International
Scholars
Journals

International Journal of Agricultural Economics and Extension ISSN 2329-9797 Vol. 7 (2), pp. 001-010, February, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Estimation of farm level technical efficiency in small scale maize production in the Mfantseman Municipality in the Central Region of Ghana: A stochastic frontier approach

Felix Larry Essilfie*, Maxwell T. Asiamah and Fred Nimoh

Department of agricultural economics, agribusiness and extension, Kwame Nkrumah University of Science and Technology, P. M. B, Kumasi, Ashanti Region, Ghana.

Accepted 10 October, 2018

The primary objective of the study was to estimate the levels of technical efficiency in small scale maize production in the Mfantseman Municipality of Ghana using the Stochastic Frontier Approach. The study also attempted to determine some socio-economic characteristics and management practices which influence technical efficiency in maize production. Responsiveness of yield to production inputs was also estimated by computing input elasticities. The marginal value product for fertilizer, labor and seed were also calculated. Finally, the marginal physical products, average physical products, relative efficiency of resource use and the returns to scale of input use were calculated. Results indicated that the mean technical efficiency of small scale maize production in the study area is 58%; however, this ranges from 17 to 99%. There is distinct and inter gender variability in technical efficiency in the maize producing villages. In addition, the number of years of school the farmer has had in formal education, age of the farmer, household size, and off – farm income activities of the farmer impact on technical efficiency. The estimated marginal physical products showed that, ceteris paribus, each additional unit use of maize seed increased output by 31 kg (0.31 bags). Fertilizer also increased output by 12 kg (0.12 bags) and labor increased output by 29 kg (0.29 bags). Lastly the estimated return to scale is 1.49 indicating increasing returns to scale of maize production in the study area.

Key words: Stochastic, production, frontier, technical efficiency, Mfantseman.

INTRODUCTION

Maize has been cultivated in Ghana for several hundred years. After being introduced in the late 16th century, it soon established itself as an important food crop in the Southern part of Ghana (Morris et al., 2001). Very early on, maize also attracted the attention of commercial farmers, although it could not achieve the economic importance of traditional plantation crops, such as oil palm and cocoa (Morris et al., 2001). Over time the eroding profitability of many plantation crops(attributable mainly to increasing disease problems in cocoa, deforestation and natural resource degradation, and falling world commodity prices) served to strengthen interest in commercial food crops, including maize (Morris et al., 2001). Today, maize is Ghana’s most important cereal crop. Maize is the most widely consumed staple food in Ghana. A nationwide survey carried out in 1990 revealed that 94% of all households had consumed maize during an arbitrarily selected two-week period (Morris et al., 2001). An analysis based on 1987 data showed that maize and maize - based foods accounted for 10.8% of household food expenditures by the poor, and 10.3% of food expenditures by all income groups. (Morris et al., 2001).Maize production is one of the major farming activities undertaking by the farmers in the

---

*Corresponding author. E-mail: flexoo2006@gmail.com.

Mfantseman Municipality. The Ghana government's policy objective for the grain (such as maize) sub-sector is to encourage increased production so that self-sufficiency and food security for the country can be achieved. However, the performance of maize production has been dwindling due to poor access to credit in spite of numerous Agricultural Financial support institutions (such as Agricultural Development Bank etc.), inadequate use of recommended technologies, high costs of inputs, inadequate agricultural extension services, low prices from the agricultural market reforms resulting in lower input use, and high level of technical and allocative inefficiencies. Lack of credit translates into inadequate working capital, and therefore, farmers are unable to purchase productivity-enhancing inputs such as seeds, fertilizers, pesticides and land preparation. One way of reducing the cost of production is to increase farm output by increasing technical efficiency. In this regard, it is necessary to quantify current levels of technical efficiency in the study area so as to estimate losses in production that could be attributed to inefficiencies due to differences in socio-economic characteristics and management practices. The main objective of the study is to estimate the farm level technical efficiency in small-scale maize production among the maize farmers in the municipality. Specifically, the study seeks:

1. To determine the technical efficiency of maize production in the Municipality.
2. To estimate the level of responsiveness (elasticity) of yield with respect to the factor inputs; namely seed, labor and fertilizer.
3. To estimate the Return- To- Scale for the production frontier, APP, MVP and MPP for each input.
4. To examine the economic efficiency of input use in the study area.

Statement of hypothesis

The null hypothesis specifies that each small-scale maize farmer in the study area is technically efficient and that variations in actual maize output are due to random variations.

Concept of production and efficiency

In explaining the relationship between output and input a production function model is necessary. According to Kibaara, 2005, a production function model specified as:

$$Q = f(S, F, L) \tag{1}$$

Where *Q* represents output, *L* represents the amount of labor; *S* represents quantity of seeds used in production of *Q* while F represents the amount of fertilizers applied. The production relationship can be specified in several forms such as linear functional forms, Quadratic functional forms, Cobb-Douglas functional form etc. The marginal physical product (MPP) of an input is the extra output that can be produced by employing additional unit of that input while holding all other inputs constant (Kibaara, 2005). Example:

$$MPP_L = \frac{\partial Q}{\partial L} = f_L \tag{2}$$

This is derived from the first derivative of the production function. However, if labor is employed indefinitely while holding all the other inputs of production constant, this results into diminishing marginal productivity where the rapid increase in use of additional labor results to lower productivity (Kibaara, 2005). Hence, the second derivative is less than zero:

$$\frac{\partial MPP_L}{\partial L} = \frac{\partial^2 q}{\partial L^2} = f_{LL} < 0 \tag{3}$$

The average physical product (APP) is a measure of efficiency. The APP depends on the level of other inputs employed in the production process (Kibaara, 2005).

$$App_L = \frac{Output}{Labor} = \frac{Q}{L} = \frac{f(S, F, L)}{L} \tag{4}$$

The concept of returns to scale shows how output responds to increase in all inputs together (Kibaara, 2005). Returns to scale can either be constant, decreasing or increasing. The elasticity of production measures the proportionate change in output with respect to a proportionate change in inputs. This is derived by dividing the MPP by the APP (that is, MPP/ APP).

Determining the economic efficiency of input use

Given the output price (Py), its marginal value product (MVP) can be computed by multiplying (MPP*Py). Relative efficiency of resource use (r) is the ratio of MVP of an input to the corresponding marginal factor cost (MFC) of that input (MVP/MFC). The MFC of an input is the cost of one unit of a given input. If r = 1, input is efficiently used, if r > 1, input is underutilized and if r < 1, input is over utilized (Goni et al., 2007). Economic optimum takes place at a point where MVP = MFC. If relative efficiency (r) is not equal to 1, it implies that input use is not optimized (not efficiently utilized). Adjustment could therefore be made in input used in the production process to restore r = 1.

Assumptions of the Study

Several assumptions underlie this study:

1. The first assumption is that, the farmers have an identical production function.
2. It is assumed that the farmers' only aim is profit maximization and that inputs allocation is directed solely towards this end.
3. The farmers are fully knowledgeable about all the relevant factors including technical relationships, price, cost levels, institutions and attitudes of people which affect their operations.
4. It is also assumed that no unforeseen changes take place during the production process.
5. Additionally, the study assumes that all the key production inputs and socioeconomic characteristics are included in the specification of the stochastic frontier model.
6. Finally, the assumption of the composed error term $(e = v + u)$ that is symmetric independently distributed as $N(0, \sigma^2 v)$ random variables independent of *u.* Additionally, *u* is assumed to be nonnegative truncated half-normal distribution, $N(0, \sigma^2 u)$.

Technical efficiency

The technical efficiency of an individual farm is defined in terms of the ratio of the observed output to the corresponding frontier output, conditioned on the level of inputs used by the farm. Technical inefficiency is therefore defined as the amount by which the level of production for the farm is less than the frontier output (Kibaara, 2005). Technical efficiency is estimated from the error term (*ei*). The ei is an error term made up of two components: *Vi*is a random error having a zero mean as $(0, \sigma^2 v)$ which is associated with random factors such as measurement errors in production and weather, which the farmer does not have control over, $U_i$is a *non-negative* random variable associated with farm-specific factors which leads to the *ith* farm not attaining maximum efficiency of production. *Ui* is associated with technical inefficiency of the farm and ranges between zero and one (Kibaara, 2009).

It is important to note that technical inefficiency can only be estimated if the inefficiency effects are stochastic and has a particular distribution specification (Battese and Coelli, 1996). Some of the considered distributions for U_i are the truncated half normal, gamma and exponential distributions.

The stochastic frontier approach

The parameterized stochastic frontier function both embraces technical inefficiencies of the production process and the probabilistic, random effects leading to productive inefficiency (Burhan et al., 2009). In this sense, there appears a composite error term involving technical inefficiency and random effects. Therefore, stochastic frontier functions enable the researcher to measure both the technical efficiency sources and impact of measurement errors or factors that are not directly related with production process itself (Burhan et al., 2009). The estimated function appears as a frontier or benchmark with the parameter estimates indicating whether the enterprise or production unit is producing at the production or profit frontier. The next step is to measure the distance between the observed dependent variable and the benchmark value. This quantitative distance provides the value of technical inefficiency when random effects are disaggregated from the estimated composite error term. As the composite error term involves probabilistic outlier effects as well as the attributes of technical inefficiency, the out or in shifts from the frontier can be observed across enterprises. In order to disaggregate the effects of the random shocks, which refer to stochastic changes in the frontier across observation units rather than direct shifts in the frontier, it is assumed that the stochastic part of the error term follows a bi-directional normal distribution (Burhan et al., 2009). In addition to the normally distributed stochastic error term, the technical inefficiency error, referring to the inefficiency of the production-cost-profit function, is a part of the estimated composite error, which has a unidirectional distribution structure (discrete normal, Truncated, exponential, and gamma). Therefore, the composite error term involves the symmetrical stochastic error and unidirectional technical inefficiency term, referring to shifts of enterprises from the benchmark (Burhan et al., 2009). After the composite error term, the disaggregated and the technical inefficiency are obtained, the methodology enables interpretation of the reasoning of the technical inefficiency. In this, manner, the demographic and socio-economical situation of the farms and farmers are considered as independent variables explaining the retrieved technical inefficiency referring to the shifts from the benchmark due to technical incapability of enterprises (Burhan et al., 2009). Therefore, the inefficiency values are regressed against the demographic, environmental or structural features of the farms in order to determine the factors impacting technical inefficiency and their level of impact (Burhan et al., 2009). As it is understood for the case, the parametric methodologies, specifically the stochastic frontier approaches, produce inferable outcomes for the technical capacity of the production unit for either agriculture or other productive sectors.

RESEARCH METHODOLOGY

The study area

The Mfantseman Municipal assembly is located at Latitude 5°.7' to 5°.20' north of the equator and Longitude 0°.44' to 1°.11' west of the Greenwich Meridian. It has a total land area of 612km^2 and an arable land of 49,000 ha. The study area has a temperature range between 24 to 28°C, a relative humidity of 79% and an annual total rainfall of 900 to 1600 mm. The major crops grown in the Municipal are cereals (Maize), root and tubers (Cassava, Taro, Cocoyam and Yam), vegetables Fruits (pineapple mainly sugar loaf) and Tree crops (Citrus and Oil palm).

Sampling technique

A multistage sampling technique (purposively and random sampling technique) was adopted in selecting 100 maize farming respondents in four villages (Krofu, Atakwaa, Dominase and Kuntu) from the four operational zone (Mankessim Zone, Ekumfi Zone, Abeadze Zone and Saltpond/Nkusukum Zone) in the Municipal.

Method of data analysis

Descriptive data analysis in the form of Means, Standard deviations, Percentages and Frequencies were used to summarize the socio-economic characteristics of the maize farmers in the study area. The technical efficiency and the output were analyzed by using the technical efficiency and production models and test of hypothesis was done by using the likelihood ratio test.

The proposed production function

The stochastic frontier production function was independently proposed by Aigner et al., (1977) and Meeusen and Broeck (1977). The stochastic production function is defined by:

$$Y_i = f(X_i\,;\,\beta) + e_i \text{ where, } i = 1, 2, \ldots, N \tag{5}$$

$$e_i = v_i - u \tag{6}$$

Where Y_i represent the output level of the *ith* sample farm; $f(X_i; \beta)$ is a suitable function such as Cobb-Douglas or translog production functions of vector, X_i, of input for the *ith* farm and a vector, ß, of unknown parameters (Kibaara, 2005). *ei is* an error term made up of two components: *Vi* is a random error having zero mean, $N(0; \sigma^2 v)$ and it is assumed to be symmetric independently distributed as $N(0, \sigma^2 v)$ random variables and independent of U_i. On the other hand, U_i is a non-negative truncated normal, $N(0; \sigma^2 u)$ random variable associated with farm-specific factors, which leads to the *ith* farmer not attaining maximum efficiency of production; U_i is associated with technical inefficiency of the farmer and ranges between zero and one. N represents the number of farmers involved in the cross-sectional survey of the farms (Kibaara, 2005):

$$\hat{TE}_i = Y_i / Y_i^{*},$$

where $Y_i^{*} = f(x_i\,;\,\beta)$, *highest predicted value for the ith farm*

$$\hat{TE}_i = Exp(-u_i) \tag{7}$$

$$\text{Technical inefficiency} = 1 - \hat{TE}_i \tag{8}$$

Empirical model specifications

This study specifies the stochastic frontier production function using the Cobb-Douglas specification. The model is specified as follows:

$$\ln Y_i = \beta_0 + \sum_{i=1}^{3} \beta_i \ln X_i + e_i \tag{9}$$

$$e_i = v_i - u_i$$

Where Y_i is the output of the farmer and X_i are the inputs (Labor, Fertilizer and Seeds) and the β, s are the parameters to be estimated. The efficiency model is specified as follows:

$$u_i = \delta_0 + \sum_{i=1}^{6} \delta_i Z \tag{10}$$

The U_i is the inefficiency model and the variable Z_i (that is, Age, Number of years of schooling, Household size, Extension contact, Credit access and Off-farm income) are the farm/farmer characteristics that have direct influence on the farmers' efficiency (Idiong, 2007).Equation 11 shows a joint estimation of a stochastic frontier production function in stata 10:

$$\mathbf{lnyield} = \beta_0 + \beta_1 \mathbf{lnseed} + \beta_2 \mathbf{lnfert} + \beta_3 \mathbf{lnlab} + \delta_1 \mathbf{age} + \delta_2 \mathbf{schyrs} + \delta_3 \mathbf{HHS} + \delta_4 \mathbf{extcon} + \delta_5 \mathbf{cred} + \delta_6 \mathbf{offinc} + \mathbf{v} \tag{11}$$

Where: Yield = Output of maize in kilograms; Seed = Seed input in kilograms; Fert = Fertilizer input in kilograms; Labor = Labor in man – days; Age = Age of farmers in years; Schyrs = Years of schooling (Education); HHS = Household size of farmers (numbers); Extcon = Extension contact (1 = Contact and 0 = No contact); Cred = Credit access (1 = Access and 0 = No access); Offinc = Off – farm income activities (1 = Yes and 0 = No)

β_0 - β_i and δ_0 - δ_i = unknown parameters to be estimated.
V = Error term

The first section is the stochastic frontier production function while the second part captures the inefficiency variables. The model

Table 1. Summary statistics for variables in the stochastic frontier model for the small scale Maize farmers.

Variable	Unit	Mean	Std. Dev
Yield	kg/acre	805.66	184.59
Seed	kg/acre	7.45	0.81
Fertilizer	kg/acre	69.38	9.50
Labor	Man-days	77.37	24.56
Schooling	Yrs	4.52	3.94
HHS	Num	5.73	3.05

Source: Field survey (2009).

generates variance parameters which then follow that:

(12)

and the ratio of the two standard errors as used by Kibaara (2005) is:

$$\sigma^2 = \sigma^2_u + \sigma^2_v$$

According to Alemu et al. (2008), the variance ratio parameter which relates the variability of U_i to total variability can be calculated in the following manner;

$$\lambda = \sigma_u / \sigma_v \quad (13)$$

$$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2) \quad (14)$$

RESULTS AND DISCUSSION

Summary statistics

The study is conducted to provide baseline information for subsequent monitoring of smallholder production efficiencies to assess the impacts of changes in the agricultural policy environment on selected socio-economic factors in the study area. The Table 1 shows the summary statistics for the variables used in the stochastic frontier model.

The mean yield per acre was 805.66 kg. This was obtained by using: 69.38 kilograms of fertilizer, 7.45 kg of seed and 77.37 man - days of labor. The mean number of schooling years for the study area is 4.52 years with zero and 17 years as the minimum and maximum number of schooling years respectively. The mean household size for the study area is 5.73 with 1 and 12 as the minimum and maximum number of household size respectively.

Table 2 shows the descriptive statistics for the socioeconomic variables used in the inefficiency models. From Table 2, 58.6% of the respondents are 50 years and above and they are the most active work group that are involved in maize production in the study area. Table 2 also indicates that 54.5% are females and they dominate small-scale maize production in the study area. This was found because the males in the study area are into production of other cash crops particularly pineapple production. Only 19.2% have extension contact in the study area. The implication is that, majority of the small-scale maize farmers in the study area do not have extension contact. 93.1% of the respondents do not have access to credit. This indicates only few (6.9%) of the [illegible]

The technical efficiency from Cobb- Douglas

Frontier production function

Data are analyzed using different functional forms that is, the translog, quadratic, transcendental and Cobb-Douglas production functions. Table 3 shows the results of the stochastic frontier model from the Cobb-Douglas production function.

The estimate of the stochastic production frontier

The parameters and related statistical results obtained from the stochastic frontier production function are presented in Table 3. Seed and labor were positive (increasing) and significant factors which indicate that the use and allocation of these factors were profitable and as such a unit increase in these inputs will eventually result in an increase in maize output of the farmers. Fertilizer was not significant. It was observed that the small-scale maize farmers in the study area are rational in the use of fertilizer in that no farmer is able to apply two bags (100 kg) of fertilizer per acre of maize farm. This result confirms the findings of Idiong (2007) that small-scale farmers have the belief that a well paddle soil requires little or no fertilizer application.

Table 2. Descriptive statistics on other demographic features of the respondents in the study area.

Variable	Frequency	Percentage
Age (Yrs)		
20 – 29	11	11.1
30 – 39	11	11.1
40 – 49	19	19.2
50 plus	58	58.6
Gender (1 = Male and 0 = Female)		
Male	45	45.5
Female	54	54.5
Extension Contact (1 = Contact; 0 = No contact)		
Contact	19	19.2
No contact	80	80.8
Credit Access (1 = Access; 0 = No access)		
Access	6	6.1
No access	93	93.9
Off-farm Income (1 = Yes; 0 = No)		
Yes	64	64.6
No	35	35.4

Source: Field survey (2009).

Determinants of technical efficiency of sampled

Small-scale maize producers in the area

The Maximum Likelihood Estimates (MLEs) of determinants of technical efficiency of small-scale maize producers in the study area are presented in Table 3. The findings in Table 3 reveals that the coefficients for age is negative; indicating that technical efficiency increases with increase in age and farming experience respectively. In other words older farmers are more efficient than younger ones. These empirical results agrees with an observation by Beniam et al. (2004) that the older a farmer gets, the more experienced he/she will be. It was observed that older farmers appear to be more efficient than younger farmers due to their good managerial skills, which they have learnt over time (Beniam et al., 2004). Besides, given the importance and significance of land, labor, capital and other resources in farm production, it could be argued that young farmers are deficient in resources and might not be able to apply inputs or implement and certain agronomic practices efficiently (Beniam et al., 2004). As timely application of inputs and implementation of management is expected to enhance efficiency, young farmers may find this challenging (Beniam et al., 2004). The estimated coefficient of schooling years is appropriately signed in this study and statistically significant at 5% and it confirms with the findings of Oyewo et al. (2009) that farmers with more years of formal education tend to be more technically efficient in maize production, presumably, due to their enhanced ability to acquire technical knowledge, which makes them closer to the frontier output. The estimated coefficient of household size is positive and statistically significant at 10%. The implication is that large household size increases the population pressure on the farmers' limited resources due to increases in household spending (on health, food, education, clothing etc.) and thereby reducing timely operation of farming activities. Finally, off-farm income activity is negatively related to efficiency and statistically significant at 10%. This results agrees with the findings of Alemu et al. (2008) that the effect of off-farm income activity on farming could be negative if farmers have higher chances of obtaining off-farm and non-farm employment, ultimately, reducing technical efficiency.

The diagnostic statistics

It is evident from the study that the estimates for lambda (λ) and sigma – squared (σ^2) in the study area are 1.0745 and 0.6053 respectively and are statistically significant at 1%, indicating a good fitness and correctness of the specified distribution assumption. The

Table 3. The technical efficiency from Cobb- Douglas frontier production function.

Variable	Parameter	Coefficient	Z–Value
Stochastic frontier			
Intercept	β_0	1.7392**	2.19
lnSeed	β_1	0.8566***	6.00
lnFert	β_2	0.1868	1.30
lnLabor	β_3	0.4410***	2.97
Inefficient model			
Age	δ_1	-0.6886**	-2.10
Schyrs	δ_2	-0.1874**	-2.22
Hsehldsize	δ_3	0.1014*	1.75
Extcontact	δ_4	0.9572	1.55
Credit	δ_5	-3.1694	0.77
Off-farm income	δ_6	1.4047*	1.83
Variance parameter			
Sigma-squared	σ^2	0.6053***	3.70
Gamma	γ	0.7102**	1.19
Lambda	λ	1.0745	
Log likelihood Function		-110.96	
Mean technical Efficiency		58%	

Source: Field survey (2009) (***, **, * are 1, 5 and 10% significant levels, respectively).

lambda is the ratio of the variance of U to the variance of V, indicating that, the one – sided error term U dominates the symmetric error term V and so variations in the actual output of maize is due to differences in farmers' practices rather than random variation. Gamma (γ) is also a measure of level of the inefficiency in the variance parameter, it ranges between 0 and 1. For the Cobb-Douglas model used for the study area, it is estimated at 0.7102. This indicates that 71% of the total variations in maize output are due to technical inefficiencies in the study area.

The technical efficiency for the study area

In the study area the predicted technical efficiencies vary substantially among the maize farmers in the study area; ranging from 0.17 and 0.994 with the mean technical efficiency estimated to be 0.582 or 58%, a frequency distribution of technical efficiencies is presented in Table 4.

The Table 4 shows that very few of the farmers in the study area have technical efficiencies of 0.91-1.00; it also indicates that there is wider distribution of technical efficiencies among the small-scale maize farmers in the study area which reveals that more can be done for effecting improvements in the technical efficiencies of the small-scale maize farmers in the area.

Input elasticity and return-to-scale

Determination of elasticity is necessary for the estimation of responsiveness of yield to inputs. The inputs on the stochastic frontier are statistically significant and have the expected signs. Table 5 shows the results of the input elasticities for each input in the Cobb - Douglas frontier production function. A one percent increase in the quantity of fertilizer applied will increase maize output by 0.19% (P = 0.194) ceteris paribus. In addition, a one percent increase in seed rate, increased output by 0.86% (P = 0.000) and a one percent increase in labor will probably increase maize yield by 0.44% (P = 0.003).

The study shows that yield has the highest responsiveness to seed, followed by labor. The prior assumption was that yield is more responsive to seed than to labor. The result confirms this assumption and agrees with the results of Kibaara (2005) that there is a high tendency by some maize farmers to increase their maize yield due to the usage of more quality varietal

Table 4. Distribution of technical efficiency of small-scale maize farmers in the study area.

Efficiency class	Number of farmers	Percentage
≤ 0.50	18	18.2
0.51 - 0.60	11	11.1
0.61 – 0.70	45	45.5
0.71 – 0.80	13	13.1
0.81 – 0.90	9	9.1
0.91 – 1.00	3	3.0
Total	99	100

Source: Field survey (2009).

Table 5. Input elasticity and RTS.

Variable input	Elasticity
Seed	0.86
Fertilizer	0.19
Labor	0.44
RTS	1.49

Source: Field survey (2009).

seeds in production. As shown in the above results, all the input elasticities are inelastic; indicating that a one percent increase in each input results in a less than one percent increase in yield (Kibaara, 2005).The summation of the partial elasticity of production with respect to every input for a homogeneous function (all resources varied in the same proportion) is 1.49. This represents the returns-to-scale coefficient, also called the function coefficient or total output elasticity. If all factors are varied by the same proportion in the long-run, the function coefficient indicates the percentage by which output will be increased (Kibaara, 2005). In this case, the production function can be used to estimate the magnitude of returns-to-scale. Constant returns-to scale holds if the sum of all partial elasticities is equal to one. If this sum is less than one, the function has decreasing returns-to-scale: if more than one, as shown in this result, an increasing returns-to-scale exists. Therefore, an increase in all inputs by one percent increase maize yield by more than one percent.

Marginal physical product (MPP), marginal value product (MVP), marginal factor cost (MFC) and average physical product (APP)

In order to assess the condition of the farmers' output and profit maximization (Economic Efficiency of Input Use), marginal physical product (MPP), marginal value product (MVP) and average physical product (APP) are also estimated. Table 6 shows MPP, MVP, MFC, APP and MVP/MFC

Seed has the highest MPP: therefore an increase in maize seed by one kilogram is estimated to increase output by 0.31 bags (equivalent to 31 kilograms) per acre. An increase in fertilizer application by an additional kilogram is estimated to increase maize yield by 0.12 bags per acre (12 kilograms). On the other hand, additional labor, that is, a person-day, is estimated to increase the maize yield by 0.29 bags (29 kilograms) per acre. Given the level of technology and prices of inputs and outputs, economic efficiency of resource use is estimated by equating the Marginal Value Product (MVP) to the productive Marginal Factor Cost of the inputs. An input is optimally used if there is no significant difference between the MVP and the MFC, that is, if the ratio of MVP to the MFC is equal to 1 (MVP/MFC = 1). Table 6 shows that the ratios of MVP to MFC are less than unity (1) for all inputs except seed. This indicates fertilizer and labor are over utilized while seed is under-utilized. This confirms the findings of Kibaara (2005) that, maize production has not reached the optimal use of input (seed), and could probably benefit by increasing the quantity of seed used in maize production. The estimated MPP from this study are consistent with results from studies by Kibaara (2005) and Ingosi (2005). However, results from this study are probably lower because estimation is by a different function, a Cobb - Douglas, while Kibaara and Ingosi used translog and transcendental production functions respectively.

Table 6. Marginal physical product, average physical product, marginal value product, and marginal factor cost.

Input	MPP	APP	MVC	MFC	MVP/MFC
Seed	0.31	0.36	24.80	13.50	1.84
Fertilizer	0.12	0.63	9.60	24.00	0.40
Labor	0.29	0.66	23.20	40.00	0.58

Source: Field survey (2009) (APP = MPP/elasticity and MVP = MPP*output price and r = MVP/MFC).

Table 7. Likelihood ratio test (hypothesis testing).

Null hypothesis	Chi^2	Df	P > |Z|	Decision
H_0; u = 0	75.62	13	0.000	Reject H_0

Source: Field survey (2009).

Table 8. Range of technical efficiency by gender.

Range of T E (%)	Male (%)	Female (%)	Total
≤50	20	16.7	18.2
51 – 60	4.4	16.7	11.1
61 – 70	51.1	40.7	45.5
71 – 80	15.6	11.1	13.1
81 – 90	4.4	13.0	9.1
91 – 100	4.4	1.8	3.0
Total	100	100	100

Source: Field survey (2009).

Hypothesis testing

The null hypothesis specifies that each small-scale maize farmer in the study area is technically efficient in production and that variations in actual maize output are due to random variations. This is rejected among the small-scale maize farmers in favor of the presence of inefficiency effects in Table 7.

Technical efficiency based on gender

The farm-specific technical efficiency is segregated into two categories (Male and Female). Table 8 shows that 4.4% of the male farmers and 1.8% of the female farmers operate at over 91% mean technical efficiency, which are considered to be within the technical efficiency range. Therefore, this shows that most technically efficient farmers are in the male category. Moreover, 20% of producers in the male category and 16.7% in the female category, have a mean TE below 50%, and thus, are considered to be below technically efficient level.

However, analysis of TE of the whole sampled population indicates that 70.0% of the farmers are technically efficient (Table 4), that is, above an efficiency class of 60.0%. Further analysis shows that the male category has the higher number of farmers with the highest technical efficiency; where 75.5% of the producers in the male category compared to the 66.6% in the female category have mean technical efficiency above 60%. This implies that the males are more technically efficient in maize production than the female farmers in the study area. The Table 8 shows the technical efficiency class among sex in the study area.

CONCLUSION AND POLICY RECOMMENDATIONS

This study was conducted to estimate the technical efficiency of small-scale maize production in the Mfantseman Municipality and to explain variations in technical efficiency among farmers through managerial and socio-economic characteristics. Farm specific technical efficiencies are computed using 2008/2009 maize production cross sectional data from the four villages selected from the four operational zones in the Municipality. A stochastic frontier approach was used to estimate the technical efficiency using stata 10. Different production functional forms including translog, Cobb-Douglas and quadratic production functions were considered after which the Cobb-Douglas production function was extensively discussed. Results showed that the overall mean technical efficiency for the study area was 58%. This result indicates that, there is a 42% scope for increasing maize production by using the present inputs and technology. However, TE ranges between 0.17 to 0.994% among the maize farmers in the study area. Elasticity of inputs is computed. A one percent increase in seed is estimated to increase yield by 0.86%. In addition, a one percent increases in fertilizer rate increases yield by 0.19%, while an increase in labor by one person-day will probably increase yield by 0.44%. A prior expectation was that maize yield is more responsive to seed use than labor. The descriptive statistics shows a mean seed rate of 7.45 kg/acre, a value that is close to the recommended 9 kg per acre. There is lower responsiveness of yield to an increase in fertilizer. One possible explanation is probably because maize farmers are highly rational about the use of fertilizer and that no farmer applies up to 2 bags (100 kg) on an acre of maize farm. In addition, the issue of poor timing of fertilizer application could be another contributing factor to low responsiveness of yield to fertilizer. The average physical product (APP), marginal value product (MVP), and the marginal factor cost (MFC) were estimated and the MVP and MFC were equated to assess the optimal use (economic efficiency) of inputs. Results show that maize farmers are operating at the second stage of production. For the fertilizer and labor inputs MVP is less than their MFCs whiles for seed input, the MVP is greater than its MFC. This is an indication that the maize farmers can still optimize output and profit by increasing seed use and decrease fertilizer and labor use. Household characteristics have been evaluated and results show that level of education, age of the farmer, off-farm income and household size are the major factors that influence the technical efficiency levels of the farmers in the study area.

To improve the technical efficiency and optimal use of inputs in the study area, the following policy recommendations should be noted:

1. The positive correlation between access to credit and efficiency of the farmers implies that policies that will make agriculture credit from government and NGOs available to these farmers will go a long way in addressing their resource acquisition problems. This is because the use of agricultural credit to acquire inputs increases technical efficiency and thus shifts the actual production frontier closer to the potential frontier. Credit is necessary to encourage technical innovations, such as use of yield-enhancing inputs, which cost slightly more, but shifts production and improves the entire input-output relationship.

2. It was revealed by the study that years of schooling had a positive correlation with technical efficiency and therefore farmers should be encouraged to improve their levels of education by enrolling in Adult and or continuing Education Centers in the study area.

3. More effort should be made on the part of the extension agents in educating the farmers on technologies that will help them boost their efficiency levels.

REFERENCES

Aigner DK, Lovell CK, Schmidt P (1977). “Formulation and Estimation of Stochastic: Frontier Production Function Models.” J. Econom., 6:21-37.

Alemu BA, Nuppenau EA, Boland H (2008). Technical Efficiency of Farming Systems across Agro-ecological Zones in Ethiopia: An Application of Stochastic Frontier Analysis.

Battese GE, Sohail JM, Manzoor A (1996). “An Investigation of Technical Inefficiencies of Production of Wheat Farmers in Four Districts of Pakistan.”J. Agric. Econ., 47 (1): 37-49.

Beniam NJ, Tonye J, Wandji N, Nyambi G, Akoa M (2004). “Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon.

Burhan O, Ceylan RF, Kizilay H (2009). A Review of Literature on Productive Efficiency in Agricultural Production.Akdeniz University, Faculty of Agriculture, Department of Agricultural Economics. J. Appl. Sci. Res., 5(7): 796-801.

Goni M, Mohammed S, Baba BA (2007). Analysis of Resource-Use Efficiency in Rice Production in the Lake Chad Area of Borno State, Niger, Sept. 2007. J. Sustain. Dev. Agric. Environ., 3: 31-37.

Idiong IC (2007). Estimation of Farm Level Technical Efficiency in Smallscale Swamp Rice Production in Cross River State of Nigeria: A Stochastic Frontier Approach. World J. Agric. Sci., 3(5): 653-658.

Ingosi A (2005). Economic Evaluation of Factor Influencing Maize Yield in the North Rift Region of Kenya. Masters of Science Thesis, Colorado State University.

Kibaara BW (2005). Technical efficiency in Kenyan’s maize production: an application of the stochastic frontier approach. In partial fulfillment of the requirements For the Degree of Master of Science Colorado State University Fort Collins, Colorado.

Meeusen W, Van den Broeck J (1977). “Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error.” Int. Econ. Rev., 18: 435-444.

Morris ML, Tripp R, Dankyi AA (2001). Adoption and Impacts of Improved Maize Production Technology:A Case Study of the Ghana Grains Development Project. Economics Program Paper, 9 -01: 2-5

Oyewo IO, Rauf MO, Ogunwole F, Balogun O (2009). Determinants of maize production among maize farmers in Ogbomosho South Local Government in Oyo State. Agric. J., 4(3): 144-149.