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SMALL SCALE MAIZE PRODUCTION IN NORTHERN GHANA: STOCHASTIC PROFIT FRONTIER ANALYSIS

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ABSTRACT

The importance of small scale maize production to the development of Ghana is quiet clear however very little is known about their profit efficiency and its determinants. The study used the stochastic efficiency frontier model. A multistage random sampling method was used to obtain 144 small scale maize farmers across northern Ghana. The average measure of profit efficiency of 61% was recorded in the area with a minimum and maximum efficiency of 11% and 100% respectively. This implies there is an opportunity to increase profit by 40%. The inefficiency model showed that educational level, farming experience, and household size have negative coefficients, meaning that as these variables increases the profit efficiency of the farmer increases. Whiles the variables sex of farmer and age are positive and vice versa. This implies female farmers are more efficient than their male counterparts.

Keywords: small scale maize production, profit efficiency, stochastic frontier.

INTRODUCTION

Maize (*Zea mays*) is a major staple crop in Ghana. It is also an important component of poultry and livestock feed and to a lesser extent, a substitute in the brewing industry. Maize is an important commodity in West Africa sub-regional trade, particularly between Ghana, Burkina Faso, Mali, Togo and Niger through mainly informal trading. Maize is grown in the whole of Ghana with an estimated 15% grown in the northern sector of the country. On average, the volume of maize produced in Ghana increased by 13.3% in 2012. Currently, the national average maize yield is estimated at 1.6 tonnes per hectare. Using improved technologies, yields of 4 - 5 tonnes per hectare have been recorded in on-farm demonstration fields. Lower yields have been attributed to traditional farming practices, the use of low-yielding varieties, poor soil fertility and limited use of fertilizers, low plant population, and inappropriate weed control.

Obviously agricultural production is fraught with risks and unpredictability (lack of rainfall, storms damaging crops, floods etc.) and high inputs use do not always result in high returns. However generally speaking, improvements can most often be realized by farmers who do invest in using improved seeds, fertilizer and improved production practices etc.

The agricultural sector in Ghana, contributes significantly to the economy, with estimates as high as 37% of GDP in 2005 and 23.1% in 2012. The main staple crops produced in Ghana are maize, cassava, yam, and plantain. In general, these crops are produced and consumed across the country. Farming is dominated by smallholder production, estimated to contribute over 90% of national food production with the majority of these small scale producers being among the poorest households in Ghana.

Small scale farming faces several constraints including an effective lack of access to production inputs and efficient produce markets. New technologies such as improved seed varieties and agro-chemicals have been found to be considered as very expensive by the average small scale farmer who usually has very limited access to credit from the formal sector. This implies that adoption of technologies is low among small scale and so are resulting in low annual yields and incomes. Small scale farmers continue to use traditionally unproductive methods that result in low productivity and high post-harvest losses. As a result, the continuous use of the same plots of land season after season, without fertilizer application, the soil becomes less fertile, contributing to low yields. However, there are some farmers who are making the best use of their meagre resources and skills to raise themselves out of this situation. Such farmers have proven that they can be assisted to pull other framers out of poverty through better agro-business management so that they can become more efficient and competitive.

Conventionally, the performance of a firm is judged utilizing the concept of economic efficiency, which is made up of two components - technical efficiency and allocative efficiency (Kalarijan and Shand, 1999). According to Vensher (2001) a firm is said to be technically efficient when it produces as much output as possible with a given amount of inputs or produces a given output with the minimum possible quantity of inputs. Similarly, Ellis (1988) defines technical efficiency as the maximum possible level of outputs obtainable from a given set of inputs, given a range of alternative technologies available.

Though technical efficiency is as old as neoclassical economics, its measurement is not. Probably this is explained by the fact that neoclassical economics assumes full technical efficiency. Two main reasons justify the measurement of technical efficiency (Kalarijan and Shad, 1999). First, a gap exists between realized efficiency and theoretical assumption of full technical

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efficiency. It has been observed by Bauer (1990), and Kalarijan and Shad (1999) that where technical inefficiency exists, it will exert a negative influence on allocative efficiency with a resultant effect on economic efficiency.

The issue of technological efficiency has also caught the attention of researchers. Technological change occurs through processes, which can yield more output for the same or less quantity of input than older processes. Some researchers argue that the introduction of such a new process can be thought of as rendering all previous processes technically inefficient (Ellis, 1988). According to Meier (1995), under this view, ' technology' comprises the series of all known techniques for producing a particular output - though the invention of a new technology does not guarantee its availability to all producers. It should therefore be realized that there is a difference between inefficiency due to operating off the isoquant for a given technology as opposed to inefficiency due to failure to move to a different isoquant made possible by a new technology (Ellis, 1988). The former can be exemplified by a situation in which the same output of maize can be obtained by using a lesser quantity of the input. An example of the latter will be a situation in which a new technology is introduced and the firm is unable to use it for various reasons.

Ellis (1988) notes two forms of technological change; the first is process innovation, which improves the production of existing products; the second is product innovation, which develops sustainable improved outputs. While technological change represents innovation, improving technical efficiency under a given technology is essentially about catching up with what is technologically possible (Fare *et al*., 1997). The basic concept underlying the estimation of technical efficiency lies in the description of a production technology. Production technologies are usually represented by isoquants, production functions, costs functions or profit functions.

Several studies have attempted to estimate the efficiency of agricultural production (Xu and Jeffrey, 1998; Khem *et al*., 1999; Gavian and Ehui, 1999). According to Xu and Jeffrey (1998) empirical studies of production efficiency have employed a variety of modeling approaches including deterministic versus stochastic; parametric versus nonparametric; and programming methods versus statistical methods. On very broad basis, these techniques can be categorized into stochastic frontier production approaches and nonparametric mathematical programming approaches (Khem *et al*., 1999).

A review of the strengths and weakness of these approaches has been done by Ceolli (1995). The main strengths of the stochastic frontier approaches are that they deal with factors beyond the researcher's control and measurement errors (stochastic noise) and allow for statistical test of hypotheses that pertain to production structure and the degree of inefficiency. The weaknesses of this approach include the need to impose an explicit parametric form for the underlying technology and an explicit distributional assumption for the inefficiency term. The main strengths of the nonparametric approaches (also called Data Envelopment analysis, DEA) are that they avoid parametric specification of technology and the distributional assumption of the inefficiency term. Weaknesses of the DEA are that it is deterministic and attributes all deviations from the frontier to inefficiencies thereby rendering the model liable to measurement errors or other errors in the data set.

In the developing world, most of the studies that examine efficiency have focused on technical efficiency (Bravo-Ureta and Pinhiero, 1993). Without understating the importance of technical efficiency, improvement in economic efficiency will lead to greater production efficiency. Only few studies have examined the effects of technical change of efficiency (Xu and Jeffrey, 1998; Pierani and Rizz, 2003). Given the variety of empirical tools available the choice of the 'best' method is ambiguous (Xu and Jeffrey, 1998). In their view, to a certain degree, the choice between alternative modelling techniques is somewhat arbitrary since the ordinal efficiency ranking of farms obtained for alternative models are comparable.

In the stochastic frontier approach, the technical relationship between inputs and outputs of a production process is described by a production function which establishes the maximum level of output attainable from a given vector of input. As a result it is called the production frontier. Production frontier efficiency can be traced back to the seminal work of Farrell (1957). The Stochastic Production Frontier (SPF) was however developed independently by Aiger, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977).

It is necessary to review specific methodologies used by earlier researchers. Both Khem *et al*. (1999) and Xu and Jeffrey (1998) have used a dual stochastic frontier efficiency decomposition model though the Khem *et al*. (1999) went a step further by comparing the stochastic approach to a nonparametric method using the same data set. The common stochastic frontier function used by both studies is given as:

Where Y is output, Xa is input vector and β the vector of production function parameters, V is a random error term with zero mean, and U, a nonnegative one-sided error term which gives a measure of inefficiency. Both writers used the Cobb-Douglas functional form, which though less flexible compared to the translog functional form is self-dual and has been used in many empirical studies.

Estimation methods exist for the estimation of efficiency and inefficiency equations. These are: the maximum likelihood procedure, the corrected Ordinary Least Square method (COLS) (Jaforullah and Premachendra, 2003) and Zellner's Seemingly Unrelated Regressions (SURE) approach. In stochastic efficiency estimation the use of OLS results in parameter estimates which are less efficient (especially the intercept) compared to maximum likelihood estimates (Greene, 1980).

Since the stochastic frontier model is nonlinear, a nonlinear estimation procedure produces consistent and efficient estimates (Greene, 1980). According to Greene

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(1980), while OLS provides best linear unbiased estimates of the slope and the computed standard errors, it provides a downwardly biased estimate of the intercept. Consequently, he suggests that the OLS estimates of the intercept be adjusted by the largest positive OLS residual. This two-step procedure is what is called the Corrected Ordinary Least Squares (COLS) method.

Estimation of the factors that cause inefficiency has generated considerable debate in frontier studies. According to Khem *et al*. (1998) the most popular procedure is to first estimate efficiency scores and regress them against a set of firm - specific factors or to use nonparametric or analysis of variance (ANOVA). Whilst Kalirajan (1991) and Ray (1988) defend this two step procedure, Kumbhakar *et al*. (1991), Battese and Coelli (1995) challenge this approach by arguing that firm specific factors should be incorporate directly in the estimation of the production frontier because such factors have a direct impact on efficiency. Notwithstanding this criticism, the two-step procedure is still quite popular investigating the relationship between efficiency and firm - specific variables (Khem *et al*., 1998). Existing studies aiming to incorporate firm - specific effects directly into the frontier model are limited to the parametric approach (Kumbhakar *et al*., 1991; Battese and Coelli, 1995)

Similarly, Reifschneider and Stevenson (1991) suggest the expression of the inefficiency effects as an explicit function of a variable vector and a random perturbation, as well as the estimation of all the parameters in a single-stage maximum-likelihood procedure. Likewise, Bonilla *et al*. (undated) present a model for a stochastic production function, in which the technical inefficiency effects are specified to be a function of some firm - specific factors, together with their interactions with the input variables of a production frontier.

MATERIALS AND METHODOLOGY

Specifically this research is restricted to the northern part of the country which is mainly savannah. The dry land savannah zone of the Northern Region of Ghana occupies 40% of the country. It comprises sub−humid to semi−arid guinea and Sudan savannah. Although there are many constraints to farming, there are considerable opportunities too. Farmers have succeeded to intensify land use significantly. To continue this increase in food production for the exploding population is an enormous challenge. Agriculture is the predominant livelihood strategy for people in this area. The crops grown include Guinea corn, maize, yams and soybeans. Farm sizes are small. Livestock (cattle, sheep and goats) are owned mainly for subsistence purposes.

The small scale maize farmer living within northern Ghana was the unit of study. Small scale farmers were sampled through a multistage sampling approach. The region was classified in to three main regions representing the three ecological zones in the northern sector. These included northern, upper east and upper west regions. From each region three major maize producing districts were purposively chosen, after which one community each from the districts was randomly selected giving us a total of nine communities. 16 small scale maize farmers were randomly selected from each community giving us a total sample size of 144. The main data for the study was primary data, which was collected from the farmers using structured questionnaires. Data was analyzed using descriptive statistic and the stochastic profit frontier function model.

The stochastic profit frontier (SPF)

The SPF method of analyzing efficiency is chosen for this study. The justification is that, unlike other methods (for example the Data Envelopment Analysis, DEA) the SPF allows for the sensitivity of dada to random shocks by including a conventional random error term in the estimation of the profit frontier such that only deviations caused by controllable decisions are attributed to inefficiency (Joforullah and Premachandra, 2003). Inefficiency is assumed to be part of the error term consisting of two parts-a random error term which is normally distribution N (0, σ^2) and represents random shocks and statistical errors, and the inefficiency term which is one sided (non-negative). The inefficiency error term is assumed to have a half normal distribution. The SPF is expressed mathematically as:

$$\pi_i = f(\mathrm{X_i}, \beta)\, \mathrm{e}^{\mathrm{v-u}} \tag{1}$$

In logarithm terms the SPF is expressed as

$$\mathrm{Ln}\ \pi_i = \mathrm{Ln}f\ (\mathrm{X_i}, \beta) + \mathrm{V_i} - \mathrm{U_i} \tag{2}$$

Where π_i is the output vector, X_i is the input vector, β is an unknown parameter vector, Vi is the random error term assumed to be identically and independently distributed (iid N (0, σ^2)), U_i is the inefficiency term independently distributed from V_i.

In this study the half normal distribution of the error term used by Jaforullah and Premachandra (2003) in a cross sectional data similar to this study is adopted.

Model specification

Profit efficiency in this study is defined as profit gain from operating on the profit frontier, taking into consideration farm-specific prices and factors. Considering a farm that maximizes profit subject to perfectly competitive input and output markets. The explicit Cobb-Douglas functional form for the small scale maize farmers in the study area is therefore specified as follows:

$$\ln\pi_i = \ln\beta_0 + \beta_1\ln\mathrm{Z_{1i}} + \beta_2\ln\mathrm{P_{1i}} + \beta_3\ \ln\mathrm{P_{2i}} + \beta_4\ \ln\mathrm{P_{3i}} + \beta_5\ \ln\mathrm{Z_{2i}} + (\mathrm{V_i} - \mathrm{U_i}) \tag{3}$$

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Where: Π_i represents normalized profit computed as total revenue less variable cost divided by farm specific maize price; Z_1 represents Farm size (ha); P_1 represents average cost per man day of labour; P_2 represents average price per kg of fertilizer; P_3 represents average price per kg of seed; Z_2 represents average price of farm tools.

The inefficiency model (U_i) is defined by:

$$U_i = \alpha_0 + \alpha_1 M_{1i} + \alpha_2 M_{2i} + \alpha_3 M_{3i} + \alpha_4 M_{4i} + \alpha_5 D \tag{4}$$

Where: M_1, M_2, M_3, M_4 and D represent age, educational level, farming experience, household size and sex of proprietor, respectively. This inefficiency model differs slightly from that of Ogundari Kolawole (2006) by the introduction of the sex variable.

Sex of proprietor D which is a dummy variable is defined as,

$D_1 = 0$ female

$D_2 = 1$ male

These socio-economic variables are included in the model to indicate their possible influence on the profit efficiencies of the maize farmers (determinant of profit efficiency). The variance of the random errors, σ^2v and that of the profit inefficiency effect σ^2u and overall variance of the model σ^2 are related thus:

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

This measures the total variation of profit from the frontier which can be attributed to profit inefficiency (Battese and Corra, 1977). The log likelihood function estimates the gamma (λ) as:

$\lambda = \sigma^2 u / \sigma^2 v + \sigma^2 u$. The parameter λ represents the share of inefficiency in the overall residual variance with values in interval 0 and 1. A value of 1 suggests the existence of a deterministic frontier, whereas a value of 0 can be seen as evidence in the favour of OLS estimation.

The estimate for all parameters of the stochastic frontier profit function and the inefficiency model are simultaneously obtained using the program Limited Dependent variables (LIMDEP). A three-step estimation method is used in obtaining the final maximum likelihood estimation. The likelihood maximization procedure uses Davidson Fletcher Powel Quassi Newton algorithm.

And, for this study, two different models were estimated in the final MLE. Model 1 is the traditional response function OLS in which the efficiency effects are not present ($U_i = 0$). It is a special form of the stochastic frontier production function model in which the total variation of output due to technical inefficiency is zero that is $\gamma = 0$. Model 2 is the MLE model where there is no restriction and thus $\gamma \neq 0$. The two models were compared for the presence of profit inefficiency effects using the gamma (γ) test of significance.

Hypothesis and significance test

The following null hypothesis is tested using the gamma test:

There is no inefficiency of profit ($\gamma = 0$).

RESULTS

The results from the data analysis shows that the mean yield of 600 kg/ha of bagged maize (shelled maize) was recorded over the sample area with a standard deviation of 230 kg/ha (source field data). This gives us a coefficient of variability (CV) to 38%. The variability as measured by the CV revealed that majority of the farmers' recorded average yield of maize that varied greatly from the average yield recorded in the sample area. Also an average of GH¢ 0.158 per kg of maize was recorded in the sampled area as price of output. Table-1 gives the summary statistics of variables for the estimation of the stochastic profit frontier model. The mean gross margin (GM) of GH¢ 948.00, a minimum gross margin of GH¢ 14.00, a maximum gross margin of GH¢ 4, 125 .00 and standard deviation of GH¢ 810.06 were obtained. The greater variability indicates that farmers cultivate different sizes (hectare) of farm land with the majority of the maize farmers having average GM very close to that recorded in the sample area. These are shown in Table-1 below.

Table-1. Summary statistics of variables for the estimation of stochastic frontier model.

Variables	Minimum	Maximum	Mean	Std. deviation
Profit	14.00	4, 125.00	948.0	810.06
Farm size (ha)	2	41	8.8	6.4
A unit cost of labour per man day (GH¢)	0.50	1.00	0.86	0.129
Ave. price of fertilizer per kg (GH¢)	12	25	20.57	1.245
Ave. price of seed per kg (GH¢)	0.4	0.8	0.487	0.057
Ave. cost of farm tools (GH¢)	17.00	14, 400.00	506.28	1, 829.28
Age (Yrs)	24	72	44.12	10.9
Educational level (Yrs)	3	6	3.86	1.66
Farming experience (Yrs)	3	48	18.08	10.79

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Maximum likelihood estimates of the parameters of the stochastic profit frontier

The maximum likelihood estimates of the parameters of the stochastic profit frontier model are presented in appendix D. Table-2 below show that apart from the cost of farm tools the estimated coefficients of the parameters of the normalized profit function based on the assumption of competitive market are positive. The positive coefficient of cost per man day of labour is against expected sign. This may be due to the fact that maize production is labour intensive as most operation are done manually which resulted in increase in the cost of labour since hired labour are frequently used by the farmers in an attempt to meet their production plan. Based on this, the variables in the normalized profit model which have positive coefficient, meaning that as these variables (farm size, cost of labour, seed cost and fertilizer cost) increase the normalized profit of the farmer increases, whiles the variable (cost of farm tools) is negative and vice versa.

Table-2. Maximum likelihood estimates of the stochastic profit frontier function.

Variables	Parameters	Model 1 (OLSE)	Model 2 (MLE)
General Model			
Constant	β_0	0.795 ***(5.39)	1.488 ***(8.33)
Farm size (ha)	β_1	0.6215 ***(6.21)	0.585 ***(5.08)
Ave. cost per man days of labour GH ¢	β_2	0.0419 **(2.19)	0.0241 (0.975)
Ave. price of fertilizer per kg GH ¢	β_3	0.0812 ***(3.19)	0.0837 ***(2.80)
Ave. price of seed per kg GH ¢	β_4	0.0213 (0.94)	0.0172 (0.87)
Ave. price of farm tools GH ¢	β_5	-0.0128 **(-2.15)	-0.0077* (-1.88)
Inefficiency Model			
Constant	∂_0	0	-0.980 (0.250)
Sex	∂_1	0	0.082 (0.120)
Age (Yrs)	∂_2	0	0.0142 (0.0074)
Household size (Yrs)	∂_3	0	-0.0153 (-0.0126)
Educational level (Yrs)	∂_4	0	-0.00715 (-0.0187)
Farming experience (Yrs)	∂_5	0	-0.011 (-0.0074)
Variance			
Sigma square	$\sigma^2 = \sigma_U^2 + \sigma_V^2$	0.43	0.703 ***(15.79))
Gamma	$\gamma = \sigma_U^2 / \sigma_U^2 + \sigma_V^2$	0	0.87 ***(3.87)
Log likelihood	llf	-88.27	-80.17

Figures in parentheses are ‘t’ ratios, *estimate is significant at 10% level
**estimate is significant at 5% level, ***estimate is significant at 1% level
N=141

The following null hypothesis was tested using the gamma test:
There is no inefficiency of profit ($\gamma = 0$).
$\gamma = 0$, t-calculated = 3.87 whiles t-value from table=1.960
Decision: $\gamma \neq 0$

This means that there was profit inefficiency among maize farmers in the study area as confirmed by the significance of the gamma (γ) estimate. The estimated gamma parameter (γ) of model 2 (MLE) of 0.87 in Table-2 was highly significant at 1 percent level of significance. This implies one-sided random inefficiency component strongly dominates the measurements error and other random disturbance. This means that about 87 percent of the variation in actual profit from maximum profit (profit frontier) among farmers mainly arose from differences in farmers’ practices rather than random variability.

Distribution of profit efficiencies of the maize farmers

Distribution of profit efficiencies of the maize farmers in the study area is presented in Table-3. Table-3 revealed that average measure of profit efficiency of 60.0 percent was recorded in the area. This suggest that an average of about 60 percent of potential maximum profit is gained due to production efficiency while the remaining short fall of discrepancy between observed profit and the frontier profit can be attributed to both technical and allocative inefficiencies as had earlier been confirmed by the gamma test. Table-3 further shows that about 45.4 percent of the farmers had profit efficiency from 0.61 and above (refer to appendix A), indicating that comparatively less than half of the farms under assumption of the perfect competition market used for the analysis were fairly

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efficient in allocating their cost structure in course of maize production.

Table-3. Distribution of profit efficiencies of maize farmers.

Efficiency	Frequency	Relative frequency
0.11-0.20	3	2.3
0.21-0.30	9	7.0
0.31-0.40	12	9.4
0.41-0.50	1 9	14.8
0.51-0.60	27	21.1
0.61-0.70	19	14.8
0.71-0.80	13	10.2
0.81-0.90	8	6.3
0.91-1.00	18	14.1
TOTAL	128	100.0
Minimum	0.12	
Maximum	1.00	

Determinants of profit efficiency of maize producers

The parameters estimates for determinants of profit efficiency using the stochastic Cobb Douglass profit function are presented in the lower part of Table-2 However, the analysis of inefficiency models shows that the signs and significance of the estimated coefficient in the inefficiency model have important implication on the profit efficiency of the farmer. Based on this, the variables in the inefficiency model which have negative coefficient, meaning that as these variables (educational level, farming experience, and household size) increase the profit efficiency of the farmer increases, hence increase in profit. Whiles the variables (sex of proprietor and age) are positive and hence vise versa. The positive coefficient of age is in agreement with the work of Abdulai and Huffman (1988) while the negative coefficient of educational level was in conformity with Kumbhakar and Bhattacharya (1992b), Ali and Flin (1989), Abdulai and Huffman (1988) and Huffman (1974).

The results from the stochastic profit frontier analysis showed that their profit efficiency was positively influenced by (age, educational level, farming experiences and household size). These findings have important policy implications in improving production efficiency among farmers in Northern Ghana. Nevertheless government should make it a priority to encourage both men and women to go into maize farming in an attempt to bridge the gap between them.

The investments in rural education through effective extension delivery program in the current political and economic environment in Ghana will provide farmers with skills essential to increase efficiency.

In conclusion, the result of this study has clearly shown that employing the stochastic profit frontier allows a detailed analysis of the determinant of specific farm efficiency. The profit efficiency of 0.60 suggest that considerable amount of profit is gained among maize producers in the sampled area. The inefficiency associated with controllable decisions is about 87% hence government through MOFA should educate farmers on how to reduce controllable inefficiency in their production. Farmers need to be educated and young men and women should be encouraged to go in to farming.

The study examined the performance of micro and small agribusinesses in Northern Ghana. Two objectives were set and these include; assess the profit efficiency of micro and small agribusinesses (maize producers), and determine the factors that influence profit efficiency. The stochastic profit frontier analysis was used to assess the profit efficiency of maize farmers.

Determinants of profit efficiency among the small-scale maize farmers were identified using stochastic Cobb-Douglas profit frontier model. The parameters estimated using the Cobb-Douglas profit frontier indicate that all the inputs have positive signs on the profitability of maize farming in Northern Ghana except the unit cost of farm tools. The negative sign of cost of farm tools may be due to the high cost of fuel leading to excessive cost of the use of such equipments by the farmers, thus leading to extra cost incurred on the part of the farmers. Deciles profit efficiency distributions has shown that maize farmers were fairly efficient in their resource allocation, judged by the fact that more than half of the farmers having profit efficiency of 0.61 and above with an average profit efficiency of 0.60 suggesting that considerable amount of profit is gained due to the relative level of efficiency observed in the sample area.

CONCLUSIONS

The following conclusions and policy recommendations are made based on the results of the study. The results from the stochastic profit frontier analysis showed that their profit efficiency was positively influenced by (age, educational level, farming experiences and household size). These findings have important policy implications in improving production efficiency among farmers in Northern Ghana. Nevertheless government should make it a priority to encourage both men and women to go into maize farming in an attempt to bridge the gap between them.

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production. Farmers need to be educated and young men and women should be encouraged to go in to farming.

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