small-scale coffee farmers
- The socioeconomic and demographic do not significantly influence the farm's technical efficiency.

1.9 Justification of the Study

Given the importance of coffee industry to the country, measuring the level of technical efficiency cannot be overemphasized. The decline the in the coffee sector further dictates the importance of examining the factors influencing technical efficiency. In addition, Kenya wishes to attain a middle income status by the year 2030 as stated in the policy strategy paper-Vision 2030. One way of making the vision succeed is to ensure that the GDP grows by at least 10% by the year 2012. Therefore, there is need to increase growth in all sectors of the economy so as to generate broad-based economic growth; coffee industry is one of such a sector. This goal cannot be realized if productivity and efficiency of the coffee industry is not increasing. This would require that the available resources be efficiently utilized which in turn require good knowledge of the current level of efficiency or inefficiency of the coffee farms as a component of the coffee industry.

Measurement of efficiency is also important because it is only by measuring efficiency and separating its effects from the effects of the production environment that one can explore hypotheses concerning the sources of technical efficiency differentials. Identification of sources of inefficiency is essential to the institution of public and private policies designed to improve performance. The ability to quantify efficiency also provides decision makers with a control mechanism with which to monitor the performance of the production system or units under control (Ajibefun and Daramola, 2003).

While studies have analyzed technical efficiency in agricultural sector for instance, Factors affecting technical efficiency among coffee farmers in Cote d'Ivoire (J. Nyemeck, 2003), Estimation of technical efficiency in Tanzanian sugarcane production, (E.Ashimogo, 2005) and Technical efficiency in Kenya's maize production (B.Kibaara,2005) among others, limited studies have been conducted using the stochastic frontier approach, particularly with respect to coffee sub-sector in Kenya. Furthermore, the ever challenging policy environment and the limited studies on technical efficiency on coffee farms call for more attention in this area. One way of reducing cost of production is to increase farm output by increasing technical efficiency. In this regard, it is necessary to quantify the current levels of technical efficiency so as to estimate losses in production that could be attributed to inefficiencies due to differences in socio-economic characteristics and management practices. This study aims to fill the necessary information gap an add value to the existing body of evidence on technical efficiency in agricultural crops in the country.

Chapter Two: Literature Review

2.1 Introduction

Measurement of technical efficiency is one of the important topics of research in both developing and developed countries due to various reason amongst them: it is a performance measure by which production units are evaluated; it is only by measuring efficiency and separating its effects from the effects of the production environment that one can explore hypothesis concerning the sources of efficiency differentials; identification of sources of inefficiency is essential to the institution of public and private policies designed to improve performance.

2.2 Theoretical Review

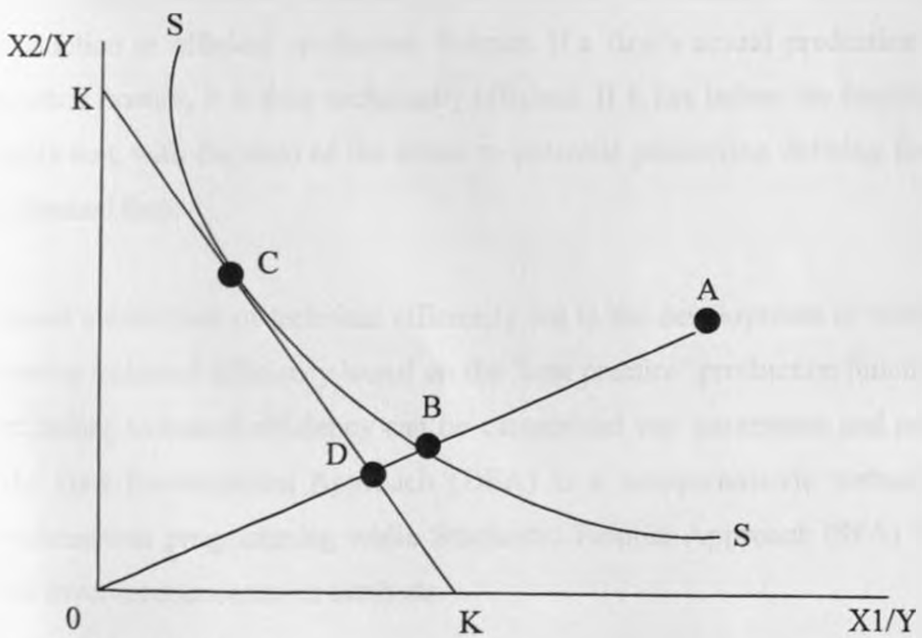
The concept of efficiency is concerned with the relation between scarce input resources (e.g. labour, capital, machinery etc) and either intermediate or final outcomes. Technical efficiency relates to the physical relation between input and output. The development of microeconomic efficiency measurement began with Farrel (1957) who proposed that the efficiency of any firm consists of two components: *technical efficiency or physical component and allocative efficiency.*

Technical efficiency refers to the ability of a producer to avoid waste by producing as much output as input usage allows or by using as little input as output production allows. Technical efficiency of an individual firm is defined in terms of the ratio of the observed output to potential output, given the available technology. *Allocative efficiency* reflects the ability of a firm to use inputs in optimal proportions, given their respective prices. A production process is said to be allocatively efficient if it equates the marginal rate of substitution between each pair of inputs with the input price ratio. Departure from this optimal condition can be explained by ;

a) Underutilization or over utilization of inputs resulting from the failure to minimize cost because of institutional, structural or managerial problems, and b) uncontrolled random exogenous shocks such as uncertainty in input and output prices and quality of inputs. The two measures are combined to provide a measure of total *economic efficiency.*

The concept of efficiency proposed by Farrell (1957) is illustrated in figure 2 using two inputs (x_1, x_2) and a single output y i.e. $y = f(x_1, x_2)$, under the assumption of constant returns to scale (which means that a given percentage change in input leads to a similar change in output). Knowledge of the unit isoquant (SS) of the *fully efficient firm* permits the measurement of technical efficiency. If a given firm uses quantities of inputs, defined by point A, to produce a unit of output, the technical inefficiency of that firm could be represented by the distance BA, which is the amount by which all inputs could be proportionally reduced without a reduction in output. This is usually defined as the ratio BA/OA, which measures the proportion by which all inputs could be radially contracted to attain efficient production. Technical efficiency (TE) of a firm is commonly measured by the ratio. TE=OB/OA, which is equal to one minus BA/OA. It will take a value of between zero and one, and hence provides an indicator of the degree of technical efficiency of the firm. A value of one indicates the firm is fully technically efficient. For example a firm operating at point B is technically efficient because it lies on the unit isoquant i.e. OB/OB=1

Figure 2: Input-oriented technical, allocative and economic efficiencies



Source: Coelli et al, 1998

If the input price ratio, represented by the line KK in figure 2, is also known, allocative efficiency (or price efficiency) may also be calculated. The allocative efficiency (AE) of the firm operating at A is defined to be the ratio; AE=OD/OB,

The distance DB represents the reduction in production costs that would occur if production were to occur at the allocatively (and technically) efficient point C, instead of at the technically efficient, but allocatively inefficient, point B. The total economic or productive or overall efficiency (EE) is defined as the product of technical and allocative efficiency.

EE=OD/OA,

Where the distance DA can also be interpreted in terms of cost reduction due to moving from A to C. TE*AE= (OB/OA)*(OD/OB) = (OD/OA) =EE

The efficiency measures defined above assume that the production frontier is known. The frontier has to be estimated.

2.3 Approaches to Technical Efficiency Measurement

The level of technical efficiency of a particular firm is characterized by the relationship between observed production and some ideal or potential production (Greene, 1993). The measurement of firm specific technical efficiency is based upon deviations of observed output from the best production or efficient production frontier. If a firm's actual production point lies on the best practice frontier, it is fully technically efficient. If it lies below the frontier, then it is technically inefficient, with the ratio of the actual to potential production defining the level of efficiency of individual firm.

Farrell's definition of technical efficiency led to the development of methods for estimating the relative technical efficiency based on the 'best practice' production function. The approaches for estimating technical efficiency can be categorized into parametric and non-parametric methods. The Data Envelopment Approach (DEA) is a non-parametric method that involves use of mathematical programming while Stochastic Frontier Approach (SFA) is a parametric method that involves econometrics methods.

The non-parametric approach or mathematical programming method has mainly focused on the development of DEA methods engaged for assessing efficiency under multiple-input and multiple-output production technologies. DEA does not require specification of a functional form of the production frontiers or making assumptions about the error term.

There are two primary orientations of the DEA approach to assess technical efficiency; input and output orientation. The input based measure considers how inputs may be reduced relative to a desired output level. The output based measure indicates how output could be expanded given the input levels. There is also a non-orienting DEA measure in which the frontier output and various concepts of technical and economic efficiency may be determined without being conditional on input or output levels being held constant. A common criticism of the DEA is that it is purely deterministic and thus cannot accommodate stochastic nature of the data and therefore efficiency estimates may be biased if the production process is largely characterized by stochastic elements.

The SFA is the most popular and has the advantage of taking into account measurement errors or random effects, it does not attribute all deviations from the frontier to inefficiency and it allows statistical hypotheses testing regarding the nature and magnitude of inefficiency. However, the criticism of this method resides in the need to specify beforehand the functional form of the production function and the distributional form of the inefficiency term and the assumption of a functional form of the distribution of inefficiency measures.

The production frontier can be viewed as composed of those parts of a farm's production function that yield maximum output for a given set of inputs. It is possible that a firm within its scale of operation may not be able to reach the frontier, that is, the production function for the farm. On the other hand, there may be farms whose outputs are closer to the production frontier, given their levels of inputs.

2.4 Determinants of Technical Efficiency

There are two main approaches used to analyze the determinants of technical efficiency from a stochastic frontier production function. The first approach, called the two-step approach which has two steps. First, it estimates the stochastic frontier production function to determine technical efficiency indicators. Second, indicators thus obtained are regressed on explanatory variables that usually represents the firms' specific characteristics. using the ordinary least squares (OLS) method. The two-step approach has been used by authors such as Kalirajan (1981). Parikh. Ali and Shah (1995), and Ben-Belhassen (2000) in their respective studies. This method has two major drawbacks. First. in order to use Jondrow et al., 1982 approach to predict the values of technical efficiency indicators. the inefficiency effects are assumed to be independently and identically distributed. Secondly. the technical efficiency indicators are assumed to depend on a certain number of factors specific to the firm.

The second approach is a one-step approach; it uses the maximum likelihood procedure. Authors such as Kumbhakar et al. (1991) and Reifschneider and Stevenson (1991) have used this approach whereby the inefficiency effects are defined as an explicit function of certain factors specific to the firm. Using this approach, Battese and Coelli (1995) proposed a stochastic frontier production function of panel data in which technical inefficiency effects are specified in terms of explanatory variables, including a time trend to take into account changes in efficiency over time. By following the one-step approach the model of technical inefficiency is specified in the following manner:

In this study we use the one-step approach since it has the advantage of being less open to criticism at the statistical level. and helps in carrying out hypothesis testing on the structure of production and degree of efficiency. In addition, stochastic frontier approach has found wide acceptance within the agricultural economics literature because of their consistency with theory, versatility and relative ease of estimation.

2.5 Empirical Review

Kalirajan and Shand (1985) estimated a stochastic frontier Cobb-Douglas production function using data from 70 rice farmers in a district in India. The variance of farm effects was found to be highly significant component in describing the variability of rice yields. Kalirajan and Shand (1988) estimated the time-invariant panel-data model using data for Indian rice farmers over five consecutive harvest periods. The farm effects were found to be highly significant component of the variability of rice output. A regression of the estimated technical efficiencies on the farm-or farmer-specific variables indicated that farming experience, level of education, access to credit and extension contacts had significant influences on the variation of farm inefficiencies.

By applying their model of technical inefficiency effects using panel data on Indian paddy rice producers, Battese and Coelli (1995) found a positive relationship between the degree of inefficiency and the producer's age, and a negative relationship between the degree of inefficiency and the educational level of the producer. Coelli and Battese (1996) used the same approach to analyze the factors affecting the technical inefficiency of Indian farmers, and found the mean technical efficiency levels to be 0.74 and 0.71, respectively, for the villages of Aurelle Kanzara and Shirapur. They also found a negative correlation between technical inefficiency and variables such as farm size and the level

Mulugeta (1996) estimated smallholder efficiency of Ugandan coffee and food-crop production using both the deterministic parametric and stochastic frontier efficiency measures. In the production of coffee, about 82 per cent were in the 80-100 per cent efficiency interval, with mean 86 per cent and minimum 67 per cent, while in production of food crops only 27 per cent of the farms were in the 80-100 per cent efficiency interval, with mean 70 per cent. About a third of the farmers were above 90 per cent efficiency level in coffee production. The study explored causes of inefficiency which included variables such as age of coffee tress, age of the household head, access to the non-labor input market, transportation facilities, business ownership and use of insecticides. The study results indicated that the potential of improving the technical efficiency of coffee and food-crop were immense. The study also indicated that both coffee and food-crop production could expand without shifting resources from one crop to the other.

Obwona (2006) estimated a translog production function to determine technical efficiency differentials between small and medium-scale tobacco farmers in Uganda using a stochastic frontier approach. The results of the study indicated that there was a great variation in the levels of efficiency among farmers, ranging from 44.8 percent to 97.3 percent with mean efficiency level of 76.2 percent. The estimated efficiencies were explained by socioeconomic and demographic factors. The results showed that there was potential for improving the production efficiency of tobacco farmers and some farmers were found to be operating at as low as 45 percent level of efficiency. The study also found that production efficiency at farm level depends on a number of socioeconomic and demographic factors. The factors identified as contributing positively towards improving farmers' efficiency include: accessibility to credit, extension services, family size, health status, hired workforce, fragmentation of land and education. One major drawback of this study is the inability of the author to show in clear terms whether there is any differential in efficiency between the two groups of farmers.

A study by Ogundele O. and Okoruwa V.O. (2003) examined technical efficiency differentials between farmers planting traditional rice varieties and those planting improved varieties in Nigeria. The results from these analyses showed that significant increase recorded in output of rice in the country could be traced mainly to area expansion. The use of some critical inputs such as fertilizer and herbicides by the farmers were found to be below recommended quantity per hectare. There was also significant difference in the use of such inputs as labor between the two groups of farmers. Other variables that were found to contribute to technical efficiency are hired labour, herbicides and seeds. The estimated average technical efficiencies for the two groups were correspondingly high (above 90 percent), which indicated that there was little opportunity for increased efficiency given their present technology.

An analysis of the productive performance of robusta coffee farmers in a low income area in Côte d'Ivoire also used the two-step approach (Nyemeck et al., 2001). Instead of adopting the parametric approach, these authors used the DEA method to calculate technical efficiency indexes. The efficiency indexes obtained were regressed on the set of socioeconomic variables with the help of double censure Tobit model. They determined that belonging to a mutual aid group and family size negatively significantly affects the level of technical efficiency. The efficiency indexes they calculated varied between 2 per cent and 100 per cent with a mean of 36 per cent. The analysis suggested that the policymakers should foster the development of the formal farmers' club or association by building capacity of the farmers. The analysis also supported public sector involvement in the provision of information on labour force management to the peasant farmers as a means to improve efficiency levels and thus household incomes.

G.Cardenas, D.Vedonor and J. Houston (2004) analyzed the coffee production system for 24 districts in Veracruz, Mexico during a five-year cropping period. A stochastic frontier approach was used to estimate an input distance function and evaluate production efficiency during the period. Factors such as coffee quality and access to markets were tested in terms of their effects on technical efficiency. Results showed that the production process in these districts, as measured by technical efficiency, appeared to be stable over time despite price fluctuations in the global market. Production of staple crops (corn along with coffee) resulted in lower efficiency. Factors contributing to higher efficiency included higher population density, production of specialty crops other than coffee or staple crops, and higher altitude, which is typically associated with production of higher quality coffee. The study suggested further analysis which could also be enriched by utilizing longer data series and additional data on off-farm activities, and introducing risk management to the frontier analysis of production process.

The study on efficiency of smallholder coffee farms in Vietnam by A.R.Rios and G.E.Shively (2005) indicated that small farms were less efficient and cost inefficiency than large farms. Inefficiencies observed in small farms appeared to be related, in part, to the scale of investments in irrigation infrastructure. A total of 209 farmers were interviewed. The survey obtained data on land use, agricultural production, irrigation practices and management, input level in agriculture, labor, processing and marketing of farm produce and use of credit. The technical efficiency indexes for large farms were, on average, larger than for small farms. In addition, a higher percentage of large farms were technically efficient. Nonetheless, large farms still had the potential to increase their output by almost 35 percent. Cost efficiency indices indicated that large farms had the potential to reduce costs by 42 percent and small farms had the potential to reduce costs by 58 percent. Some of the sources of inefficiency identified in the study were education of household head, farm ownership, number of pumps used on the farm irrigation and length of irrigation pipeline. Inefficiencies observed on the small farms were suggested to be due primarily to other factors than farm size.

The study on technical efficiency in Kenya's maize production (B. Kibaara, 2005) estimated technical efficiency in maize production using the stochastic frontier approach. The results of the study indicated that the mean technical efficiency of Kenya's maize production was 49 percent;

however, this ranged from 8 to 98 per cent. Technical efficiency was also found to vary by cropping system; the mono-cropped maize fields had higher technical efficiency than the intercropped maize fields. The number of years of school the farmer had on in formal education, age of household head. health of the household head. gender of the household head. use or none use of tractors and off-farm income were found to have an impact on technical efficiency. The study suggested an extension of the study to analyze all the maize fields of a farm and that a study on allocative efficiency would probably give more insight to the efficiency studies.

E.Ashimogo (2005) estimated the technical efficiency in Mtibwa Sugar Estate growers' scheme in Tanzanian. The study determined and compared the level of technical efficiency of out grower and non-out grower farmers, and examined the relationship between level of efficiency and various specific factors. The study was conducted using a sample of 140 out growers and non-outgrowers farmers using the Cobb-Douglas production frontier. The technical efficiency of out growers and non-out growers were 76.43 per cent and 80.65 per cent respectively. This indicated there was a chance of increasing the output of both farmers without increasing the levels of inputs used. Several factors affected the technical efficiency, this included; age, origin of the farmer, education level and farm area. The study showed that there were significant positive relationships between the age, education and experience with technical efficiency.

I.A. Ajibefun and A.G.Daramola (2006) analyzed efficiency of micro-enterprises in the Nigerian economy using cross sectional data on 180 micro-enterprises selected from block-making, metal-fabricating and saw milling occupational groups. Their quantitative estimates were obtained from the stochastic frontier production functions and they indicated a wide variation in technical and allocative efficiencies within and across occupational groups and across operational scales. This wide variation indicted that there was ample opportunity for these enterprises to raise their level of efficiency. Education level and age of enterprise owners were some of the variables found to be highly significant in affecting the level of efficiency.

A.Nchare (2007) analyzed factors affecting the technical efficiency of Arabica coffee producers in Cameroon. In this study, a translog stochastic production frontier function, in which technical inefficiency effects were specified to be functions of socioeconomic variables were estimated using the maximum-likelihood method. The data used were collected from a sample of 140 farmers during the 2004 crop year. The results obtained showed the mean technical efficiency index to be .896 and 32 per cent of the farmers estimated had technical efficiency indexes of less than 0.91. The determinants of technical efficiency analyzed in the study included. age of household head. education level. family size, contact with extension workers, access to credit, membership in mutual aid group, variety of coffee planted and distance between house and coffee plot. The analysis revealed the educational level of farmers and access to credit were the major socioeconomic variables influencing the farmers' technical efficiency. The findings proved that further productivity gains linked to the improvement of technical efficiency could still be realized in coffee production in Cameroon. The results further revealed that coffee farmers could benefit from economies of scale linked to increasing returns to boost production.

2.6 Conclusion

The empirical studies reveal that farmers. in general. allocate their productive resources inefficiently. Moreover, there are many variables that influence the technical efficiency of farmers which include the farmer's age, level of education and experience, farm size, family size. number of farm workers per hectare and distance between the farm and the nearest city amongst others. The studies reveal that there is potential to increase agricultural production significantly, simply by improving the level of producer technical efficiency without additional increase in inputs. The foregoing review of empirical literature reveals that there have been very few studies that have estimated technical efficiency using stochastic frontier method of estimation. Some of the studies did not investigate sources of technical efficiency and technical efficiency differentials. The model in this study accommodates both the measurement of technical efficiency and inefficiencies.

Chapter Three: Methodology

This chapter presents stochastic frontier production function and empirical models estimated in the study. The empirical model adopted in this study is the Battese and Coelli (BC) (1995). It permits the estimation of the parameters of the factors believed to influence the levels of the technical inefficiency effects, together with the separate components of technical inefficiency. The inefficiency effects model is important in order to lender the study more useful for policy recommendations

3.1 Production Function

A production function defines the technological relationship between the level of inputs and the resulting level of output. If estimated econometrically from data on observed outputs and input usage, it indicates the average level of outputs that can be produced from a given level of inputs (Schmidt, 1986).

Production technology can be represented by a production function, such as Cobb-Douglas (CD) and Constant Elasticity of Substitution (CES) or the translog production function. CD production function imposes more stringent assumptions on the data than the translog because the elasticity of substitution has a constant value of 1 (i.e. the functional form assumption imposes a fixed degree of substitutability on all inputs). And the elasticity of output is constant for all inputs (i.e. a 1 per cent change in input level will produce the same percentage change in output, irrespective of any other arguments of the function). The CES production function on the other hand is limited to two variables and it is not possible to estimate in its form using MLE therefore making it unsuitable for use as a basis of a production frontier. However, a Taylor series expansion of the function yields a functional form of the model that can be estimated. The translog production function imposes no restrictions upon returns to scale or substitution possibilities, but has the drawback of being susceptible to multicollinearity and degrees of freedom problems (Coelli et al, 1998).

An implicit assumption of production functions is that all firms are producing in a technically efficient manner, and the representative (average) firm therefore defines the frontier. Variations from the frontier are thus assumed to be random, and are likely to be associated with mis- or un-measured production factors. In contrast, the production frontier assumes that the boundary of the production function is defined by 'best practice' firms. It therefore indicates the maximum potential output for a given set of inputs along a ray from the original point. Some stochastic noise is accommodated, but an additional one-sided error represents any reason firms would be away from (within) the boundary. Observations within the frontier are deemed 'inefficient', so from an estimated production frontier it is possible to measure the relative efficiency of certain groups or a set of practices from the relationship between the observed production and some ideal or potential production (Greene, 1993).

3.2 Stochastic Frontier Production Function

Stochastic production frontier was proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van de Broeck (1977). There has also been a range of their applications in literature. Battese and Coelli (1995) proposed a stochastic frontier production function, which has firm effects assumed to be distributed as a truncated normal random variable, in which the inefficiency effects are assumed to be directly influenced by a number of variables. The stochastic frontier production has two error terms, one to account for random effects and another to account for technical inefficiency in production. The generalized stochastic frontiers production model can be expressed for two groups of farmers as:

$$y_i = f(X_1;\alpha)\exp(v_i - u_i); i = 1, \ldots\ldots N \qquad 3.1$$

Where y_i is the dependent variable, x_1 is the independent variables, v_i is the usual symmetric noise associated with the random factors not under the control of the firms/farmers, while the one-sided error u_i with $u_i \geq 0$, represents the non-negative random variables which captures technical inefficiency relative to the stochastic frontier. The random errors, v_i, are assumed to be independently and identically distributed as $N\left(0, \sigma_v^2\right)$ random variables, independent of $u_i's$ are also assumed to be independently and identically distributed.

Technical efficiency (TE) of an individual firm is defined as the ratio of the observed output (y) to the corresponding frontier output (y^*), conditional on the levels of inputs used by the firm. Thus the technical efficiency of firm i in the context of the stochastic frontier production function (3.1) is:

$$
\begin{aligned}
TE &= y_i / y_i^* \\
&= f(X_i;\alpha)\exp(v_i - u_i) / f(X_i;\alpha)\exp(v_i) \\
&= \exp(-u_i). \qquad 3.2
\end{aligned}
$$

Technical efficiency for each farmer is then calculated as:

$$TE = \exp\left(E(U / V - U)\right) \qquad 3.3$$

From literature on technical efficiency estimation. four distributional assumptions about the error terms have been proposed: an exponential distribution (Meeusen and Van der Broeck. 1971); a normal distribution truncated at zero, for example, (Stevenson. 1980); a half-normal distribution truncated at zero (Jondrow et al, 1982); and a two-parameter Gamma/ normal distribution (Greene, 1990).

There is no *a priori* justification for choosing one distributional form over the other for the technical inefficiency effects u_{it}, all have advantages and disadvantages (Coelli, Rao and Battese. 1998). For example the exponential and half-normal distributions have a mode of zero, implying that a high proportion of the firms being examined are perfectly efficient. The truncated normal and two-parameter gamma distribution both allow for a wider range of distributional shapes, including non-zero modes. However, these are computationally more complex (Coelli, Rao and Battese, 1998). Empirical analyses suggest that the use of gamma distribution may be impractical and undesirable in most cases. The estimation of two parameters in the distribution may result in identification problems, and several hundreds of observations would be required before such parameters could be determined. Further, a maximum of the log-likelihood function may not exist under some circumstances.

3.3 Empirical specification

A number of previous studies specified a Cobb-Douglas production function to represent the frontier function; however. the Cobb-Douglas imposes a severe prior restriction on the farm's technology restricting the production elasticities to be constant and elasticities of input substitution to unity. This study specifies the stochastic frontier production function using the flexible translog specification. This model does not impose restrictions on substitution elasticities and is more flexible than a Cobb-Douglas specification (McFadden and Mundlak, 1978). A general-form translog distance function can be written as:

$$lny = \beta_0 + \sum \beta_i lnx_1 + 1/2 \sum \sum \beta_{ij} lnx_i lnx_j + v - u; u \geq 0 \quad 3.4$$

Following Battese and Coelli (1992), a one-step maximum likelihood estimation procedure will be used. The parameters of the model and the variance parameters will be estimated using the method of maximum likelihood. The program FRONTIER 4.1 developed by Coelli (1996) will be used to compute the parameter estimates by maximizing a nonlinear function of the unknown parameters in the model subject to the constraints.

This study will employ a sectional data model for inefficiency effects in stochastic production frontiers based on the Battese and Coelli (BC) (1995) model. The inefficiency effects will be set to be a function of a set of explanatory variables the parameters of which will be estimated simultaneously with the stochastic frontier. Since the approach is stochastic, the coffee producers can be off the frontier because they are inefficient or because of random shocks or measurement errors. Efficiency is measured by separating the efficiency component from the overall error term.

Specification and estimation of the Stochastic Production Frontiers (SPF) requires a particular functional form of the production function to be imposed. The functional form that is assumed in this study is the translog production function which is a second order log-linear form. This is a relatively flexible functional form, that is, it imposes few restrictions on the data in terms of the elasticities of output and elasticities of substitution between inputs (Lundvall, 1999). It thus allows the data to indicate the actual curvature of the function, rather than imposing apriori restrictions. The translog production function is specified as follows:

$$InY = \beta_0 + \sum_{i=1}^{6} \beta_i InX_{ij} + 0.5\sum_{i=1}^{6} \sum_{k=1}^{6} \beta_{ik} InX_{ij} InX_{kj} + V_{ij} - U_{ij} \qquad 3.5$$

Where In indicate the natural logarithm and subscript i and j respectively represent the inputs I used by farm j. u_j is the non negative random term representing the technical inefficiency in production of farm j. it is assumed to be independently and identically distributed between observations, and is obtained by truncation at point zero of the normal distribution with mean u_j, and variance σ_u^2. Other variables are indicated as follows:

Y =value of coffee output harvested on the given farm (kg)

x_1 =amount of labour (person/days)

x_2 = total quantity of fertilizer used in coffee farms (kg)

x_3 =total quantity of pesticide used in coffee farms (litres)

x_4 =total area under coffee (acres)

x_5 =age of coffee trees (years)

x_6 = capital on coffee

V =statistical disturbance error term

$\beta 0$ - β_7 = parameters to be estimated

3.4 Determinants of Technical Efficiency

Two methodological approaches that have been used to analyze the determinants of technical efficiency from a stochastic frontier production function. The first one is the two-step approach which involves estimating the stochastic production function to obtain technical efficiency scores and then regressing these efficiency scores on explanatory variables that represent the firms' specific characteristics such as age, firm size, using the Ordinary Least Square method or tobit regression.

However, the two-stage approach has a major disadvantage in that, first, the inefficiency effects are assumed to be independently and identically distributed in order to use the approach of Jondrow, et al. (1982) to predict the values of the technical inefficiency effects. Secondly, the predicted inefficiency effects are assumed to be a function of a number of firm-specific factors, which implies that they are not identically distributed, unless all the coefficients of the factors are simultaneously equal to zero.

Aware of the inconsistencies of the two-stage approach, Kumbhakar, et al. (1991) and Reifschneider and Stevenson (1991) specified stochastic frontier models in which the inefficiency effects were defined to be an explicit function of a certain factors specific to the firm, and all the parameters simultaneously estimated in one-step using maximum likelihood procedure. Huang and Liu (1994), by following the second approach, developed a model in which the technical inefficiency effects were specified to be a function of some firm-specific factors together with their interaction with the input variables of the frontier function.

Thus, this study will follow one-step approach of Battese and Coelli (1995). The technical inefficiency effects, u_{it}, is specified as follows;

$$u_i = z_i\delta + w_i \qquad 3.6$$

Where u_{it} are non-negative variables which are assumed to be independently distributed as truncations at zero of the $N(m_i, \sigma_u^2)$ distribution;

m_i is a vector of firm-specific effects, with $m_i = z_i\delta$;

z_i is a vector of variables which may influence the efficiency of the firm:

δ is a vector of parameters to be estimated:

w_i, the random variable, is defined by the truncation of the normal distribution with mean zero and variance σ^2, such that the point of truncation is $-z_i\delta$. An estimated measure of technical efficiency for the ith firm may be obtained as;

$$TE_i = \exp(u_i) \qquad 3.7$$

The unobservable quantity u_i may be obtained from its conditional expectation given the observable value of $(v_i + u_i)$ (Jondrow et al., 1982; Battese and Coelli, 1988).

The single step approach is used in this model since it is less open to criticism at the statistical level, and helps in carrying out hypothesis testing on the structure of production and degree of efficiency (Nchare, 2007). The knowledge that the farms are technically inefficient might not be useful unless the sources of the inefficiency are identified (Admassie and Matambalya, 2002). Thus the second stage of this analysis is to investigate the sources of the farm-level technical inefficiency for the sampled farmers. The model specification for small-scale farmers will be:

$$U = \delta_0 + \delta_1 PE_1 + \delta_2 PYS_2 + \partial_3 PA_3 + \delta_4 SC_4 + \delta_5 AC_5 + \delta_6 VEX_6 + \delta_7 HHM_7 + \delta_8 LTT_8 + \partial_9 POI_9 \qquad 3.8$$

PE_1 =Producer coffee experience (years)

PYS_2 =Producer's years of schooling

PA_3 =Producer's age (years)

SC_4 =system of cultivation

AC_5=access to credit

VEX_6=Visits by extension workers

HHM_7 =Household members

LTT_8 =Land title deed

POI_9 = Producer off-coffee income

δ = Inefficiency parameters to be estimated

The model specification for large-scale farmers will be:

$$U = \delta_0 + \delta_1 PE_1 + \delta_2 PYS_2 + \partial_3 PA_3 + \delta_4 SC_4 + \delta_5 AC_5 + \delta_6 VEX_6 \qquad 3.9$$

PE_1 =Producer coffee experience (years)

PYS_2 =Producer's years of schooling

PA_3 =Producer's age (years)

SC_4 =system of cultivation

AC_5=access to credit

VEX_6=Visits by extension workers

In the model represented by equations 3.5, 3.8 and 3.9, the β and δ coefficients and the variance parameters $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \sigma^2 /(\sigma^2_u + \sigma^2_v)$ are simultaneously estimated by maximum likelihood method using frontier 4.1 software developed by Coelli (1996).

In order to test the hypothesis whether the Cobb-Douglas production function is an adequate representation of the data, given the specifications of the translog model, a generalized likelihood-ratio test (LR) is carried out. The LR statistic has approximate chi-square distribution $(\chi^2_{(n)})$ with degrees of freedom equal to the number of parameters (n) involved in the null hypothesis (H_0). The LR test statistic (λ) is carried out as follows:

$$LR = -2\left[Ln(l(H_0)) - Ln(l(H_1))\right] \square \chi^2_{(n)} \quad 3.10$$

Where $l(H_1)$ is the likelihood function value for the frontier model in which the parameter restrictions that are stated by the appropriate null hypothesis are imposed. and $l(H_1)$ is the likelihood function value for the more general and unrestricted frontier model.

3.5 Hypothesis of the study

The study in examining technical efficiency of the sugar producers will test the following hypothesis;

1. H0: All the coffee farms are efficient and hence no room for efficiency growth.
2. H0: There is no significant difference in technical efficiency scores of small-scale coffee farms and large-scale coffee farms.
3. H0: Socioeconomic and demographic do not significantly influence technical efficiency of the coffee producers.

3.6 Data and Area of Study

This study is based on cross sectional data collected from Githunguri divison. Kiambu district coffee growing areas during the month of December 2008. Kiambu district is selected as the study site because it was among the first to pioneer coffee production by African farmers. and also because it has typically heavy participation by small scale farmers in coffee production. A structured questionnaire was used to interview the farmers (see in appendix I & II). In addition, direct observation will be used to validate the survey.

Kiambu District is situated in Central province of Kenya and it is boarded by Nairobi province and Kajiado District to the South, Thika and Machakos districts to the east, Murang'a and Nyandarua districts to the north and Nakuru District to the west. Kiambu currently comprises of five divisions namely Kiambaa, Limuru, Lari, Githunguri and Kikuyu. Rainfall in Kiambu district ranges from an average from 1,466 mm to 753 mm. The district has a total area of 1,323.9 km2 with a population of 802,625,000 persons. The major agricultural products in this area include crops (maize, beans, and potatoes), livestock (cattle, goat, sheep and pig) and poultry.

3.7 Sampling procedure

The survey employed stratified sampling design, where stata was defined according to the integrated household survey sampling framework provided by the Central Bureau of Statistics to arrive at the final sample. The survey process involved four stages as follows: the selection of location, selection of sub-location, the selection of sample points (the villages) and a sample of 100 households and 40 coffee plantation estates from the villages was selected.

Data, including information on farmers' socioeconomic circumstances and coffee production were collected at the farm level using a structured questionnaire. The questionnaires were administered in kikuyu, Kiswahili and languages depending on the convenient mode of communication of the farmer/farm manager being interviewed. However, the filling of the questionnaires was done in English. The farmer survey was undertaken in December, 2008, using a single-visit survey approach. The farmers were grouped into 'small' and 'large' coffee producers. Small-scale farmers were those that grew coffee within an area of less than 5 acres while large-scale farmers are those that grew coffee within an area of 5 acres or more.

3.8 Measurement of the variables

Output of coffee is measured in kilograms (kg) for an individual coffee farm in a given year. Owing to the difficulties of estimating capital; capital will be estimated as the net book value of assets at the end of each year. Fixed value of assets will be aggregated together and used as a proxy for capital. The acres of land under coffee cultivation represent the land variable. Fertilizer and pesticide inputs refers to the amount of fertilizer (in kilograms) and amount of pesticides (in liters) that were applied on coffee farms during the year of study. Area of land refers to the area under coffee measured in acreage. Age of coffee trees refers to the number of years coffee trees have been in existence since they were planted on the coffee farms.

Labour will be in terms of the person-day as the base unit. The labour includes both the family and hired labour and weighting was done in accordance to the Food and Agriculture Organization (FAO) method. For a woman, working hours were multiplied by 0.75 and for children below 18 years the hours were multiplied by 0.5. The working hours are determined in person-days by dividing actual working hours by eight. The fertilizer variable quantity corresponds to the one that was applied on coffee trees in the course of the 2006 crop year. This is because the impact of fertilizer on production is only felt one year after its application. . The value of pesticide used during the year 2007 is used, to which the value of transportations to the plantation.

The family size refers to the number of people living in the household during the 2007 crop year. The farmer's educational level refers to the number of years spent in school while the coffee experience is determined by the number of years spent on coffee farming. The number of visits paid to coffee farms and plantations during the 2007 crop year is used to represent the agricultural extension worker's contact with the farmers. Age represents the actual age of the coffee farmers. System of cultivation refers to mono-cropping; only coffee is planted on the coffee farms or multi-cropping; other plants are planted on the coffee farms. Land title deed is a proxy used to determine the ownership of the coffee land by the coffee farmers. Producer-ff coffee income refers to the total value of all other income that the coffee farmer receives from other sources apart from the coffee farms during the year of study.

Chapter Four: Empirical Results

The study uses a cross-section data from a sample of 140 small- and large-scale farmers. A stochastic production frontier approach is used to estimate the farmer specific technical efficiencies. The estimated efficiencies are then explained by socioeconomic and demographic factors.

4.1 Data Analysis and Empirical Results

This chapter presents descriptive statistics for the variables used in the stochastic frontier production function and inefficiency effects model plus Maximum Likelihood Estimations (performed using Frontier 4.1) to simultaneously estimate stochastic production frontier and the technical inefficiency effects model.

4.2 Descriptive statistics

Table 3: The descriptive statistics of the variables included in the production

(a) Small-scale farmers

Variable	Mean	Std. Dev.	Min	Max
Coffee	1,970	2,292	70	50,000
Labour	311	301	25	1,712
Capital	580	202	20	2,880
Fertilizer	2,125	3,026	0	11,392
Pesticides	4,349	5,989	0	33,000
Age of coffee	62	18	30	100
Coffee Acres	1.2	0.99	0.13	4

(b) Large-scale farmers

Variable	Mean	Std. Dev.	Min	Max
Coffee	27,662	38,076	4,500	103,000
Labour	3,648	3,907	176	16,653
Capital	1,751,820	803,520	100,550	9,000,000
Fertilizer	3,961	4,134	0	20,000
Pesticides	96,682	93,453	18,850	443,050
Coffee Acres	62	56	11	230
Age of Coffee trees	67	14	43	95

Source: Author's computation

Large-scale farmers produced the highest amount of coffee on average at a mean of 27,662 kilograms, while the small-Scale farmers had the lowest output at 1,970 kilograms. The highest amount of capital employed was by large-scale farmers at a mean value of 1,751,820 while small-scale farmers had the lowest at 580. The small-scale farmers registered the lowest labour employed at an average of 311 persons/days while the large-scale farmers registered the highest at an average of 3,648 Persons/day. The minimum amount of fertilizer applied was by small-scale farmers at a mean of 2,125 kg while large-scale farmers applied the highest at a mean of 3,961 kg. The large-scale farmers applied the highest amount of pesticides at an average value of 443,050 while the small-scale farmers applied the least amount at an average value of 33,000.

The age of coffee tress for the farmers interviewed reveal that small scale coffee trees are relatively young with a mean age of 62 years compared to the 67 years for the large scale farmers. The minimum age of coffee trees by small-scale farmers was at 30 years while for large-scale farmers was at 43 years. The maximum age of coffee trees by small-scale farmers was at 100 years while for large-scale farmers was at 95 years. The highest coffee farm acreage for small-scale farmers was at 4 acres while for the large-scale farmers was at 230 acres. On average, small scale farmers cultivated coffee on 1.2 acres of land while the large scale farmers cultivated coffee on 62 acres. Large-scale farmers had the highest values for the means, minimum and maximum for all the variables compared to the small-scale farmers. High values of variables for large-scale farmers can be explained by the fact that these farmers have the larger coffee farms as compared to the small-scale coffee farmers in Kenya accounting for about 53% of the agriculture's sub-sector output.

Table 4: Descriptive statistics of the variables included in the inefficiency effects model

(a) Small-scale farmers

Variable	Mean	Std. Dev.	Min	Max
Coffee experience	22	12	5	55
Years of schooling	14	6	0	25
Age of farmer	45	3	25	88
System of cultivation	0.3	0.5	0	1
Credit facility	0.36	0.48	0	1
Agricultural agents	0.21	0.56	0	2
Household members	5	2	2	8
Title deed	0.75	0.44	0	1
Off-coffee income	436,338	432.479	0	2,655.800

(b) Large-scale farmers

Variable	Mean	Std. Dev.	Min	Max
Coffee experience	28	13.65	3	55
Years of schooling	17	7	10	30
Age of farm manager	45	2.5	35	60
System of cultivation	1	0	0	1
Credit facility	0.3	0.46	0	1
Agricultural agents	1	1.2	0	5

Source: Author's computation

The socio-economic characteristics of the farmers interviewed reveal that both the small-scale farmers and large-scale farm managers are relatively of the same age with a mean age of 45 years. The oldest small-scale farmer has an age of 88 years while for a large-scale farm manager is 65 years. In addition, the large-scale coffee managers are more experienced on coffee farms with an average of 28 years as compared to 22 years for the small-scale farmers. Further, the large-scale managers have more education with a mean of 17 years of schooling as compared to 14 years of the small-scale farmers. On farm ownership, 90 per cent of the small-scale farmers owned their coffee farms as compared to 100 per cent farm ownership for the large-scale farmers. Notably, 95 per cent of the small-scale farmers did not get any credit facility as compared to only 30 per cent of the large-scale farmers. The main reasons given were: for lack of credit is lack of collateral, too many conditions and difficulties in paying.

Most small-scale farmers practiced multiple cropping on their coffee farms (86 per cent) while all the large-scale farmers practiced mono-cropping. This could have attributed to the low coffee production the small-scale coffee farms. The agricultural agents rarely visited small-scale farmers while the large-scale farmers were visited more than once by the agricultural agents. Most small-scale farmers relied on off-coffee income with an average of Ksh 436,338 per year. This could be attributed to the low income on coffee thus farmers tend to look for other means of income such as livestock farming and poultry keeping.

4.3 Maximum likelihood estimation results

In identifying the appropriate functional forms, the presence of inefficiency and its trend, several statistical tests were carried out. The log-likelihood ratio tests LR (defined in equation 3.10) was used for misspecification analysis (Kumbhakar et al., 1997). Generalized log-likelihood has been used to test robustness of the estimated model. The Generalized LR tests that were performed to test various null hypotheses are presented in table 3 below.

Table 5: Generalized Likelihood-Ratio tests of the hypothesis for the parameters of the Stochastic Frontier production function

(a) Small-scale farmers

Test	Null Hypothesis	Log likelihood	Value of λ	Critical Values	Decision
Production function					
1	$H_o : \beta_{ij} = 0$	44	36.56	32.67	Reject H_o
Inefficiency model					
2	$H_o : \gamma = 0$	52	49.84	19.68	Reject H_o
3	$H_0 : \partial_i = .. = \partial_9$	60	41.50	18.31	Reject H_o

Source: Author's computation

Note: Critical values for the third test were obtained from Kodde and Palm (1986, p. 1246, Table 1), which gives critical values for testing null hypothesis involving parameters having values on the boundary of the parameter space at the 5% level of significance.

(b) Large-scale farmers

Test	Null Hypothesis	Log likelihood	Value of λ	Critical Values	Decision
Production function					
1	$H_o : \beta_{ij} = 0$	48	87.14	32.67	Reject H_o
Inefficiency model					
3	$H_o : \gamma = 0$	91.84	138.42	15.51	Reject H_o
4	$H_0 : \partial_i = ... = \partial_6$	45	153.44	14.08	Reject H_o

Source: Author's computation

Note: Critical values for the third test were obtained from Kodde and Palm (1986, p. 1246, Table 1), which gives critical values for testing null hypothesis involving parameters having values on the boundary of the parameter space, at the 5% level of significance.

The first test was to find out whether the Cobb-Douglas (CD) production function is an adequate representation of the data, given the specifications of the translog model. The generalized likelihood ratio test was used and the results are shown in table 5 above. The test involved setting the second-order coefficients of the translog frontier as simultaneously equals to zero.

The generalized log likelihood ratio statistic for testing, $H_0 : \beta_{ij} = 0$, provided large-scale and small-scale statistics of 36.56 and 87.14 respectively distributed as χ^2 with 21 degrees of freedom which is 32.67 at 5% level of significance. Thus, the null hypothesis that the CD frontier is an adequate representation of the data is rejected meaning that the translog frontier is an adequate representation of the data thus; the remaining discussions of the paper are based on this model.

The null hypothesis explored in test two is that all farmers are operating on the technically efficient frontier and random technical inefficiency effects are zero i.e. $H_0 : \partial_1 = ... = \partial_6$ for large-scale and $H_0 : \partial_1 = .. = \partial_9$ for small-scale. The generalized LR statistic for testing the absence of technical inefficiency effects from the frontier was calculated to be 91.84 for large-scale and 52_for small-scale. These values are significant, because they exceed the critical values from table I of Kodde and Palm (1986). The degrees of freedom for large-scale and small-scale farmers equals to 10 and 7 respectively. Hence, the null hypothesis of no technical inefficiency effects i.e. γ=0 is rejected, suggesting that inefficiency was present in both the large-scale and small-scale production and that the traditional average response function is not an adequate representation of the data.

The third test considered the null hypothesis that the inefficiency effects are not a function of the explanatory variables i.e. $H_0 : \partial_1 = ... = \partial_6$ for large-scale and $H_0 : \partial_1 = .. = \partial_9$ for small-scale. The null hypothesis is rejected confirming that the joint effect of these variables on technical inefficiency is statistically significant.

Table 6: The Maximum Likelihood Estimates (MLE) for the parameters of the stochastic model (dependent variable: log of coffee in kg).

The results of the estimated translog production frontier are represented in the following table below:

(a) Small-scale farmers

Production function

Variable	Coefficient	Standard error	t-ratio
Constant	-2.0474	0.9986	-2.0503
Log Labour	-0.1470	0.9812	-0.1498
Log Fertilizer	0.1815	0.9907	0.1833
Log Pesticide	-0.1424	0.9795	-0.1454

Log Capital	3.1668	0.9965	3.1780
Log Age of coffee trees	2.6711	0.9864	2.7079
Log Area under coffee	0.2957	0.9839	0.3005
Log $(\text{Labour})^2$	0.0537	0.4952	0.1084
Log Labour*Log Fertilizer.	-0.0077	0.2802	-0.0276
Log Labour *Log Pesticide	0.0084	0.2516	0.0333
Log Labour*Log Capital	-0.2939	0.8509	-0.3455
Log Labour*Log Age of coffee trees.	0.0213	0.8067	0.0264
Log Labour *Log Area under coffee	0.0050	0.6966	0.0072
Log $(\text{Fertilzer})^2$	-0.0051	0.3064	-0.0165
Log Fetilizer*Log Pesticide	-0.0020	0.0453	-0.0435
Log Fertilizer*Log Capital	0.0350	0.5189	0.0675
Log Fertilizer*Log Age of coffee trees	-0.0247	0.7832	-0.0316
Log Fertilizer*Log Area under coffee	0.0022	0.1415	0.0154
Log $(\text{Pesticide})^2$	0.0205	0.1096	0.1866
Log Pesticide*Log Capital	-0.1224	0.7844	-0.1561
Log Pesticide*Log Age of coffee trees	0.0103	0.6702	0.0154
Log Pesticide*Log age of coffee trees	-0.0063	0.4192	-0.0151
Log $(\text{Capital})^2$	0.5996	0.9919	0.6045
Log Capital *Log Age of coffeee trees	-0.3591	0.9324	-0.3851
Log Capital *Log Area under coffee	0.1879	0.8384	0.2241
Log $(\text{Age of coffee trees})^2$	-0.3176	0.7148	-0.4443
Log Age of coffee trees*Log Area under coffee	0.0038	0.7949	0.0048
Log $(\text{Area under coffee trees})^2$	-0.0332	0.4667	-0.0711

Number of observations = 100 at 5% d.f

(b) Large-scale farmers

Production function

Variable	Coefficient	Standard error	t-ratio
Constant	-1.0720**	0.9618	-1.1146**
Log Labour	-0.3737	0.7539	-0.4956

Log Fertilizer	2.7150**	0.8119	3.3438**
Log Pesticide	-4.0493**	0.9565	-4.2335**
Log Capital	1.4702	0.4576	3.2128
Log Age of coffee trees	2.3193	0.6846	3.3877
Log Area under coffee	-2.5448*	0.8630	-2.9486*
Log $(\text{Labour})^2$	0.2139	0.0200	10.7226
Log Labour*Log Fertilizer.	-0.3456	0.1454	-2.3760
Log Labour *Log Pesticide	0.5787	0.6148	0.9413
Log Labour*Log Capital	-0.1583	0.0300	-5.2709
Log Labour*Log Age of coffee trees.	-0.0821	0.0229	-3.5863
Log Labour *Log Area under coffee	0.3097	0.1353	2.2895
Log $(\text{Fertilzer})^2$	5.8721	0.2096	2.8019*
Log Fetilizer*Log Pesticide	-1.1173**	0.6017	-1.8569**
Log Fertilizer*Log Capital	0.0328	0.1153	0.2848
Log Fertilizer*Log Age of coffee trees	0.8096	0.1087	7.4457
Log Fertilizer*Log Area under coffee	-3.8024	0.3170	-11.9948
Log $(\text{Pesticide})^2$	.5018**	0.7079	70.8890
Log Pesticide*Log Capital	3.3008	0.5177	6.3764
Log Pesticide*Log Age of coffee trees	-3.8072	0.6621	-5.7497
Log Pesticide*Log age of coffee trees	2.6378*	0.6804	3.8770*
Log $(\text{Capital})^2$	-0.2827	0.0266	-1.064*
Log Capital *Log Age of coffeee trees	0.0667	0.0214	3.1230
Log Capital *Log Area under coffee	0.0482	0.0585	0.8250
Log $(\text{Age of coffee trees})^2$	-0.0138	0.0071	-1.9363
Log Age of coffee trees*Log Area under coffee	-0.2730	0.0444	-6.1461
Log $(\text{Area under coffee trees})^2$	-0.0412	0.1022	-0.4033

Number of observations = 40 at 5% d.f

The results reveal that the use of fertilizer, capital inputs and fertilizer inputs are the major determinants of the level of output for both small-scale and large-scale farmers. The findings concur with those of Evenson and Mwabu (1998) that demonstrated positive and significant relationship between fertilizer-use and productivity. The age of coffee trees is also an important factor to the level of coffee output. The coffee acres though important in coffee output, it is not statistically significant variable for the small-scale farmers at five per cent level. This could be attributed to the fact that the small-scale farmers own small pieces of land and are limited on purchasing more land due to high cost of land and limited availability of land. Labour input though it didn't not reveal major contribution to output, it was important variable and statistically significant at five per cent level.

4.4 Farmers' Technical Efficiency Indexes

The determinants of technical efficiencies obtained from the one-step maximum likelihood procedure are presented in Table 7 below.

Table 7: Technical Efficiency of Coffee Producers

Technical Efficiency	*Small-scale farmers*	*Large-scale farmers*
0.80 – 0.85	1	-
0.86 – 0.90	17	1
0.91 – 0.95	54	12
0.96 – 1.00	28	27
Total	*100*	*40*
Mean technical efficiency	0.93	0.97

Author's construction from data results

The mean technical efficiency for small-scale farmers and large-scale farmers is computed as 93 per cent and 97 per cent respectively. This implies that the small-scale farmers and large-scale farmers lose close to 7 per cent and 3 per cent of the potential output to technical inefficiencies. Though the magnitude of technical efficiency varies from one farmer to another, the statistical results shows that large-scale farmers are slightly more efficient compared to small-scale farmers. Further analysis at the frequency distribution of the levels of inefficiencies revealed that about 72 per cent of the large-scale farmers experienced inefficiency levels of over 5 per cent compared to only 40 per cent of the large-scale farmers. Generally all the coffee farmer's were below the 100% efficient level.

The estimated coefficients of the explanatory variables in the model for the determinants of technical inefficiency in equations 3.8 and 3.9 are presented in table 8 below. These estimated coefficients are important for policy recommendations.

Table 8: Results of the Technical Inefficiency model

Inefficiency model

(a) Small-scale farms

Variable	Parameter	Coefficient	Standard-error	t-ratio
Constant	δ_0	0.0048	0.9696	0.0049
Coffee experience	δ_1	0.0013	0.1272	0.0099
Years of schooling	δ_2	0.0032	0.1034	0.0313
Age of farmer	δ_3	0.0082	0.8777	0.0094
System of cultivation	δ_4	-0.0056	0.9494	-0.0059
Credit facility	δ_5	-0.0062	0.9316	-0.0067
Agricultural agents	δ_6	0.0069	0.9345	0.0074
Household members	δ_7	0.0046	0.8486	0.0055
Title Deed	δ_8	-0.0032	0.6384	-0.0049
Off-coffee income	δ_9	0.293***	0.341***	-0.0858

(b) Large-scale farms

Variable	Parameter	Coefficient	Standard-error	t-ratio
Constant	δ_0	-0.0054	0.7084	-0.0076
Coffee experience	δ_1	0.0049	0.0022	2.2851
Years of schooling	δ_2	-0.0005	0.0034	-0.1573
Age of farmer	δ_3	-0.0099	0.0200	-0.4935
System of cultivation	δ_4	-0.0054	0.7084	-0.0076

Credit facility	δ_5	0.0132	0.0244	0.5400
Agricultural agents	δ_6	-0.0168	0.0096	-1.7432

*Significant at 1%
Source: Author's computation

The main factors that influenced the degree of inefficiency for the smalls-scale farmers are coffee system of cultivation, title deed and credit facility. As evidence during the descriptive analysis of data, for the small-scale farmers, as the farmers advance in age, their inefficiencies increase. This could be attributed to the fact that most of the elderly farmers continued to utilize the old methods of farming and do not bother to adapt to new methods of producing coffee. In addition, these farmers have low levels of education and often provided poor supervision by agricultural agents and lack quick response to emergencies such as crop disease outbreaks. In addition, the access to credit facility by the small-scale farmers would reduce the inefficiencies. Access to credit facility has a negative coefficient. This is because access to credit facility reduces the financial difficulties of farmers thus enabling them to buy inputs for the coffee farms. These results are similar to those obtained by Kalirajan and Shand (1986), and Obwona (2005). Ownership of title deed has a negative relationship with technical inefficiencies. The title deeds enhances coffee farmers' land tenure security by testifying to ownership rights and incase the land is not officially marked out, the small-scale farmers tend to be less efficient.

The main factors that influenced large-scale farmer's degree of inefficiency are years of schooling, system of cultivation, age of coffee farmers and agricultural agents. The farmers who spend more years in schooling tend to be more efficient in coffee production. Similar results were obtained by Seyoum et al. (1998). The system of cultivation also has a significant effect on large-scale coffee farmers, thus when farmers practice mono-cropping as opposed to multi-cropping, they tend to be more efficient in coffee production. The results indicates that the younger farmers are more skillful in the search for information and the application of new techniques which will in turn improve their level of technical efficiency. Other factors like credit facility for the large-scale farmers influence inefficiency, but they are found to be highly insignificant and hence dropped from the model.

Chapter Five: Summary, Conclusion and Recommendations

The objective of this chapter is to present a summary of the paper; policy recommendations that can be implemented; conclusions that have been drawn from the analysis and limitations of the study.

5.1 Summary

The main objective of this research paper is to analyze the factors that influence the technical efficiency of coffee farmers in Githunguri Division, Kiambu district. A translog stochastic production function is estimated using the Maximum Likelihood estimation method. The inefficiency effects models for the small-scale farmers is specified as a function Coffee experience, years of schooling, age of coffee farmers, system of cultivation, access to credit, extension workers, household members, title deed and off-coffee income. The inefficiency effects models for the large-scale farmers is specified as a function Coffee experience, years of schooling, age of coffee farmers, system of cultivation, access to credit and extension workers. One-step approach of Battese Coelli (1995) is used to simultaneously estimate the stochastic production function and the inefficiency effects model two avoid the biases associated with two-step procedure.

The mean technical efficiency of the large-scale and small-scale coffee producers is calculated to be 97 per cent and 93 per cent respectively. This means that the large-scale farmers are 3 per cent off the fully efficient frontier while the small-scale are 7 per cent and thus there is room to expand output by increasing their level of technical efficiency. The estimated value of the variance parameter γ is close to 1 and significantly different from zero. This shows that nearly all the variations in the production of coffee are explained by technical inefficiencies. The education level, age of farmer, access to credit and system of cultivation has shown to have significant negative influence on the farmer's technical inefficiency. The large-scale farmers have a high technical efficiency compared to the small-scale farmers. The mean inefficiency is about 3 per cent for the large-scale farmers and 7 per cent for the small-scale farmers. An improvement towards higher education, access to credit and mono-cropping cultivation would increase coffee productivity in the Githunguri division and the country at large.

5.2 Policy recommendations

The study shows that there are gains linked to improvements in technical efficiency among the coffee farmers in Githunguri division. 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 coffee on the farms. This might involve the government subsidizing the cost of the inputs and availing affordable credit and extension services to the coffee farmers.

5.3 Conclusions

Given the findings of the study, it can be concluded that there are opportunities for the coffee farmers in Githunguri Division to increase their level of output by increasing their current level of technical efficiency. This will enhance the productivity of the coffee sub-sector so that it can to cope with increased competition in the coffee industry. This will also lead to increase of foreign earnings through exportation of coffee. 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 coffee 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.

5.4 Limitations of the study

The study used the stochastic frontier approach (SFA) to estimate the frontier and this methodology is unable to handle multiple outputs. Output such as the dry coffee beans output is not included in the study due to lack of accurate information from coffee farmers. The DEA approach relative to the frontier approach permits an assessment of a multiple input, multiple output technology. The study assumed that the productivity of workers in the coffee farms was the same because the farmers could not be able to provide accurate data on man hour or for different category of work done in the coffee farms. The study did not include all factors that could have been incorporated in the technical inefficiency model such as risk, the market imperfections, and the age of the workers and coffee experience of the workers among others. The study estimated physical inputs by use of physical measures which made it impossible to measure differences in input quality such as coffee quality, quality of labour force, quality of pesticides and fertilizers, etc. Researchers use monetary values of inputs to overcome the problem of heterogeneity of inputs i.e. differences in quality: however in this study it was impossible to obtain uniform monetary values as farmers had wide range of differing coffee prices. This study did not look at growth in total factor productivity to find out whether technical change is as a result of improved efficiency or innovation. Effects of prices which are considered high by the coffee producers and their effects on coffee exports on technical efficiency can be examined.

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APPENDIX

Table A1: Coffee Plantation Questionnaire

Questionnaire No.:____________________
Date Administered: ____________________ Location:______________

Sub-location:____________________ Village:____________________ Household No.________

Name of Interviewer:____

Section A: Household Characteristics

1) Fill in your details as follows:

Name of farm manager	Sex (A1)	Age(years) (A2)	Marital status (A3)	Highest level of education(see code) (A4)	Number of years in school (A7)

A1 1= male, 0 = female

A2 1= 20-30yrs, 2= 30-40yrs, 3= 40-50yrs, 4= 50-60yrs, 5= 60yrs and above

A3 1= Monogamous Married, 2 = Polygamous Married, 3 =Living Together, 4 = Divorced, 5 = Separated, 6 = Widow or Widower, 7 = Never Married

A4 1= none, 2 = nursery, 3 =Primary, 4 = secondary, 5 = Post secondary,

Section B : Economic Status

2) Indicate the coffee t you grew in year 2007 on present site and the amount you sold to the market.

Crop (B1)	Mono-cropped (B2)	Acres	2007 Harvest in kgs	Amount sold in kgs	Price sold per unit

B2 1= Mono- cropped, 2= Multi-cropped

3) How old are the coffee trees? ____________________

4) How many years have you worked as coffee manager______________?

5) What problems do you face when producing coffee?

a)____

b)____

Section C: **Labour and farm inputs and payment in coffee farming**

6) Indicate the labor inputs that you engaged in your coffee farm(s) during the year 2007 and their respective costs.

i) Labour Inputs

a) Short-rains season

Activity	Hired labour/per day			payment: kshs/per day		
	Men	Women	Children	Men	Women	Children
Spraying						
Weeding						
Pruning						
Harvesting						

7) Long-rains season

Activity	Hired labour/per day			payment: kshs/per day		
	Men	Women	Children	Men	Women	Children
Spraying						
Weeding						
Pruning						
Harvesting						

8) Indicate the machine costs that you engaged in your coffee farm (s) during the year 2007 and their respective costs.

i) Machine costs

Activity	Machine hours/day	Machine cost/day kshs)
Spraying		
Weeding		
Other(specify)		

9) Indicate the farm inputs that you engaged in your coffee farm(s) during the year 2006 and 2007 and their respective costs.

Farm input	2006	2007	source	Price per unit (kshs)
Fertilizer (kg)				
Pesticides (ltr)				
Other(specify)				

10) What farming tools do you use in your coffee plantation and how much did they cost?

Tool	Year of purchase	Quantity	Cost	Net realizable value today

Section D: Extension workers and credit facilities

11) Have you ever been visited by agricultural extension workers in your farm in the year 2007.

a) Yes□ b) No □

12) If yes in (10) above, how many times did they visit you? _____________

13) Does the farm owner have access to credit facility to assist in the coffee farming?

a) Yes □ b) No □

14) If yes, which credit facilities does he/she have?

a) Coffee Co-operatives□ b) Saccos □c) Bank□ d) Other (specify)____________

Section E: Coffee market

15) Where do you market your coffee?

a) K.P.C.U____ b) Others (specify)________________

16) What is the distance in km from your coffee farm(s) to the place where you market your coffee__________________

17) While transporting your coffee production to the market, how much did you incur in kshs during the year 2007?

____

Thank you.

Table A2:Small-scale farmer Questionnaire

Questionnaire No.:____________________

Date Administered: ____________________Location:_______________

Sub-location:_____________________ Village:____________________ Household No.________

Name of Interviewer:____

Section A: Household Characteristics

1) List all the individuals who normally live and eat their meals in this compound. starting with the household head.

Name (A1)	Relationship with head (A2)	Sex (A3)	Age(years) (A4)	Marital status (A5)	Highest level of education(see code) (A6)	Number of years in school (A7)	Main occupation (A8)	Side occupation (A9)

A2 1 = Head, 2 = Spouse. 3 = Son. 4 = Daughter, 5 = Father/Mother, 6 = Sister/Brother, 7 = Grandchild. 8 = Other Relative (Specify), 9 = Servant,
10 = Other (Specify)

A3 1= male, 0= female

A4 1= 20-30yrs, 2= 30-40yrs. 3= 40-50yrs, 4= 50-60yrs, 5= 60yrs and above

A5 1= Monogamous Married, 2 = Polygamous Married. 3 =Living Together, 4 = Divorced, 5 = Separated. 6 = Widow or Widower, 7 = Never Married

A6 1= none, 2 = nursery. 3 =Primary, 4 = secondary, 5 = Post secondary

A8 1 = farming, 2 = Casual laborer, 3 = Employed, 4 = Family business, 5 = Self-employed, 6 = others (specify)

Section B : Economic Status

2) i) What other economic activities are you engaged in?

a) Activity_______________ Permanent □ Temporary/Contractual□

b) Activity_______________ Permanent □ Temporary/Contractual□

ii) What is the monthly earning from these activities respectively?

a) Monthly income___________________

b) Monthly income___________________

3) Do you hold a title for your land/shamba? (a) Yes□ (b) No□

4) If No, who holds the title? ____

5) How many years have you worked as coffee manager_______________?

6) Indicate the crops that you grew in year 2007 on present site and on separate pieces of land and

the amount you sold to the market.

i) This site

Crop (B1)	Mono-cropped (B2)	Acres	2007 Harvest in kgs	Amount sold in kgs	Price sold per unit

B2 1= Mono- cropped. 2= Multi-cropped

ii) Separate parcels of land

Crop (B1)	Mono-cropped (B2)	Acres	2007 Harvest in kgs	Amount sold in kgs	Price sold per unit

B2 1= Mono- cropped. 2= Multi-cropped

7) Indicate the livestock that you kept in your farm(s) during the year 2007 and the quantity you sold.

Livestock (B1)	Acres	Proceeds in Litres/kg/trays	Amount sold in litres/kg/trays	Price sold per unit

8) How old are the coffee trees? ____________________

9) What problems do you face when producing coffee?

a) ____

b) ____

Section C: Labour and farm inputs and payment in coffee farming

10) Indicate the labor inputs that you engaged in your coffee farm(s) during the year 2007 and their respective costs.

i) Labour Inputs

a) Short-rains season

Activity	Family Labour/per day			Hired labour/per day		
	Men	Women	Children	Men	Women	Children
Spraying						
Weeding						
Pruning						
Harvesting						

b) Long-rains season

Activity	Family Labour/per day			Hired labour/per day		
	Men	Women	Children	Men	Women	Children
Ploughing						
Weeding						
Pruning						
Harvesting						

ii) Cost of labor inputs

Activity	Hired labour: kshs/per day		
	Men	Women	Children
Spraying			
Weeding			
Pruning			
Harvesting			

11) Indicate the farm inputs that you engaged in your coffee farm(s) during the year 2006 and 2007 and their respective costs.

Farm input	2006	2007	source	Price per unit (kshs) - 2006	Price per unit (kshs) - 2007

Fertilizer (kg)					
Pesticides (ltr)					
Other(specify)					

12) What farming tools do you use in your coffee plantation and how much did they cost you?

Tool	Year of purchase	Quantity	Cost per each item (kshs)	Net realizable value Today (kshs)/per item

Section D: Extension workers and credit facilities

13) Have you ever been visited by agricultural extension workers in your farm in the year 2007.

a) Yes□ b) No □

14) If yes in (11) above, how many times did they visit you? ____________

15) Do you have access to credit facility to assist you in coffee farming?

a) Yes □ b) No □

16) If yes, which credit facilities do you have:

a) Coffee Co-operatives□ b) Saccos □ c) Bank□ d) Other (specify)____________

Section E: Coffee market

17) Do you market your coffee through a co-operative society?

a) Yes □ b) No □

18) If No in (17) above, where do you market your coffee production? _________________

19) What is the distance in km from your coffee farms to the place where you market your coffee_________________

20) While transporting your coffee production to the market, how much did you incur in kshs during the year 2007?

____

Thank you.