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Technical Efficiency of Maize Farmers across Various Agro Ecological Zones of Ghana

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Abstract

The study analyses the technical efficiency of maize farmers across various agro ecological zones of Ghana. To carry out this analysis, a translog stochastic production frontier function, in which technical inefficiency effects are specified to be a function of socioeconomic, institutional and environmental variables, is estimated using the maximum likelihood method. Cross sectional data was collected for the 2010 crop year from a sample of 453 maize farmers from the Bekwai Municipality, Nkoranza South District and Gushiegu District of the Forest, Transitional and Savannah Zone respectively. The mean technical efficiency of the sampled maize farmers across the three agro ecological zone is 64.1%. The mean technical efficiency of maize producers in the forest, transitional and savannah zones are 79.9%, 60.5% and 52.3% respectively. The results reveal that extension; mono cropping, gender, age, land ownership and access to credit positively influence technical efficiency. High input price, inadequate capital and irregularity of rainfall are the most pressing problems facing maize producers in the forest, transitional and savannah zones respectively. The study therefore recommends that policies that would improve extension service, education and development of crop varieties suitable to the different agro ecological zones should be pursued.

Keywords: Stochastic, production, frontier, technical efficiency, translog, agro ecological zone

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1.0 Introduction

The idea arising out of Schultz (1964) hypothesis that smallholder farmers are reasonably efficient in allocating their resources and respond positively to price incentives has triggered much attention in Sub-Sharan Africa. Indeed, the level of efficiency of small holder farmers has important implications for the choice of development strategy; reason being that most Sub-Saharan countries derive over 60 percent of their livelihoods from agriculture and rural economic activities (Owuor & Shem, 2009). If farmers are sufficiently efficient then increases in productivity require new inputs and technology to shift the production possibility frontier upward. But, on the other hand, if there are significant opportunities to increase productivity through more efficient use farmer's resources and inputs with current technology, a stronger case could be made for improvement through eliminating the factors or determinants of inefficiency.

The productivity of a farmer does not only depend on the physical resources and a technology available, but also on the prevailing environmental production conditions such as rainfall and temperature. Sherlund, Barret & Adesina (2002) argue that the presence of inefficiency among small scale farmers could partly be due to consistent omission of the variables representing environmental production conditions in numerous efficiency studied conducted over the years. Maize is a major staple for many Ghanaians that also acts as a substitute for other cereals in short supply. Despite the increase maize production over the years in Sub-Sharan Africa, Ghana has a maize supply deficit of maize and makes up for this shortage through imports (Codjoe, 2007).

Ghana is divided into three main agro ecological zones, namely the forest, transitional and savaanah zones. The food production potential of the agro ecological zones has been recognized for years, where new agricultural technologies have been introduced. These technological packages are often very similar, yet are targeted at farms and communities in different ecologies and at different levels of development of infrastructure and human capital. Consequently, they perform differently in different locations and the overall outcomes fall short of the potential (Alemu, Nuppenu & Boland, 2002). In the dissemination of new technologies, farmers in these agro ecological zones are treated as though their constraints and opportunities are similar.

Such an approach is also adopted in applied research, where a majority of farm productivity stratifies farms only by farm characteristics. Such methods presume that all farms produce under similar environmental conditions and as such differences in the output and productivity among farms are mostly due to the scale of operation. This is not the case, however, traditional small holder agriculture, which relies heavily upon the underlying agro ecological (environmental) conditions that vary markedly over time and space affect productivity and efficiency of resource use as witnessed by Okike, Jabbar, Manyong, Smith & Ehui (2004). In this regard, it is necessary to quantify the technical efficiency of maize producers across the three agro ecological zones of Ghana and identify the factors that influence their technical efficiency. The main objective of the study is to assess the technical efficiency of maize producers across various agro ecological zones of Ghana.

2.0 Empirical Literature on Efficiency

There are various socio-economic, demographic, institutional, environmental factors and non-physical factors that affect efficiency (Kumbhakar & Bhattachury, 1992). These factors include gender, age, educational level, household size, experience in farming, hybrid seed, access to credit, off-farm work, membership of a farmer based organisation, mono cropping, land tenancy and so on (Tesfay, Reuben, Pender, & Kuyvenhoven 2005; Nchare, 2007; Abdulai & Eberlin, 2001; Rahman & Hassan, 2006). Abdulai & Eberlin (2001) pointed out that, the level of schooling represented human capital, access to formal credit and farming experience contribute positively to production efficiency, whiles farmer's participation in off- farm employment tends to reduce production. Sherlund *et al* (2002) further emphasized that variables such as farm size, cropping experience, gender, age and rainfall also affect the technical efficiency of farmers.

Some empirical studies such as Owour & Shem (2009) have shown a negative relationship between education and technical efficiency of farmers. This is counterintuitive as human capital is expected to produce positive impacts. Education enhances the managerial and technical skills of farmers. According to Battese & Coelli (1995) education is hypothesized to increase the farmers' ability to utilize existing technologies and attain higher efficiency levels. Owour & Shem (2009) however indicated that educational level is negatively correlated to technical efficiency of farmers.

One possible explanation is that technical skills in agricultural activities, especially in developing countries are more influenced by "hands on" training in modern agricultural methods than just formal schooling. Another school of thought has it that technical inefficiency tends to increase after 5 years of schooling. This could probably be explained by the fact that high education attenuates the desire for farming and therefore, the farmer probably concentrates on salaried employment instead (Kibaara, 2005). Ultimately, this reduces labour availability for farm production thereby lowering efficiency. Nevertheless, it could be argued that access to better education enable farmers to manage resources in order to sustain the environment and produce at optimum levels.

Also ownership of land also influence the technical efficiency of farmers (Helfand & Levine, 2004; Giannakas, Tran, & Touvelekas 2001; Reddy, 2002; Coelli, Rehman & Tirtle, 2002). Empirical results on ownership of land on inefficiency are mixed. A positive relationship is consistent with the hypothesis that longer years of leasing motivate farmers to work harder to meet their contractual obligations (Helfand & Levine, 2004; Coelli *et al*, 2002). A negative relationship on the other hand is linked to the agency theory, reflecting monitoring problems and adverse incentives between the parties involved in diminishing business performance (Giannakas *et al*, 2001; Reddy, 2002).

The size of farmers' household is another factor that influences the efficiency of farmers. Abdulai & Eberlin (2001) pointed out that although large household size puts extra pressure on farm income for food and clothing, but at times ensure availability of enough family labour for farming activities to be performed on time. Opposite to this is that farmers with surplus labour force are likely to use the rest of the family labour, and hence operate inefficiently or farmers with bigger household size would have to allocate more financial resources to health, education and so on for members of the household and thus affect production (Nchare, 2007).

As far as the impact of off-farm work on technical efficiency is concerned, literature offers mixed results. Some argue that off-farm labour supply curtails farming efficiency (Abdulai & Huffman, 2000). Others contend that the additional income generated by other household members who engage in off-farm work, can more than compensate for the constraints caused by reduced farm labour availability. Tesfay *et al*, (2005) found a positive impact of off-farm work on technical efficiency.

It may also be hypothesized that managerial input may be withdrawn from farming activities with increased participation of the educated in off-farm work, which leads to lower efficiency. Abdulai & Eberlin (2001) found higher inefficiency of production with the involvement of farmer households in off-farm activities. In any case, the effect of off-farm work on production efficiency may not be determined beforehand.

Another important factor that affects efficiency is access to extension services. A farmer' regular contact with extension workers facilitates the practical use of modern technologies and adoption of agronomic norms of production. Owen, Hoddinot & Kinsey (2001) in analysing the impact of extension services on agricultural production in Zimbabwe found that farmer's access to extension services increases the value of output by 15 percent. Alemu *et al* (2002) on the other hand had opposite results. Their results revealed that neither extension visits nor visits and trainings could bring about significant reductions in inefficiency levels. This could be due to the fact that the development agents remain at the edge, never reaching the farmer and that the training packages may not fit the agro ecological settings. Again it is not extension services in terms of visits but appropriateness of extension message or training.

Farming experience is gleaned from the act of agricultural production-that is conscious accumulation of know-how from farming practices. Rahman (2003) found that experience in growing modern rice varieties pay-off well. That is farmers with more than three years of experience in growing modern rice varieties earned significantly higher profit, incurred less profit loss and operate at significantly higher level of profit efficiency.

The gender of the farmer also influences technical efficiency. Kibaara (2005) observed that male farmers decrease technical inefficiency. This could probably be explained by the fact that men have greater access to credit, probably because of cultural prejudice and hence men are closer to the frontier. In addition men are most likely to attend agricultural extension training seminars (Kibaara, 2005). The FAO estimates that, in Sub-Saharan Africa as a whole, 31 percent of rural households are headed by women, mainly because of the tendency of men to migrate to cities in search of wage labour. Despite this substantial role, women have less access to land than men.

When women do own land, the land holding tends to be smaller and located at marginal areas. Rural women also have less access to credit than men, which limits their ability to purchase seeds, fertilizer and other inputs needed to adopt new farming techniques (FAO, 2002). Dolisca & Jolly (2008) studying the situation in Haiti had contrasting result that being a male farmer increases technical inefficiency. This may be explained by the fact that after land preparations women normally carry out the remaining activities involved in production at the farm and this is more evident in Africa.

Rainfall being an environmental variable also influences technical efficiency. Rainfall enhances efficiency as it improves the soil's capacity and enables it to use the fertilizer and other inputs effectively (Tchale & Suaer, 2007). Tchale & Suaer (2007) points out that higher variation in the water requirement index lowers the production efficiency especially in hybrid maize seed, which is very susceptible both to intensity and intra-seasonal distribution of rain. On the other hand excessive rainfall can cause flooding and lower efficiency.

Access to credit improves liquidity and enhances use of agricultural inputs in production as it is often claimed in development theory. Nchare (2007) pointed out that access to credit has negative influence on technical inefficiency. He explained that, it actually reduces the financial difficulties farmers face at the beginning of the crop year, thus enabling them to buy inputs.

3.0 Methodology

3.1 Study area

In table 1, we compare the three agro ecological zones in Ghana being the forest, transitional and savannah zones representing the study areas.

Table 1: A General Description of the Characteristics of the Various Study Areas

General characteristics	Forest Zone (Bekwai Municipal)	Transitional Zone (Nkoranza South District)	Savannah Zone (Gushegu District)
Location	Southern part of Ashanti Region	Middle portion of the Brong Ahafo region.	North eastern corridor of Northern Region.
Total land area	633sqkm	2300sqkm	5796sqkm
Topology	Within the forest dissected plateau.	Low lying and rising gradually.	Fairly undulating.
Climate	Semi-equatorial type.	Wet semi-equatorial region	Tropical continental climate.
Vegetation	Semi-deciduous forest zone	Savannah woodland and a forest belt.	Guinea savannah type.
Rivers /drainage	Drained by the Oda River and its tributaries.	Fairly drained by several streams and rivers.	Strewn with several streams.
Geology	Underlain by three geological formations.	Characterized by soils developed over Voltaian sandstones.	Lies entirely within the Voltaian sandstone basin
Soils	Clay, sand and gravel deposits	The geological feature together with vegetation influences and gives rise to two distinct soil categories.	Coarse lateritic upland soils and soft clay.
Rainfall	1600– 1800mm.	800-1200mm.	950-1300mm
Temperature	Fairly high and uniform temperature ranging between 32ºC in March and 20º C in August.	Average annual temperature is about 26°C.	Normally high above 35^0C

Source: MLGRD (2006)

3.2 Conceptual framework

This study employs the stochastic frontier model proposed by Aigner, Lovell & Schmidt (1977), and extended by Battese & Coelli, (1995).

$$Y_i = f(x_i, \beta)\exp(V_i - U_i) \qquad i = 1, 2....., n \tag{1}$$

Here V_i is the random error, associated with random factors not under the control of the farmer and U_i is the inefficiency effect. The possible production Y_i is bounded by the stochastic quantity, $f(x_i, \beta)\exp(V_i - U_i)$, hence the name stochastic frontier. The random error V_i is assumed to be independently and identically distributed as $N(0, \sigma_V^2)$ random variables independent of $U_i s$, which are assumed to be non-negative truncations of the $N(0, \sigma_V^2)$ distribution (i.e. half-normal distribution) or have exponential distribution.

The technical inefficiency effects are expressed as:

$$U_i = \delta z_i + w_i \tag{2}$$

Here z_i is a vector of observable explanatory variables and δ is a vector of unknown parameters and w_i are unobserved random variables which are assumed to be independently distributed and obtained by truncation of normal distribution with zero mean and constant variance.

A number of studies (Helfand & Livine, 2004; Nyemeck, Sylla & Diarra 2001) have estimated the production frontier (equation 2) and the determinants of inefficiency (equation 3) separately. According to their two-stage procedure, the production frontier is first estimated and then the technical inefficiencies are derived. The predicted inefficiencies are subsequently regressed upon a set of firm (or farm) specific variables (z_i) in an attempt to determine reasons for differing efficiencies. The two-stage estimation procedure suffers from a fundamental contradiction as inefficiency effects (or scores) are derived under the assumption that they are independently and identically distributed in the first stage.

In the second stage the predicted inefficiency scores are assumed to be a function of several firm (or farm) specific factors, which implies that they are not identically distributed unless all the coefficients of the factors are simultaneously equal to zero (Coelli, Rao & Battese, 1998).

In addition, using Ordinary Least Square (OLS) in the second stage regression fails to capture the fact that the dependent variable (U_i) is restricted to be non-negative. The two-stage procedure is unlikely to provide estimates which are as efficient as those that are obtained from the one-step estimation procedure (Coelli, 1996b). For these reasons, the Battese & Coelli (1995) model is, therefore, applied in this study and allows for a simultaneous estimation of the parameters of the stochastic frontier and the inefficiency model using the single-stage, maximum likelihood (MLE) method. The likelihood function is expressed in terms of the variance parameter σ^2 and γ , where $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$

$$\text{Technical efficiency (TE)} = Y_i / Y_i^* = f(x,\beta)\exp(V_i - U_i) / f(x,\beta)\exp(V_i)$$
$$= \exp(-U_i) = \exp(-z_i\delta - W_i) \quad (3)$$

Where Y_i is the observed output and Y_i^* is the frontier output.

3.3 Empirical Model

Farm technical efficiency is the ability of a farmer to maximize output with given quantities of inputs and a certain technology (output-oriented) or the ability to minimize input use with a given objective of output (input-oriented). However, the output-oriented technical efficiency is commonly used.

3.4 Specification of Empirical Model

Different forms of production functions are used in empirical studies, depending on the nature of data on hand. Therefore, the selection of functional form is vital in stochastic frontier production. In a number of studies, Cobb-Douglas (CD) functional form has been used to examine farm efficiency notwithstanding its well-known limitations (Thiam, Bravo-Ureta & Rivas, 2001).

Kopp & Smith (1980) indicated that functional forms have a distinct but rather small impact on estimated efficiency. Ahmad & Bravo-Ureta (1996) in their study rejected the Cobb Douglas functional form in favour of the transcendental logarithmic (translog) form, but concluded that efficiency estimates are not affected by the choice of the functional form (cited in Thiam *et al*., 2001). The Cobb-Douglas production function imposes a severe prior restriction on the farm's technology by restricting the production elasticities to be constant and the elasticities of input substitution to unity (Wilson, Hadley, Ramsden & Kaltsa, 1998).

The flexible functional form translog functional form however, does not entail restrictions of fixed rate of technical substitution (RTS) value and an elasticity of substitution equivalent to one in the CD form of the production function. Therefore, translog functional form is preferred over CD functional. It is noted that the CD is nested within the translog form if all the square and interaction terms in translog turn out to be equal to zero. Therefore, the translog functional form is adopted in this study. The empirical model is specified as:

$$\begin{aligned}\ln Y_i = {} & \beta_0 + \beta_1 \ln LAB + \beta_2 \ln FSIZ + \beta_3 \ln SED + \beta_4 \ln FERT + \beta_5 \ln(LAB)^2 + \beta_6 \ln(FSIZ)^2 \\ & + \beta_7 \ln(SED)^2 + \beta_8 \ln(FERT)^2 + \beta_9 \ln(LAB) \times \ln(FSIZ) + \beta_{10} \ln(LAB) \times \ln(SED) \\ & + \beta_{11} \ln(LAB) \times \ln(FERT) + \beta_{12} \ln(FSIZ) \times \ln(SED) + \beta_{13} \ln(FSIZ) \times \ln(FERT) \\ & + \beta_{14} \ln(SED) \times \ln(FERT) + (V_i - U_i)\end{aligned} \tag{4}$$

Here Y_i denotes maize yield (kg / acre), $FERT$ denotes quantity of fertilizer used (kg / acre), LAB denotes labour (man-days/acre), SED denotes quantity of seed planted (kg / acre), $FSIZ$ denotes maize area cultivated (acre), β_ks are unknown parameters of the production functions, $v_i s$ are random errors assumed to be independent and identically distributed $N(0, \sigma_v^2)$, $u_i s$ are non-negative random variables, assumed to be independently distributed, such that the technical inefficiency effect for the producer, u_i, is obtained by truncation (at zero) of the normal distribution with zero mean u_i and constant variance, σ^2. Specifically the inefficiency model is specified as:

$$U_i = \delta_0 + \delta_1 GEND + \delta_2 EXP + \delta_3 EDU + \delta_4 MCRP + \delta_5 HMAV + \delta_6 EXT + \delta_7 ATC + \delta_8 OFW \quad (5)$$

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Here $GEND$ denotes dummy variable 1 if farmer is male, 0 otherwise, EXP denotes experience in maize farming in years , ATC denotes dummy variable 1 if farmer has access to credit, 0 otherwise, EXT denotes dummy variable 1 if farmer had access to extension services, 0 otherwise, OFW denotes dummy variable 1 if farmer engages in off-farm work, 0 otherwise, $MCRP$ denotes dummy variable 1 if farmer practice mono cropping, 0 otherwise, EDU denotes number of years of schooling, $HMAV$ denotes dummy variable 1 if farmer cultivates hybrid maize variety, 0 otherwise , $\delta's$ are unknown parameters to be estimated.

Since the dependent variable of the inefficiency model represents the mode of inefficiency, a positive sign of an estimated parameter implies that the associated variable has a negative effect on efficiency but positive effect on inefficiency and vice versa. It is assumed that some farmers produce on the production frontier and others do not produce on the frontier. Therefore, the need arises to find out factors causing technical inefficiency. The technical inefficiency model incorporates farm and farmer specific characteristics, institutional and environmental factors.

3.5 Statement of Hypotheses

The following null hypotheses would be validated:

1) Farmers are technically efficient in maize production across various agro ecological zones of Ghana.
2) Technical efficiency of maize farmers are positively affected by socio economic factors such as gender, age and education in the three agro ecological zones of Ghana.
3) Technical efficiency of maize farmers are positively affected by institutional and non-physical factors such as, mono cropping, hybrid seed, extension, access to credit, and negatively by off-farm work in the three agro ecological zones of Ghana.

3.6 Survey Design and Sampling Method

The research employed both primary and secondary sources of data. The primary data employed was obtained through a cross-sectional survey conducted in three different agro-ecological zones in Ghana. Farm level data were collected from 453 maize producers across the three agro-ecological zones of Ghana in the 2010 calendar year. The choice of the whole calendar year is on the premise that maize can be produced throughout the year.

In the second stage of the sampling design, a district each was selected from each of the three agro ecological zones purposively. The districts are Gushiegu District (Savannah zone), Nkoranza South District (Transitional zone) and Bekwai Municipality (Forest zone). These districts were selected based on their agricultural potential, accessibility and high level of maize production in their agro-ecological zone. In the third stage, villages or communities from operational areas of MOFA were randomly selected from each of the districts representing the agro-ecological zones.

The final stage involved random selection of maize farmers proportionately according to the sizes of the various communities. A total of 151 maize farmers were sampled in the Savannah zone (Gushiegu District), 151 maize farmers were sampled in the Transitional zone (Nkoranza South District) and 151 maize farmers were sampled in the Forest zone (Bekwai Municipality).

3.7 Data Analyses

Both descriptive and inferential analyses were used to achieve the study's objectives. Descriptive analysis such as means and standard deviation were first used to describe the data. The stochastic frontier production function and the inefficiency model are simultaneously estimated with the maximum likelihood method using the FRONTIER 4.1 Econometric software (Coelli 1996a).

4.0 Results and Discussions

4.1 Descriptive Results

The descriptive results of the pooled sample are presented in table 2. The average yield is 1725.79 across the three agro ecological zones. This is obtained by using 455.43 man-days per ha of labour, 3.12 kg per ha of seed, 1.71 hectares farm size and 43.78 kg per ha of chemical fertilizer. Among the maize producers79 percent of them were males with the average age of the farmers being 43.

The average years of experience in maize farming by maize producers is 9 and 5 years being average number of years of schooling. Out of a total of 453 maize farmers, 43 percent and 45 percent practiced mono cropping and cultivated hybrid maize seeds respectively. The percentage that received extension service and credit are 46 and 29 respectively. In addition, 18 percent of the respondents engage in off-farm work.

Table 2: Descriptive statistics for the variables used in the study for the Pooled Sample

Variable	Variable Definition	Mean	Standard deviation	Min	Max
Output	Yield in kg per ha	1725.79	1216.99	33.33	18000
Labour	Labour in man-days per ha	455.43	436.67	3.75	4249
Seed	Seed in kg per ha	3.12	0.79	0.4	4.8
Farm size	Farm size in ha	1.71	1.39	0.2	10
Chemical fertilizer	Fertilizer in kg per ha	17.48	15.25	0	60
Gender	1 if farmer is a male, 0 otherwise	0.79	0.41	0	1
Experience	Experience in years	16.83	10.73	1	50
Education	Number of years of schooling	4.86	3.72	0	16
Mono cropping	1 if farmer practiced mono cropping, 0 otherwise	0.43	0.5	0	1
Hybrid seed	1 if farmer cultivated hybrid seed, 0 otherwise	0.45	0.5	0	1
Extension	1 if farmer had access to extension service , 0 otherwise	0.46	0.5	0	1
Access to credit	1 if farmer had access to credit, 0 otherwise	0.29	0.45	0	1
Off-farm work	1 if farmer engaged in off-farm work, 0 otherwise	0.18	0.39	0	1

Source: Survey, 2010

4.2 Maximum-Likelihood Estimates for the Pooled Sample

The maximum likelihood estimates of the parameters of the stochastic frontier production function and the inefficiency model across the three agro ecological zones are presented in Table 3 and 4. The estimated sigma square (σ_s^2) parameter (0.920) in the stochastic frontier production is significantly different from zero, indicating a good fit of the model and the correctness of the specified distributional assumptions. The estimated gamma (γ) parameter (0.951) is significant at 1% which means that the technical inefficiency effects are significant in determining the level and variability of maize yield.

Table 3: Maximum likelihood estimates of stochastic frontier production function for the pooled sample

Variable	Parameter	Coefficient	t-ratio
Stochastic frontier			
Constant	β_0	7.247	9.004***
Inlabour	β_1	-0.151	-0.692
Infarmsize	β_2	-0.315	-1.335*
Inseed	β_3	0.397	0.714
Infertilizer	β_4	-0.145	-0.993
Inlabour^2	β_5	0.037	1.844**
Infarmsize^2	β_6	0.04	1.179
Inseed^2	β_7	0.224	1.517*
Infertilizer^2	β_8	-0.016	-0.67
Inlabour × Infarmsize	β_9	-0.03	-0.82
Inlabour × Inseed	β_{10}	-0.083	-0.656
Inlabour × Infertilizer	β_{11}	0.587	3.387***
Infarmsize × Inseed	β_{12}	0.185	1.533*
Infarmsize × Infertilizer	β_{13}	0.039	1.517*
Inseed × Infertilizer	β_{14}	-0.135	-2.108**
Variance parameters			
$\sigma_s^2 = \sigma^2 + \sigma_v^2$	σ_s	0.92	3.022***
$\gamma = \sigma^2 / \sigma_s^2$	γ	0.951	55.020***
Log likelihood function		-271.544	
LR test of one sided error		135.71	
Mean efficiency		0.649	

Source: Survey, 2010. ***, ** and * indicate that coefficients are statistically significant at 1%, 5% and 10% respectively.

4.2.1 Determinants of Technical Efficiency

With regard to the sources of efficiency differentials among the sampled maize producers across the three agro-ecological zones, the estimates of technical inefficiency model provide some important insights. The parameter estimates in Table 4 have the relevant signs, indicating the impact of explanatory variables on technical (in) efficiency. Explanatory variables with a large impact should be the main focus in an effort to improve efficiency in maize production across the three agro-ecological zone of Ghana, since these can be influenced relatively easily.

The result of the coefficient of gender variable indicates that, being a male maize farmer increases technical inefficiency than being a female. This result is in agreement with the findings of Onyenweaku & Effiong (2005) and Dolisca & Jolly (2008) that being a male farmer increases technical inefficiency. However, Kibaara (2005) had a contrasting result that being a male farmer reduces technical inefficiency. This study there ore contributes to the debate on the role of gender in farmers' level of efficiency.

The estimate for experience is negative and significant; this suggests that the more experienced a farmer is the higher the chances of that farmer being more efficient. This can be explained by the fact that farming is done under risky environmental conditions such as erratic rainfall, therefore, farmers who have cultivated the same crop over a long period of time are able to make accurate predictions on when to sow, the inputs to use, the quantity to use as well as the timing of the use of these inputs and are therefore more efficient in the use of these inputs as compared to inexperienced farmers. This finding is similar to findings of Wilson, Hadley, Ramsden & Kaltsa (1998). Rahman (2003) also found that experience in growing modern rice varieties pay-off well.

The coefficient for years of schooling (education) was negative as expected. This result clearly demonstrates that educated farmers' are more likely to reduce their technical inefficiency than their uneducated counterparts in maize production. Similar result was reported by Abdulai & Huffman (2000), Owens, et al (2001) and Kibaara (2005) that schooling helps farmers to use information efficiently since a better educated farmer acquires more information and is able to produce from a given input vector.

There is also a negative correlation between technical inefficiency and the practice of mono cropping. This is also significant at 1% level of significance. This result may be explained by the fact that practising mono cropping not only enable farmers to work tirelessly, but also saves the maize plant from competition that might occur among various crops in case of mixed cropping for use of inputs available at the farm level. This result is in agreement with the findings of Nchare (2007).

A negative sign on the dummy variable for hybrid seed indicates that use of hybrid seed for maize production decreases technical inefficiency, yet 45 % of the total maize producers used hybrid seeds. This is probably because of the high cost of hybrid seeds, making them unaffordable to most subsistence maize producers. Again local seeds are usually preferred by most smallholder farmers because of the quality of maize flour produced through the traditional system, lower demands for fertilizer and ease in storage- it is not susceptible to pests and can easily be recycled as seed (Chirwa, 2003).

The estimated coefficient associated with contact with extension service agents is negative and statistically significant, implying that contact with extension service by farmers for advice help to reduce technical inefficiency. Al-Hassan (2008) reported similar findings that confirm that contact with extension service by farmers reduces inefficiency. The result therefore seems to emphasize the role of extension service in maize production. Agricultural extension serves as a bridge between researchers and farmers and thus represents a mechanism by which information on new technologies; better farming practices and better management are transmitted to farmers. Owens *et al*., (2001) also indicated that access to agricultural extension services, defined as receiving one or two visits per agricultural year raises the value of crop production by about 15%.

Table 4: Maximum likelihood estimates of technical inefficiency model for the pooled sample

Variable	Parameter	Coefficient	t-ratio
Constant	δ_0	0.601	1.181
Gender	δ_1	0.222	0.979
Experience	δ_2	-0.014	-1.601*
Education	δ_3	-0.036	-1.408*
Mono cropping	δ_4	-0.641	-2.615***
Hybrid seed	δ_5	-0.634	-2.250**
Extension	δ_6	-0.845	-2.473***
Access to credit	δ_7	-0.51	-1.922**
Off-farm work	δ_8	0.538	2.025**

Source: Survey, 2010. ***, ** and * indicate that coefficients are statistically significant at 1%, 5% and 10% respectively.

The negative and significant relationship between access to credit and inefficiency suggest the farmers who face credit constraint for the purchase of inputs experience higher inefficiency. Credit access indicates liquidity, which is a prerequisite for flexibility in the purchase of improved inputs. Thus the finding points at the case in the allocation of purchased factors such as fertilizer, improved planting materials and hired labour in circumstances where credit is available. This result leads credence with the findings of Owuor & Shem (2009) and Chukwuji, Inoni & Ike (2007).

The result of the coefficient estimation shows that off-farm work positively and significantly affects inefficiency. This result is consistent with the findings of Abdulai & Huffman (2000) who argued that non- farm labour supply curtails farming efficiency.

4.3 Distribution of Technical Efficiency in the Three Agro-Ecological Zones

The distribution of technical efficiency scores is given in table 5. The estimated technical efficiency for maize farmers in the forest zone ranges from 0.138 to 0.975 with a mean of 0.722 and standard deviation of 0.182. This is interpreted as follows: in the short run, there is a scope for increasing maize production by adopting techniques used by the best practice maize producer.

The estimated technical efficiency score for maize farmers in the transitional zone varies from 0.194 to 0.965 with an average score of 0.839. Even though the value of the mean indicates that farmers are technically efficient, it also suggests that there exist some potential to increase maize yield with the current technology.

With the savannah zone, technical efficiency scores for maize farmers ranges between 0.149 to 0.961 with an average score of 0.616 and standard deviation of 0.240. The low mean score noted in this zone can be attributed to a number of factors that makes them constrained in maize production. Notable among them are irregular rainfall, high temperatures and poor soil characteristics among the lot.

Table 5: Distribution of technical efficiency of maize farmers in the three agro-ecological zones

Technical efficiency scores	Forest zone	Transitional zone	Savannah zone
<0.40	7 (4.640)	4 (-2.65)	33 (-21.85)
0.40-0.50	13 (-8.61)	3 (-1.99)	21 (-13.91)
0.50-0.60	26 (-17.22)	6 (-3.97)	15 (-9.93)
0.60-0.70	16 (-10.6)	10 (-6.62)	14 (-9.27)
0.70-0.80	22 (-14.57)	14 (-9.27)	17 (-11.27)
0.80-0.90	40 (-26.49)	33 (-21.85)	36 (-23.84)
>0.90	27 (-17.88)	88 (-53.64)	15 (-9.93)
Mean	0.722	0.839	0.616
Standard deviation	0.182	0.155	0.24
Minimum	0.138	0.194	0.149
Maximum	0.975	0.965	0.961

Source: Survey data, 2010. Figures in parentheses are percentages

4.4 Equality of Means

A t-test was employed to further analyze the differences in the mean technical efficiencies of male and female maize farmers and those who engage in off-work and those that do not to ascertain whether there is a significant difference between the mean technical efficiencies obtained. The null hypotheses state that the mean technical efficiency of:

a. Male farmers are the same for female farmers.
b. Farmers who engage in off-work and those that do not.

The results of the t-test are presented in table 6. Assuming an equal variance for both male and female farmers, the difference between technical efficiencies for male and female farmers is -0.211 and is not significant meaning that there is no statistical difference between the mean technical efficiency of male and female farmers. The hypothesis that there is no significant difference between the mean technical efficiencies for male and female farmers is rejected in favour of the alternative hypothesis that there is significant difference between the mean technical efficiencies for male and female farmers.

Again, assuming an equal variance for those who engage in off-work and those that do not, the difference between their technical efficiencies is 0.172 and is not significant, meaning that there is statistical difference between the mean technical efficiency of maize producers that engage in off-work and those that do not. The hypothesis that there is no significant difference between the mean technical efficiencies for land owners and tenants is rejected in favour of the alternative hypothesis that there is significant difference between the mean technical efficiencies for those engage in off-work and those that do not.

Table 6: t-test for Equality of Means

Variable		N	Mean	t	Sign (2-tailed)	Mean difference
Off-farm work	Yes	83	0.696	-1.367	0.172	-0.036
	No	370	0.736	-1.367	0.172	-0.036
Gender	Male	358	0.721	-0.85	0.396	-0.211
	Female	95	0.742	-0.85	0.396	-0.211

Source: Survey data, 2010

4.5 Analysis of Maize Farmer' Constraints

From table 7 the most pressing problem faced by maize producers differs in the different agro ecological zones. The Kendall's Coefficient of Concordance (W) indicates that there were 58.2%, 48.2% and 68% agreement among rankings by maize producers in the forest, transitional and savannah respectively and these are significant at one percent. Therefore it can be concluded that there is a reasonable degree of agreement among the respondents in the ranking of constraints to maize production in the three agro ecological zones. The low level of agreement can be attributed to the heterogeneous nature of the maize farmers in the different agro ecological zone.

The null hypothesis that there is no agreement among rankings by farmers is rejected in favour of the alternative hypothesis that there is an agreement among rankings of farmers. Input price is the most pressing problem in the forest zone with a mean rank of 3.02. In the transitional zone inadequate capital constitute the highest ranked problem with a mean rank of 3.90. Irregularity of rainfall is also ranked high in the savannah zone by maize producers.

Table 7: Ranks of constraints faced by maize farmers

Constraints	Forest Mean rank	Rank	Transitional Mean rank	Rank	Savannah Mean rank	Rank
Irregularity of rainfall	7.61	9	5.09	4	2.91	1
Poor soil fertility	8.18	11	5.94	5	7.73	7
Soil erosion	10.08	12	9.6	11	9.83	11
Seasonal flooding	12.09	13	12.34	13	4.51	5
Temperature	7.79	10	10.52	12	4.45	4
Pest incidence	6.98	6	7.46	9	8.96	9
Disease incidence	6.74	5	8.5	10	10.08	12
Cost of labour	4.04	3	4.04	2	3.61	3
Inadequate harvesting and drying facilities	6.99	7	6.65	8	9.02	10
Lack of extension services	6.71	4	6.27	6	8.88	8
Land tenure insecurity	7.58	8	6.33	7	12	13
Inadequate capital	3.19	2	3.9	1	5.99	6
High input price	3.04	1	4.35	3	3.03	2
N	151		151		151	
Kendall's W	0.582		0.482		0.68	
Chi-square	1054.021		875.961		1.23E+03	
Degree of freedom (df)	12		12		12	
Asymptotic significance	0.000***		0.000***		0.000***	

Source: Survey Data, 2010. *** indicate 1% level of significance

5.0 Conclusions and Policy Recommendations

The mean technical efficiency of 64.9 percent of maize farmers across the three agro ecological of Ghana means that farmers are not operating on the production frontier (100% efficient), suggesting that substantial potential exist for increasing maize production with the current technology and resources available to farmers. Technical efficiency score differences in the three agro ecological zones are due to differences in input use and the constraints the faced.

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

1. Development of new varieties of crops suitable to the three different agro ecological zones is essential as the face different challenges.
2. Improvement in managerial practice and use of modern technology through extension services and rural infrastructure.
3. Promotion of education at least the basic level for farming population is crucial.

References

Abdulai A. & Huffman, W. (2000). Structural Adjustment and Economic Efficiency of Rice Farmers in Northern Ghana. *Economic Development and Cultural Change*, 48(3): 503-520

Abdulai, A & Eberlin, R. (2001). Technical Efficiency during Economic Reform in Nicaragua: Evidence from Farm Household Survey Data. *Economic Systems*, 25:113-125.

Ahmad, M. & Bravo-Ureta, B. E. (1996) Technical Efficiency Measures for Diary Using Panel Data – A Comparison Of Alternative Model Specifications. *Journal of Productivity Analysis* 7, 399-415.

Aigner, D.J., Lovell, C. A. & Schmidt, P. (1977), Formulation and Estimation of Stochastic Frontier Function Models. *Journal of Econometrics* 6 (July 1977): 21-37

Ajibefun, I.A. & Daramola, A.G.(2003). Determinants of Technical and Allocative Efficiency of Micro-Enterprises: Firm-level Evidence from Nigeria, African Development Bank, 353-395 pp.

Alemu, B.A., Nuppenu, E. A. & Boland, H. (2002). Technical Efficiency of Farming Systems across Agro-Ecological Zones in Ethiopia: An Application of Stochastic Frontier Analysis.

Al-hassan S. (2008). Technical Efficiency of Rice Farmers in Northern Ghana. Final Report Presented At AERC Biennial Research Nariobi, Kenya . April 2008.

Battese, G. E. & Coelli, T. J. (1995). A Model for Technical Efficiency Effects in A Stochastic Frontier Production for Panel Data. *Empirical Economics* 20: 325-332

Chirwa, E.W. (2003). Sources of technical efficiency among smallholder maize farmers in Southern Malawi. Department of Economics, Chancellor College, Zomba, Malawi.

Chukwuji, C. O., O. E. Inoni & P. C. Ike. (2007). Determinants of Technical Efficiency in Gari in Delta State, Nigeria. *Journal of Central European Agric.*, 8(3): 327-336.

Codjoe S. N. A (2007) "Supply and Utilisation of Food Crops In Ghana, 1960-2000"*African Journal Of Food, Agriculture, Nutrition And Development*, 7(2), 1-15

Coelli, T. J. (1996a). A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation. CEPA Working Paper 96/07. University of New England, Armidale, Australia.

Coelli, T. J. (1996b). Specification and estimation of stochastic frontier production function. Unpublished PhD Dissertation, University of New England, Australia.

Coelli, T.J., Rehman, S. & Tirtle, C. (2002). Technical, Allocative, Cost and Scale Efficiencies in Bangladesh Rice Cultivation: A Non-Parametric Approach". *Journal of Agricultural Economics,* 533607-606.

Coelli,T., Rao, D.S.P. & Battese, G.E. (1998). An Introduction to Efficiency and Productivity Analysis. Kluwer-Nijhoff, Boston.

Dolisca, F. C. & M. Jolly. (2008). Technical efficiency of traditional and non-traditional crop production: A case study from Haiti. *World Journal of Agric. Sciences,* 4(4): 416-426.

Food and Agriculture Organization (FAO). (2002). Structural Adjustment Policies and the Agricultural Sector, Theoretical Concepts for Analysis of Economic Policies: The Salter-Swan-Model". http//www.fao.org/tc/tca/31chap8.htm.

Giannakas, K. , Tran, K.C. & Zouvelekas, T. V. (2001). Predicting Technical Efficiency in Stochastic Production Frontier Model in the Presence of Misspecification: A Monte-Carlo Analysis. *Applied Economics*, 352153-161.

Helfand, S. & Levine, E. S. (2004). Farm Size and Determinants of Productive Efficiency in Brazilian Centre-West. *Agricultural Economics*, 31: 241-249

Kibaara B.W. (2005). Technical efficiency in Kenyan's maize production: an application of the stochastic frontier approach, Colorado State University, USA.

Kopp, R. J. & Smith, V.K. (1980). Frontier Production Estimates for Steam Electric Generation: A Comparative Analysis. *Southern Economic Journal*, 47:1049-1059.

Kumbhakar, S. C. & Lovell, C. A. K. (2000). Stochastic Frontier Analysis. Cambridge University Press

Kumbhakar, S.C. & Bhattacharya, A. (1992). Price Distortion and Resource Use Efficiency in Indian Agriculture: A Restricted Profit Function Approach. *Review of Economics and Statistics,* 74:231-239.

Nchare, A. (2007). Analysis of Factors Affecting the Technical Efficiency of Arabica Coffee Producers in Cameroon" Final Report Presented AERC Biennial Research Workshop, Nariobi, Kenya.

Nyemeck, J. B., Sylla, K et Diarra, I. (2001). Analyse des determinants de la performance productive des producteurs de café dans une zone a faible revenue en Cote d'Ivoire, Final report, AERC, Nairobi.

Okike I. , Jabbar M.A., Manyong V. M., Smith J.W. & Ehui S.K. (2004). Factors Affecting Farm-Specific Production Efficiency In The Savannah Zones Of West Africa. *Journal of African Economies,* Volume 13 Number, pp134-165

Onyenweaku,C. E. & Effiong, E. O. (2005). Technical Efficiency in Pig Production in AkwaIbom State, Nigeria. *International Journal of Agriculture and. Rural Development*., 6: 51-57.

Owens, T., Hoddinott, J. & Kinsey, B. (2001). The Impact of Agricultural Extension on Farm Production in Resettlement Areas of Zimbabwe. Working Paper CSAE WPS/2001-6. Centre for the Study of African Economies, University of Oxford, UK.

Owuor, G. & Shem, O. A. (2009). What Are the Key Constraints in Technical Efficiency of Smallholder Farmers in Africa? Empirical Evidence from Kenya. A Paper Presented at 111 EAAE-IAAE Seminar 'Small Farms: decline or persistence' University of Kent, 26-27th June.

Rahman, S. (2003). Profit efficiency among Bangladesh rice farmers. *Food Policy*, 28:487-503.

Rahman, S. & Hasan M.K. (2006). Efficiency Effects of Environmental and Managerial Factors: The Case of Wheat Producers in Bangladesh. The Rural Citizen: Governance, Culture and Wellbeing in the 21st Century, University Of Plymouth, UK.

Reddy, M. (2002). Implications of Tenancy Status on Productivity and Efficiency: Evidence from Fiji. *Sri Lankan Journal of Agricultural Economics*, 4: 19-37

Schultz, T. W, (1964). Transforming Traditional Agriculture. Yale University Press, New Haven. CT.

Sherlund, S. M. , Barret, C. B. & Adesina, A. A. (2002). Smallholder Technical Efficiency Controlling For Environmental Production Conditions. *Journal Of Development Economics*, 69: 85-101.

Tchale H. & Suaer J. (2007). The Efficiency of Maize Farming In Malawi: A Bootsrapped Translog Frontier. Cahiers d'economie et sociologie rurales, no.82-83.

Tesfay G., Ruben, R., Pender, J & Kuyvenhoven, A. (2005). Resource Use Efficiency On Own And Sharecropping Plots In Northern Ethiopia: Determinants And Implications For Sustainability.

Thiam, A., Bravo-Ureta & Rivas, R.E. (2001). Technical efficiency in developing country agriculture: meta-analysis. *Agricultural Economics*, 25:235-243.

Wilson, P., Hadley, D., Ramsden, S., & Kaltsa, L. (1998). Measuring and Explaining Technical Efficiciecy in UK Potato Production. *Journal of Agricultural Economics,* 48(3): 294-305