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Analysis of Technical Efficiency among Smallholder Farmers in Kisii County, Kenya

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Abstract: *Land fragmentation is a major problem in most parts of the world as it restricts agricultural development, reduces productivity and opportunities for rural development. Kisii County shows a clear case of land fragmentation due to high population pressure and poverty. This study was conducted with the aim of examining the effect of land fragmentation on agricultural productivity by examining the technical efficiency of households in the area. Primary data was collected using structured questionnaires and analysis done using a Cobb-Douglas production (Stochastic Frontier) function. On factors that influenced land fragmentation, age of the household head, education level of the household head, number of males and females, generations through land has been transferred, amount of output (maize), tillage method, land size, household income, membership to a group and access to extension services were found to be significant at different levels. The technical efficiency was found to be 36.82 with more than half of the households falling below 50%. The quantity of planting fertilizer used, certified seeds and fragmentation index were found to influence the level of technical efficiency.*
Key words: *Technical efficiency, Land fragmentation, Stochastic frontier.*

I. Introduction

In Kenya, 16 per cent of the available land is high and medium agricultural potential with adequate and reliable rainfall. In these areas, there is intensive cropping and dairy production being undertaken. The high and medium agricultural potential areas are dominated by commercial agriculture with cropland occupying 31 per cent, grazing land 30 per cent, and forests 22 per cent. The Arid and Semi-arid land (ASALs) occupy the remaining 84 per cent. ASALS are not suitable for rain-fed farming mainly practiced in Kenya due to the low and erratic rainfall. As much as this is the case, it is estimated that 80% of Kenyas' population live and derive their livelihoods in the ASALs. The rest of the population occupies the high to medium land area. This puts a lot of pressure on land resulting to the high and medium potential areas being reduced to small scale farms of up to 0.5 – 10 ha. Consequently, about 81% of small-scale farmers occupy holdings of less than 2 ha (MoA, 2009).

Increasing agricultural productivity can also be achieved through smallholder agriculture commercialization. This transformation can be realized through key institutions in agriculture, livestock, forestry and wildlife, increasing productivity of crops, livestock and tree cover, improving market access for smallholders and introducing land-use policies that advocate for better use of the high and medium potential lands (ASDS, 2010).

In Kenya, there are various land tenure systems being practiced. These include communal land, Government trust land, and privately owned land. The communal land ownership system is one that follows the traditional customary rights, where all individuals in that community have a right to use land though they cannot sell it. Government trust land is land held by ministries, state corporations or other public institutions for public use. Privately owned lands are those that have been registered under freehold or leasehold system. The owners of such land can use it as collateral to access credit (MoA, 2009).

Over the years, land ownership that focuses on individual ownership and management of land that allows property inheritance by children has greatly led to land fragmentation. Having a very small piece of land and many children, leads to land being sub-divided into fragments that are not viable for production. Land fragmentation eventually leads to sub-optimal use of factor inputs lowering overall returns expected from a certain parcel of land. The factors that propagate this are loss of time due to traveling to plots, wastage of land along borders, inadequate monitoring, and the inability to use machinery such as tractors and harvesters (ASDS, 2010).

Land is considered as one of the most important resource in agriculture and lack of access to it one of the major causes of poverty (UNDP, 2002). The scarcity of agricultural land makes the issue of land use policy a critical one. Policy makers for a long time have been worried by the effect of land fragmentation on agriculture because it is expected to be a negative effect. Policies on land consolidation are frequently implemented to soften the degree of land fragmentation.

Different literature has looked at the issue of land fragmentation. Land fragmentation has been a big issue in many countries since the 17th century. The existence of fragmented landholdings is regarded a feature of less developed agricultural systems (Van Hung et al., 2007; Hristov, 2009). It can be a major obstacle to agricultural development, because it hinders agricultural mechanization, causes inefficiencies in production, and involves large cost to alleviate its effects (Thapa, 2007; Tan et al., 2008).

As a result of the effects of land fragmentation, European countries like Netherlands and France and African countries like Kenya, Tanzania and Rwanda have implemented numerous land consolidation and reform policies to reduce fragmentation (Sabates-Wheeler, 2002;Sundqvist and Andersson, 2006). In Kenya, land consolidation and land reform policies have not been fully implemented because the government cannot take a high moral ground in Kenya's land reform issues. This is because the government is solely responsible for the irregular allocation of public land to reward its political supporters.

Land fragmentation at the household level depends on factors like external policy, market factors, agro-ecological conditions and farm household socio-economic characteristics. This study will look at land fragmentation as a phenomenon existing in farm level management where people operate a number of owned non-contiguous plots at the same time.

Kisii County is highly dependent on agriculture and it is characterized by smallholder farming households. This is because most households occupy holdings that are less than 10 ha due to the rampant land fragmentation that is being propagated by the ever increasing population growth rate. The ever increasing population leads to increased pressure on land forcing people to divide their land. This leads to land fragmentation as they try to balance between agriculture and settlement. This conflict becomes intense to an extent that the land allocated to agriculture becomes so small to sustain better agricultural practices hence leading to reduced agricultural productivity. The ever increasing division of agricultural land continuously reduces the capacity of the land to sustain food production and cash crop farming. Thus fragmentation is Kisii has gone below the economic threshold leading to low productivity. Hence the productivity at this level is low that it needs evaluation.The empirical findings of this study will provide the government and agricultural stakeholders with firsthand evidence on the current situation as they try to achieve food security, eradicating poverty and hunger.

II. Methodology

2.1 Study area and Sampling techniques

The study was carried out in Kisii County which is an area highly characterized by high population, productivity and extensive land fragmentation. The study focused on two divisions (sub-counties) that isKeumbu and Kiogoro in the former Kisii Central District. The County receives rain almost throughout the year, although there are two rainy seasons (February to June and September to November). The average rainfall is over 1500 mm and is quite reliable, helping to support cash crops (such as coffee, tea and pyrethrum) and subsistence crops (maize, beans, millet and potatoes). Temperatures can range from 16^{o}C to 27^{o}C.

Kisii County is located to the south east of Lake Victoria and is bordered by six counties with Narok to the south, Migori to the west, Homa Bay to the north west, Kisumu to the north, Bomet to the south east and Nyamira to the east. It has an average area of 1,317.4 Km^2. The county has a population of 1,152,282 (Male – 48 %, Female – 52%), population density of 874.7 people per Km^2 making a national percentage of 2.9 %. This gives the county an annual growth rate of 2.75% (KNBS, 2010). The age distribution is 0-14 years (45%), 15-64 years (51.6 %), 65+ years (3.4%). The total number of households is 245,029 (KNBS, 2010).

The sampling unit for this study consisted of all smallholder farming households in Kisii County. Kisii County has a total of 245,029 households (KNBS, 2010). Sampling was done using Multi-stage sampling procedure where Kisii County was purposively selected because of its high productivity and high population. Secondly, random sampling was done to select Kiogoro and Keumbusub-county's. In the third and final stage, simple random sampling approach was used to select small holder farmers that comprised the sampling units. A sample of 196 households was randomly selected for the study.

Primary data was collected using a structured questionnaire was used to gather information on the family setup, land sizes of the household, education level of parents and their dependents, the produce from farms, farm and non-farm incomes, distance to input buying places, access to extension services, group membership, credit access, quantities of seeds, planting and top dressing fertilizer, certified seeds, labour man-days and cropping area.

2.2 Data analysis

The study used the stochastic frontier model approach to estimate the production function and determinants of technical inefficiency among smallholder farmers. The stochastic model began with Aigner and Chu, (1968) who suggested a composite error term. There a different ways of measuring technical efficiency; parametric and non-parametric (Sepehrdoust, 2011). Stochastic frontier follows the parametric approach as developed by Meeusen and van den Broeck (1977). The Data Envelopment Analysis (DEA) a development of Charneset al. (1978) follows the non-parametric way. With the stochastic frontier approach, unlike the other parametric frontier measures, there is an allowance for stochastic errors from statistical noise or measurement errors. The stochastic frontier model decomposes the error term into a two-sided random error that captures the random effects outside the control of the farm.

With the given potential estimation biases of the two-step procedure for estimating technical efficiency scores and analysing their determinants, this study used the one-stage procedure suggested by Battese and Coelli (1995).

$$\ln(y_i) = f(x_{ij}, \beta) + \varepsilon_j \qquad (1)$$

Where y is the level of output on the j[th] plot, x is the value of input iused on plot j,
$\varepsilon_i = v_j - u_j$is the composed error term, and $v_j$is the two-sided error term while $u_j$is the one-sided error term.

The random component $v_j$is assumed to be identically and independently distributed as N(0, σ^2_v) and is also independent of u_j. The random error represents random variations in the economic environment facing the production units.

The inefficiency component distribution can take different forms, but is distributed asymmetrically. The inefficiency component is a representation of features reflecting inefficiency such as farm-specific knowledge, the will, skills and effort the farmers, work stoppages, material bottlenecks and other disruptions to production (Aigneret al., 1977; Lee and Tyler, 1978). Meeusen and van den Broeck (1977) assume that $u_j$has an exponential and a half-normal distribution, respectively.

The stochastic model can be estimated by ‘corrected’ ordinary least squares (COLS) method or the maximum likelihood method. It follows the Battese and Coelli (1988) and Battese and Coelli(1995) using Battese and Corra (1977) parameterization. The maximum likelihood (ML) estimates of the production function (1) are obtained from the following log likelihood function.

$$\ln L = \frac{N}{2}\ln(\frac{\pi}{2}) - \frac{N}{2}\ln\sigma^2 + \sum_{j=1}^{N}\ln\left[1 - F\left(\frac{\varepsilon_j\sqrt{\gamma}}{\sigma\sqrt{(1-\gamma)}}\right)\right] - \frac{1}{2\sigma^2}\sum_{j=1}^{N}\varepsilon_j^2 \qquad (2)$$

where$\varepsilon_j$are residuals based on ML estimates, N is the number of observations, F( ) is the standard normal distribution function;

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

$$\gamma = \sigma_u^2 \big/ \sigma^2$$

Assuming a half normal distribution of u, the mean technical efficiency is measured by:

$$E\left[\exp\left(-u_j\right)\right] = 2\left[\exp\left(-\gamma\sigma^2/2\right)\right]\left[1 - F\left(\sigma\sqrt{\gamma}\right)\right] \qquad (3)$$

Where F is the standard normal distribution function. Measurement of farm level inefficiency requires the estimation of nonnegative error u. Given the assumptions on the distribution of v and u, Jondrowet al. (1982) first derived the conditional mean of u given ε. Battese and Coelli (1988) derived the best predictor of the technical efficiency of plot or farm j, is $TE_j = \exp(- u_j)$ as:

$$\mathrm{E}\left[I\exp\left(-u_j \middle| \varepsilon_j\right)\right] = \left[\frac{1 - F(\sigma_A + \gamma\varepsilon_i/\sigma_A)}{1 - F(\gamma\varepsilon_i/\sigma_A)}\right]\int \exp\left(\gamma\varepsilon_i + \sigma_A^2/2\right) \qquad (4)$$

Where:

$$\sigma_A = \sqrt{\gamma(1-\gamma)}\sigma^2$$

The average level of technical efficiency, predicted as TE_jin equation (4) is a function of socio-economic and institutional factors. Using the Tobit model, the factors influencing technical efficiency were determined since technical efficiency ranges between 0 and 1. 0 depicts the lower limit while 1 depicts the upper limit. Thismethod was also used by authors like Nyagakaet al. (2009).

Januszweki Index

The Januszewki (JI) index was adopted in measuring land fragmentation. This index is located within the range of 0 to 1. The smaller the JI value, the higher the degree of land fragmentation. The JI value combines information on the number of plots and average plot size(Jha et al., 2005). The index was computed as:

$$JI = \frac{\sqrt{\sum a}}{\sum \sqrt{a}}$$

where 'a' represents the parcel size and JI represents the Januszewki index.

Tobit Model
The equation is given as;

$$y_i^* = Z_i\beta + \varepsilon_i \qquad (5)$$

where:
y_i^* is a latent variable for the ith farm that is observed for values greater than η and censored for value less than or equal to η. The Tobit model takes into account censoring both from below and from above.
Z represents independent variables thought to influence efficiency. The β's are parameters to be estimated. The ε is the independently distributed error term assumed to be normally distributed with a mean of zero and a constant variance.
The y can be defines as:

$$y_t = y^* \; if \; y^* > \tau$$
$$y_i = \tau_y \; if \; y^* \leq \tau \qquad (6)$$

Because the farm specific technical efficiency range between 0 and 1, the τ can be substituted in equation 6 to get:

$$y_t = y^* \; if \; 0 < y^* < 1$$
$$y_t = 0 \; if \; y^* \leq 0 \qquad (7)$$
$$y_t = 1 \; if \; y^* \geq 1$$

The dependent variable is not normally distributed as it ranges between 0 and 1. The Model wil take this form:

$$y_i^* = \beta_o + \sum_{n=1}^{1} \beta_n Z_i + \varepsilon_i \qquad (8)$$

where:
Z will represent independent variables; age of the household head (years), education (years of schooling), gender of household head (1 if male, and 0 if female), non-farm income, membership to group (1=yes and 0=no) and farm size (hectares).
Using OLS estimation will give inconsistent and biased estimates because it underestimates the effect of parameters by reducing the slope (Gujarati, 2003).

III. Results and discussion

3.1 Sources of Technical Efficiency

The average total production of the main crop in Kisii County is 298.16 kgs of maize for one harvest season that represents a yield of 148 kgs per ha. This is approximately 3 bags of maize for each household (table 1). Most of the households use approximately 26 kilograms of planting fertilizer during every planting season. This will not increase or decrease with increase in acreage. Due to their poverty status, they prefer the subsidized priced fertilizer offered by the Kenyan government. The fragmentation index also shows how high land fragmentation is in Kisii County. Land has been so much subdivided either to cater for new homes or for planting different crops as most households are practicing intensive agriculture. The households use certified seeds of about 2 kgs per ha. This is low compared to other areas because most of them recycle the seeds from the previous harvest. Also the households used top dressing fertilizer to improve the productivity. Approximately 8 kgs were used per ha.

Table 1: Descriptives

	Sample (196)			
Variable name	Minimum	Maximum	Mean	Std. Deviation
Yield (kg/Ha)	0	3953	478.83	513.08
quantity of planting fertilizer used	.00	200.00	25.78	27.13
quantity of certified seeds used	.00	100.00	3.98	7.86
Quantity of top dressing fertilizer used	.00	125.00	14.54	20.64
JI(Fragmentation index)	.00	.30	.06	.03

The efficiency sources are differentiated if observed among farms. This is due to difference in roles played by farm and characteristics of farmers. Cobb-Douglas production function is used to estimate the efficiency and inefficiency levels of the households using some production inputs and farm characteristics on the output of crop production. In the efficiency equation, the quantity of planting fertilizer used, quantity of certified seeds used and fragmentation index were statistically significant at 1% level.

Fragmentation index was statistically significant at 1 percent and implies that it negatively affected productivity. Land has always remained the most important factor of production. With the ever increasing technologies, it becomes uneconomic to increase productivity with the highly fragmented lands in Kisii County. This is because it is hard to increase land sizes. The kind of technology in Kisii County is fixed at use of hoes and oxen ploughs. Uneconomic sub-division of land as experienced in Kisii, leads to land fragmentation affecting productivity.

Households in Kisii County practice intensive agriculture with very little mechanization. They rely on inputs such as fertilizer application as the only way of trying to improve the productivity. Lands are highly cultivated year in year out without leaving it to regenerate or even doing crop rotation. The amount of fertilizer used during planting is common and it is statistically significant at 1 percent. A 1 percent increase in the amount of planting fertilizer used increases output by 23.6 percent. Unlike use of top dressing fertilizer, which is not significant, planting fertilizer plays a significant part in increasing efficiency of these farms.

3.2 Land fragmentation effects on Technical efficiency

Land fragmentation index is negative and statistically significant at 1%. This indicates that land in Kisii County is highly subdivided and over used. A decrease in land fragmentation level by 1% will induce 13.56% increase in agricultural output. This result is consistent with that of Djokoto (2012), who estimated stochastic frontier model for Ghana using household data from 1961 to 2010.

Land fragmentation has been considered by many authors (Jabarin and Epplin, 1994; Blaikie and Sadeque, 2000), as a big obstacle to agriculture. It hinders its development by hindering mechanization, causing inefficient agricultural production and it will require a lot of costs to alleviate its adverse effects, resulting in a reduction in farmers' net incomes. This is made worse by the ever increasing agricultural market and industrialization of agricultural sector.

There are different problems that arise with land fragmentation. Some of the main ones are dispersion of the parcels, small sizes and irregularly shaped. In Kisii County, land has been subdivided into strips that are stretched downhill. This reduces access by road to the parcels of households because of their irregular shapes and many are on hilly sides. According to a study by Bentley (1987), discussions on land parcel dispersion of given households while considering the distance travelled to reach them began in 1826 by Johan Von Thunen in a publication entitled 'The Isolated State', who argued that the cost of farming increases with distance. This is because costs of moving labour, other farm inputs and machines from one parcel to another are increased due to increased travel time (Karouzis, 1977; Bentley 1987,; Niroula and Thapa, 2005), and therefore parcels far from the homestead are monitored and cultivated less intensively. Also small sized parcels of land and irregularly shaped hinder use of modern machinery and may require use of manual work in the corners and along the boundaries (Karouzis, 1977 and 1980; Bentley 1987). This is the case experienced by many households in Kisii County who depend on use of hoes and little use of animal traction method.

Table 2 shows the Maximum likelihood estimates of parameters of the frontier production/efficiency and inefficiency functions. The dummy variable for amount of planting fertilizer used is statistically significant at 1 percent level. It has a positive effect on the total amount of output per household. This shows that by using more of the planting fertilizer it will lead to higher technical efficiency, and hence, more output. A one percent increase in the amount of planting fertilizer used by farmers, output increased by 23.6 percent. Therefore for farmers to increase their farms technical efficiency, using more fertilizer is much better. This result is consistent with studies carried by Tchale (2009) in Malawi.

Table 2: Regression results for Stochastic production function

Efficiency variables	Parameter	Coeff.	Std. Err.
Lnquantplant (kg Ha^{-1})	β_1	0.2361	0.0667
Lnquantcert (kg Ha^{-1})	β_2	0.4048	0.1224
Lntop (kg Ha^{-1})	β_3	0.1375***	0.02416
Ji	β_4	-14.0276***	0.43845
Intercept	β_0	7.8980***	0.1988
Inefficiency variable			
lnHSZ	δ_1	-0.3934	0.2601
lnEHH	δ_2	-0.1383	0.2556
Accext	δ_3	-0.2343	0.2489
Lsize (Ha)	δ_4	-0.0744	0.08332
Intercept	δ_0	2.9224***	0.8116
Variance parameters			

Sigma-squared	σ^2	-1.998***	0.3779
Marginal Technical efficiency		36.82	
Log Likelihood		-238.172	
Wald chi2(4)		154.17	
Prob>chi2		0.000	
Number of observations		148	

*** significant at 1% , ** significant at 5%, * significant at 10%

The land fragmentation's negative influence on technical efficiency could be arising due to economies of scale factors. The smaller the land size being held by households, the more unlikely the household will use mechanization. This is due to their low income, and high chances that they will reuse the seeds or mix will quality seeds and minimal use of fertilizer leading to low output.

It can be argued that farmers occupying large farms use their land sparingly thus reducing depleting the soils off its nutrients making them more productive in the longrun. The small scale farmers cultivate their lands year in year out leading to reduced productivity hence increasing technical inefficiency. A study by Fernandez et al. (2009) on sugarcane farmers in Philippines concurs with this study. The findings of this study re-emphasize that land fragmentation has a negative impact on agricultural productivity.

In the inefficiency function, access to extension services, household size, education level of the household head and land size were not significant. Although from their signs, the dummy for access to extension services had a negative impact on technical inefficiency. A review on several studies done by Ali and Byerlee's (1991), shows that when farmers had access extension services, there was a negative influence to inefficiency. The coefficient for dummy for education level of the household head had a negative sign showing that with a higher level of education it would result to lower technical inefficiency. Household size dummy was presumed to have a positive effect on inefficiency. With availability of family labour, labour constraints would likely reduce on the farm. They would be able to finish farming activities in time making production more efficient.

3.3 Farm specific technical efficiency

The predicted farm technical efficiency were estimated using stochastic frontier function. The mean technical efficiency was 42.53%. The technical efficiency score are summarized in table 3.

The most efficient farm had a score of 89.6% and the least had 1.3%. This shows the gap that exists between farming households in the same area in terms of technical efficiency. Farms that are averagely technically efficient can be able to save upto 52.53% of yield loss if they try and achieve what most efficient farms manage. From table 3, the highest percentages of farmers (35.71%) were highly inefficient (less than 25%). 16% of the farms were above 75% efficiency level. More than half of the sampled households were less than 50% efficient. This shows that most farms need to improve on their efficiency to reach an average of above 50%.

Table 3: Technical efficiency of sample households

Technical efficiency level	Frequency	Percentage	Cumulative
Highly Inefficient (0-0.24)	70	35.71	35.71
Fairly inefficient (0.25-0.49)	41	20.92	56.63
Moderately Efficent (0.50-0.74)	53	27.04	83.67
Efficient (0.75-1)	32	16.33	100.00
Total	196	100.00	
Mean		42.53	
Std deviation		33.17	
Minimum		0	
Maximum		89.6	

IV. Conclusion and Recommendation

Technical efficiency in Kisii County, was found to be about 36.82%. Less than half the interviewed households were technically efficient and these households could easily improve to be fully efficient. The technical inefficiency was not significantly influenced by any of the variables used. For agricultural production to improve, the households need to be sensitized on importance of improving soil fertility and better ways of maintaining acceptable land sizes. Farmers need to be sensitized on diseconomies of land fragmentation and costs that come with their continued practice of land inheritance. This will help reduce technical inefficiency. Farmers need also to be taught on turning their farms in to agribusinesses in order to for them to be entrepreneurs. They will invest more on their farms, be able to generate more profits thereby increasing their farm incomes. This will help to create employment of youths who have shunned away from agriculture.

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