Technical Efficiency Analysis in Male and Female-Managed Farms: A Study of Maize Production in West Pokot District, Kenya

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1. Introduction

In Kenya, like many sub Saharan Africa (SSA) countries, the agricultural sector plays a very important role in the country's economy. It contributes immensely to employment and income generation for rural households, foreign exchange earnings, industrialization and economic growth. However, despite the policy reforms in recent years, aiming at liberalization of the agricultural sector from government control, there has been a decline in crop productivity. Maize, rice, cotton, coffee, among others, have been the worst affected crops, (Nyangito and Nzuma, 2004; Nyangito et. al., 2003). Reasons attributed to this decline in production include: area contraction, climatic factors, technological changes and prices (domestic and world market).

The poor performance of the agricultural sector in the past years has had tremendous consequences for the Kenyan economy. The gross national product (GNP) per capita income declined from US $ 389 in 1998 to US $ 324 in 2000. The country is becoming more and more food insecure and the proportion of the absolute poor is on the increase. The people most affected are those in the rural areas, (about 75% of the 29.7 million Kenyan population), who highly depend on agriculture for their livelihood. Communities in arid and semi-arid areas of the country (including West Pokot district) are particularly vulnerable to this food insecurity situation (Nyangito, et al., 2003). Multiple factors which contribute to the food insecurity phenomenon in these areas include: drought, livestock diseases, animal and crop pests, and limited access to appropriate technology, credit and information (Nyangito, et al., 2003). In addition, there has been a rise in the percentage of female headed households from 30% of all rural households being female headed by 1995 (World Bank, 1996) to about 37% female headed households in 2005 (Central Bureau of Statistics - CBS, 2005). The government of Kenya attributes the large number of female headed households to widowhood, divorce or separation, which generally are thought to contribute to lower levels of economic wellbeing and thus making these households more vulnerable to food insecurity (CBS, 2005).

Like in many SSA countries, in Kenya, differences in farming systems, social and cultural institutions complicate measuring gender differentials in crop production. Nonetheless, it is usually possible to use technical efficiency analysis to assess the impacts of these gender differentials on crop production, where women and men manage separate plots. In this case, technical efficiency analysis evaluates the abilities of the farm manager to produce maximum possible output, given input levels and technology (Farrell, 1957 as cited by Luibrand, 2002). What remains unclear however is, the extent gender differences in farm resource ownership and use of smallholder farmers, affect crop productivity. This paper therefore endeavours to examine this issue, with specific reference to maize production in West Pokot district, Kenya. The paper focuses on maize since it is the main (staple) crop produced and consumed in Kenya, with a per capita consumption average of 103 kilograms per year (Central Bureau of Statistics, 2003; Ouma, et al., 2004). To be able to obtain optimum yields, maize production requires the use of a lot of inputs. However, the lack of these inputs in adequate amounts has contributed to the decline in productivity.

2. Objective and Hypothesis

This paper aims at examining the effects of gender differentials in farm resource ownership and use on maize productivity in West Pokot district, Kenya. It goes further to assess the technical efficiency in maize production in male and female managed farms to identify and explain the factors that contribute to inefficiency in maize production. The underlying hypothesis in this paper is that: given the same level of production technology, there should be no significant differences in the levels of maize productivity between male and female farmers. Hence, any significant differences would be attributed to differences in access to production resources.

3. Research Methodology

A household survey was carried out in eight selected locations of West Pokot district. West Pokot district is located in the north-west of Kenya and lies in the arid and semi arid lands (ASALs) of Kenya. People in this district suffer from transitory and chronic food insecurity. Empirical evidence (Odhiambo, et al., 2004; Ouma, et al., 2002) has shown that the productivity of all major crops (including maize) cultivated in West Pokot district, is low. This low crop productivity is said to have immensely contributed to the prevailing food insecurity situation in the district.

Data were collected from a random sample of 167 farm households (120 male managed and 47 female managed farms). With the use of a self administered questionnaire, data pertaining to demographic and socio economic characteristics of the household were collected. Also collected were data regarding household asset base, financial characteristics (credit and savings), household expenditure, farm activities including data on crop and livestock production activities, division of labour, and access to agricultural extension services.

Model Specification

In this paper, the focus is on maize production, which is the main food and cash crop in the study area and Kenya as a whole. The Cobb-Douglas stochastic frontier production function has been used, in order to estimate the level of TE in a way consistent with the theory of production function. The Cobb-Douglas specification provides an adequate representation of the production technology, if emphasis is placed on efficiency measurement and not on an analysis of the general structure of the underlying production technology (Taylor, Drummond and Gomes, 1986). The Cobb-Douglas model is flexible and widely used in agricultural economics.

The Cobb-Douglas model can be specified as follows:

$$InY_1 = \beta_0 + \sum_{j=1}^{k} \beta_j In x_{ji} + V_i - U_i \quad (1)$$

Where: i indicates the i^{th} farmer of the sample (i = 1,2,3…n), In represents the natural logarithm, $Y_I$is the observed output quantity of the i^{th} farmer, x explanatory variables, β_0 is a constant, β_j is a vector of parameters to be estimated, V_i is an independent and identically distributed random error term, U_i is technical inefficiency effect, which is assumed to be non-negative random variables, independently (but not identically) distributed.

Aigner, et al, (1977) stated that, an important feature of the stochastic frontier production model is the decomposition of the error term **ε** into two independent components. The components are: the traditional random term $\mathbf{v_i}$ and the random variable $\mathbf{u_i}$, which is associated with the technical inefficiency, as shown:

$$\boldsymbol{\varepsilon} = \mathbf{v_i} - \mathbf{u_i}$$

The component v_i is assumed to be normally distributed with zero mean. The component u_i is one-sided and independent of v_i. u_i represents the shortfall in actual output from its maximum possible value, given by the stochastic frontier. In other words, it is distributed half normal or follows an exponential distribution. u_i is equal to zero for any production unit whose output lies on the frontier and it is greater than zero for any output lying below the frontier.

In the model estimation, the single-stage approach, otherwise known as the non-neutral approach, as put forward by Battese and Coelli (1995) was used. In this approach, the frontier model expresses the technical efficiency effects as a function of the vector of the farm specific variables and the random error term. According to Battese and Coelli (1995), the assumption of this approach is that, there are interactions between the farm-specific variables and the input variables. Hence, according to them, the technical inefficiency effects are expressed in terms of various farm-specific variables. Therefore, the estimation procedure entails the estimation of the production frontier and the technical inefficiency effects simultaneously.

Input variables included in the specific model used in the analysis are: fertilizer, quantity of manure, seeds, labour (expressed in hours) and credit. Additionally, other explanatory variables included are: land area under maize cultivation, distance to the main market, age of the household head, education of the household head, region dummy, gender dummy, and extension services. The specific model used in the analysis is therefore given as:

$$InY = \beta_0 + \beta_1 InX_1 + \beta_2 InX_2 + \beta_3 InX_3 + \beta_4 InX_4 + \beta_5 InX_5 + \beta_6 InX_6 + \beta_7 InX_7 + \beta_8 InX_8$$

$$+ \beta_9 InD_g + \beta_{10} D_c + \beta_{11} D_r + \beta_{12} D_e + V - U \quad (2)$$

Where:

In represents the natural logarithm, Y is total maize revenue, β_0 is a constant, $\beta_1 \ldots \beta_{13}$ are elasticities, X_1 is land area under maize cultivation, X_2 is labour input (expressed in man hours), X_3 is amount of seeds (in Kg per hectare), X_4 is amount of fertilizer (in Kg per hectare) X_5 quantity of manure used (in Kg), X_6 is age of household head, X_7 is education of household head, X_8 is distance to the main market, D_c is dummy for access to credit (1 = access to credit, 0 = otherwise), D_r is region dummy variable (1 = Kapenguria; 0 = Chepareria D_g gender dummy variable (1= male; 0 = otherwise), D_e is extension services dummy (1 = access to extension; 0 = otherwise), V is random error term, and U is the technical inefficiency effects.

The production functions for male and female managed farms were estimated separately. Another production function for the pooled regression (for all households) was also done with an inclusion of a dummy variable for the gender of farm manager (or household head). The analysis is aimed at carrying out an accurate diagnosis of whether sources of productivity differences, between male and female managed farms exist, so that important policy interventions for increasing productivity and welfare can be made. The software package LIMDEP 7.0 was used to carry out maximum likelihood estimation of the parameters of the stochastic frontier production function. A brief description of these variables is given as follows:

Access to extension services: it is expected that a farmer's production efficiency would be improved, if he/she has access to agricultural extension services. The extension agents provide information on new technologies to the farmers and information on markets for farm inputs and sale of produce.

The age of the farmer is be used as a proxy for measuring general farming experience and thus has an effect on efficiency. It is assumed that, older farmers are more experienced in farming activities and are better able to assess the risks involved in farming than younger farmers. This may contribute to the improvement of technical efficiency. However, the opposite may be true that, older farmers who did not receive a better education, may be technically inefficient than the younger ones. Education of the household head (in number of years of schooling) is taken into consideration. Education of the farmer is expected to have an effect on farm resource use and ability to adopt new technologies and hence have a positive impact on TE.

The effect of farm size on efficiency is a controversial issue. Small farms may be more efficient (in terms of transaction costs) than large ones. On the other hand, large farms have the advantage of attaining economies of scale by spreading fixed costs over more land and output, getting volume discount for purchased inputs or by achieving better markets and higher prices for their produce (Ogolla and Mugabe, 1996). In this paper, farm size refers to the land area used for the production of maize, and not on the total size of land owned by the farmer. Biasness in land ownership and access may result in productivity differences between male-managed and female-managed farms.

A farmer's ability to purchase farm inputs may depend on the financial situation of the household. Non farm income received could have an effect on crop production, since the farmer would be capable of purchasing farm inputs and pay for hired labour and machinery, this could positively affect productivity (Heidhues, 2004).

Access to credit from formal and informal institutions is important for agricultural productivity. Many poor rural farmers heavily rely on informal credit institutions to cope with food insecurity and its effects as well as to finance the purchase of farm inputs (Heidhues, 1995; Heidhues and Buchenrieder, 2004).

Regional dummy variable has been included in the model to capture the agro-ecological differences that affect farmers' TE. Farms are known to operate under different climatic and altitudinal conditions, soil quality, and physical infrastructure. Labour as an input is measured in terms of total man-hours used in the production during the cropping season, and is the sum of family labour and hired labour. Considering the level of technology generally used by smallholder farmers in producing maize in Kenya, the farmers tend to depend on family and communal/cooperative labour (Kimenyi, 2002).

Using improved seeds in crop production is one way of increasing productivity (in terms of quantity and quality) (Kiplang'at, 2003). Despite the low level of production technology used by smallholder farmers in developing countries, the use of improved seeds is said to be on the increase (Kiplang'at, 2003). The availability of these seeds is usually via extension agents or in the markets. Thus, farmers with more access to extension agents may have increased potential of using them appropriately, and subsequently improve crop productivity and their technical efficiency.

Use of chemical fertilizer is known to be a commonly used method in improving productivity and in the intensification of agricultural production as a whole. Chemical fertilizers play a big role in regions where the scarcity of farmland is a big problem and traditional fallow periods are either very short or no longer in existence. However, the appropriate use of these fertilizers is very important in achieving the desired results. Disproportionate use of fertilizers is usually common among farmers with little knowledge about them, or with little access to extension agents. In such a case, productivity may be affected negatively and hence a lower TE.

4. Results and Discussion

Descriptive Statistics

Overall, descriptive statistics in Table 1 reveal that women in the study site were disadvantaged in terms of accessing education, land, credit and extension services. T-test results show significant differences between male and female household heads in years of schooling attended.

Table 1: Summary Statistics of household Characteristics and inputs use in maize production

Characteristic	Mean values of household characteristics		
	MHH (N=120)	FHH (N=47)	T- test
Household size	7.13 (2.89)	6.96 (2.46)	
Household composition % that is:			
Male	51.20 (34.27)	48.79 (22.62)	
Female	48.8 (12.25)	51.21 (20.66)	
Adults	66.42 (25.66)	78.47 (25.66)	
Children	33.58 (27.06)	21.53 (26.78)	
Average age of household head (years)	51.97 (9.980)	38.94 (9.43)	
Years of schooling:			
Head of household	10.55 (4.54)	6.11 (5.32)	0.001***
Female household members	10.32 (2.68)	10.23 (2.77)	0.17
Male household members	12.01 (1.05)	12.30 (1.70)	0.19
Labour force (%)	76	64	
Access to credit (%)			
From formal institutions	25	19	
Informal institutions	73	81	
Access to Agriculture Extension services (%)	31	12	
Land owned	5.40 (6.20)	3.10 (5.46)	
Land under maize cultivation	2.85 (2.38)	1.60 (1.79)	
Fertilizer use (kg/ha)	51.17 (24.77)	42.45 (30.44)	0.0342*
Improved seed (kg/ha)	11.10 (3.56)	7.656 (7.656)	0.0321*
Manure (kg/ha)	34.82 (18.70)	30.25 (39.0)	0.773
Maize yield (kg per ha)	1461.61 (716.41)	1146.58 (123.58)	0.024*

Notes: Standard deviation in parentheses, *** indicates significance at level 1% and * at level 5%

In terms of labour force, male headed households were at an advantage, having 12% more labour force than the female headed households. There exist differences in input use particularly use of fertilizer and improved seeds, between the two categories of households. Male headed households have higher maize yields in comparison to the female headed households. A higher percentage of borrowing from the informal credit institutions shows the important role played by social networks in informal credit. However, informal credit alone could still be inadequate for improving farm productivity as noted by Heidhues, (1994) and Heidhues and Buchenrieder (2004). Better and unrestricted access to credit facilities is therefore a prerequisite for increasing crop productivity and technical efficiency.

Technical Efficiency Results

Estimates of the parameters of the stochastic frontier production function and inefficiency effects in maize production in the study area are presented in Table 2. The estimation was done firstly for all the 167 households in the sample that produced maize, with an inclusion of the gender dummy variable. The second and third regressions considered male and female managed farms, respectively. From Table 2, there are considerable variations in the explanatory variables, as indicated by the signs of the coefficients and the values of significance of the individual variables.

The signs in front of the estimates and their statistical significance indicate the relationship between the explanatory variables and the dependent variable and further help in explaining the effects a variable had on the technical inefficiency of maize growers in the study area. A positive sign of a parameter estimate suggests the likelihood of the response increased with the level or presence of the variable, with the remaining variables held constant. Conversely, a negative sign suggests that the likelihood of response decreased with the level or presence of the variable.

The estimates of the production function are elasticities. Implying that the individual inputs expresses the percentage increase or decrease in output that will result if an input is increased or decreased by 1%, holding all other inputs constant. In the pooled regression (all Households), the output elasticities for the farm inputs; labour, fertilizer seeds and manure are positive as expected. This shows that they positively contributed to maize production in the study area. The coefficient for credit is surprisingly negative for the pooled regression (all households) and for female managed farms, but positive (although not significant) for male managed farms. The positive coefficient of credit for male managed farms indicates that their access to credit positively contributed to their yields and consequently, their technical efficiency (TE). A negative coefficient for access to credit dummy means that farmers tended to be technically inefficient without access to credit.

The estimates for the coefficient associated with education of the household head are positive and significant for all three analyses, as expected. A farmer's educational attainment increases his ability to understand and evaluate information on new production technologies and hence, increasing his productivity. This emphasizes the significant role education plays in influencing the TE of farmers. This finding is in line with that of Bedi, et al. (2002). Likewise, access to extension services contributed to the improvement of the TE of farmers in the study area, as indicated by the positive coefficients in all the three regressions.

With the production technology used for maize production in the study area being labour-intensive, labour was a critical input. With the availability of land, the amount of labour (in man-hours) available, determined the farm size (*ceteris paribus*). Thus, a positive and highly significant labour coefficient for male managed farms implies that labour contributed positively to maize production. One reason why the labour coefficient for female managed farms is negative might be due to low labour productivity which has a negative effect on TE in female managed farms.

The coefficient for chemical fertilizer (basal fertilizer) is positive and significant for all the three regressions. The positive and significant coefficient is an indication of how important this input was to maize growers in the study area. It is the largest coefficient for both male and female managed farms.

Among the estimated coefficients of the explanatory variables that determined inefficiency, the coefficients for the gender and region dummy variables are both negative and significant. A negative and significant coefficient for the gender dummy variable indicates that there were significant differences in maize productivity between male and female managed farms. With their better access to education, credit and farm inputs, male farmers made better use of their farm resources than female farmers. The findings in this study points to special characteristics and constraints experienced by female farmers in West Pokot district, which contributed to their lower productivity relative to that of men farmers. This phenomenon can be attributed to lower human capital for women in the study area relative to men.

The coefficients for the region dummy variable are negative and significant for all the three regressions, confirming that region was a contributing factor to the inefficiency of maize farmers in the study area. The TE of farmers in Chepareria was much lower than that for farmers in Kapenguria. In Kapenguria, farmers had better access to markets and extension services due to better roads in this division. Consequently, differences in productivity in the two divisions can be attributed to differences in soil quality and climatic conditions both of which were not controlled for in the analysis.

In this study, the assumption on the age of the household head is that, general farming experience increases with age and thus, positively influences the TE of farmers. The estimate for age in the analysis for all households is negative, meaning that, the TE of farmers did not increase with age as expected. This finding is in line with findings by Brümmer and Pannin (2000) who found a decrease in TE with increase in farmer’s age. Younger farmers with a better education are more open to the adoption of new technologies than the older ones. However, in the separate analysis of male and female headed households, the age of the household head has a positive and significant coefficient for male headed households and a negative coefficient for the female headed households. In female headed households, increase in age led to inefficiency while the opposite is true in male headed households.

The estimates for the distance to the main market variable are positive, implying that the distance to the market centre contributed to farmers' TE levels. The closer farmers are to the market centres, the more efficient they tend to be. A shorter distance to market centres is expected to cut down on transportation costs. Better access to markets also facilitates the easy procurement of commercial farm inputs and the sale of farm produce, and thus improving the TE of farmers.

Table 2: Maximum likelihood estimates for the parameters of the stochastic frontier production function for maize production in West Pokot, Kenya

	All Households (Regression 1)		MHH (Regression 2)		FHH (Regression 3)	
Variables	Coefficient	T-value	Coefficient	T-value	Coefficient	T-value
Constant	10.600	10.438***	7.569	8.880***	8.975	6.219***
Gender dummy	-0.869	-5.551***	…	…	…	
Region dummy	-0.742	-4.818***	-0.460	-4.759***	-0.368	-2.490**
Farm size	0.553	4.879***	0.725	10.081***	0.524	3.619***
Education of HH	0.158	1.762**	0.341	1.669*	0.220	2.295**
Age of HH head	-0.229	-0.840	0.350	2.79***	-0.129	0.402
Distance to market	0.123	0.425	0.122	0.222	0.102	0.132
Extension services	0.087	0.577	0.141	1.335	0.079	0.05
Labour	0.440	0.430	0.154	3.589***	-0.189	-0.151
Fertilizer	0.135	1.646*	0.957	2.165**	0.248	2.298**
Seeds	0.033	0.408	-0.597	-0.491	-0.277	-1.631
Credit	-0.037	-0.290	0.652	-0.013	-0.612	-0.409
Manure	0.086	0.219	0.035	0.123	0.065	0.0
Log Likelihood function	-80.234		-67.85		-13.763	
Number of observations	167		120		47	
Variance parameters						
Sigma-squared - σ^2 (v)	0.612		0.041		0.032	
Sigma-squared - σ^2 (u)	0.782		0.229		0.239	

Note: … denotes variable not included in the analysis
***; ** and * denotes significance at 1%, 5% and 10% levels respectively
FHH – female headed households; MHH – male headed households

The positive and highly significant estimates of farm size for all three regressions suggest that the TE of farmers in the study area increased with an increase in farm size. This result can be explained in terms of ability of farmers with large farms to use their farms as collateral to obtain credit, which in turn can be used to procure farm inputs and pay for hired labour and machinery. Also, the advantage of attaining economies of scale could be a contributing factor, since fixed costs could be spread over more land and output, and farmers may get volume discounts for purchase of inputs. This finding is in agreement with that of Ogolla and Mugabe (1996). However, it disagrees with a study by Luibrand, (2002) in Vietnam, which states that farmers with larger farm sizes tend to be less technically efficient.

It is evident from the estimates of the variance parameters that technical inefficiency effects were present in both categories of households. The parameter responsible for the inefficiency effects is the variance of *u* (which is the variance of the output below the frontier).

Conclusion

A Cobb-Douglas stochastic frontier function is applied in the analysis of farm level data of maize production in Kenya. The empirical result show that out of the explanatory variables identified, the main factors that tended to contributed significantly to technical efficiency are education of the farmer, access to credit, fertilizer use and distance of the farm to the main road. Education of the farmer had a positive and highly significant impact on the efficiency of maize production. Women farmers were disadvantaged given their low levels of education. Access to credit was a constraint to female farmers and affected their technical efficiency. The elasticity for fertilizer use show that a higher intensity in fertilizer application in maize production may contribute to increase in yields. It is evident from the estimates of the variance parameters that technical inefficiency effects were present in both male and female managed farms. Results reveal that efficiency of the farms is associated with high level of input use, human and financial capital characteristics of the farm households.

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