TECHNICAL EFFICIENCY ANALYSIS OF MAIZE PRODUCTION: EVIDENCE FROM GHANA

Beatrice Bempomaa & Henry de-Graft Acquah

Department of Agricultural Economics and Extension,
University of Cape Coast, Ghana

Abstract: The study applies the single-stage modelling stochastic frontier approach to investigate the performance of maize farmers in the Ejura-Sekyedumase District of Ghana. It estimates the level of technical efficiency and its determinants for 306 maize farmers. Findings indicated that land, labour and fertilizer influenced output positively whilst agrochemicals and seeds affected output negatively. A wide variation in output was also found among producers of maize. The study further revealed that age, sex and off-farm work activities were significant determinants of technical inefficiencies in production. Results from the maximum likelihood estimate of the frontier model showed that averagely, farmers were 67% technically efficient, implying that 33% of maize yield was not realized. The return to scale which measures the productivity level of farmers was 1.22, suggesting that the farmers are operating at an increasing returns to scale.

Keywords: Technical Efficiency, Productivity, Stochastic Frontier, Elasticity, Return to Scale

Introduction

Agriculture plays a vital role when it comes to the growth and development of the Ghanaian economy. This sector ensures poverty reduction especially for the rural communities by generating employment and income to farmers. Again, the agricultural sector guarantees the availability of food. This becomes an important factor when dealing with domestic inflation because it arises as a result of increases in food prices. Agriculture contributes significantly to the nation's Gross Domestic Product (GDP) although it contribution has been declining recently. According to Ghana Statistical Service (2013) report at basic prices, agriculture's contribution to GDP in 2008 was 31.0 and this figure rose to 31.8 in 2009. However, these figures fell to 29.8, 25.3, 22.7 and 21.3 percent for 2010, 2011, 2012 and 2013 respectively. Taking initiatives to promote the growth of the agricultural sector is one of the most effective ways of reducing poverty, hunger and malnutrition. In the pursuit to enhance agricultural productivity, it is imperative that we come out with a road map through which that goal could be achieved. This leaves us with the questions: do we enhance productivity through the introduction of new technologies or do we improve existing technologies? Over the years much attention has been given to the development and the adoption of new technologies. This initiative is believed to enhance farm output and increase income levels of farmers. However, growth in output cannot only be achieved through technological innovation but also through the efficiency in which such technologies are used. This has made researchers and policy makers recognise the importance of efficiency as a way of fostering production. Empirical evidence shows that the gap between actual and potential outputs could be closed by utilising minimum inputs to achieve a possible maximum output (Audibert 1997).

In the Ejura-Sekyedumase District of Ghana, the agricultural sector serves as the main source of employment and income generation for the people. Maize is the major type of food crop grown and the District is the principal producer of maize in the Ashanti region. Facts from the Statistics, Research and Information Directorate of the district shows that estimated cropped area (HA) of maize has been increasing since 2006 but the estimated output in metric tonnes has been declining. The estimated cropped area in hectares increased from 11,951 in 2006 to 13,486 in 2007 and to 17,500 in 2008. In contrast, output in metric tonnes declined from 30,833 in 2006 to 28,861 in 2007 and to 24,419 in 2008 (MoFA 2013). One would presume that as area under crop cultivation of maize increases so would output but this is not the case. This phenomenon may arise as a result of inefficiencies leading to variations in output. Differences in yields can arise between and amongst farmers who have the same farming locations, same seed varieties, soil type and equal amount of fertiliser. The cause of variation in output is as a result of the differences in management practices followed by the farmers. The presence of gaps in efficiency means that output could be increased without requiring additional conventional inputs and without the need for new technology. If this is the case, then empirical measure of technical efficiency in maize production is necessary in order to determine the extent of the gains that could be obtained by improving performance in agricultural production with a given technology.

A lot of work has been carried out in maize production. Mostly these researches are related on how to improve maize yields by looking at pest and disease resistant variety, nutritional quality variety and access to financial institution among others (Morris, Tripp and Dankyi 1999; Bio 2010 and Kpotor 2012). However, much work has not been done when it comes to investigating technical efficiency of maize production in Ejura-Sekyedumase where a lot of maize production is undertaken. It is on these premises that this study investigates technical efficiency in maize production and derives policy implications.

This study therefore examines technical efficiency and its determinants in Ghanaian maize production. Specifically, the study seeks to (1) estimate the level of technical efficiency in maize production; (2) identify the factors that influence technical efficiency; (3) estimate the productivity level of maize farmers.

Materials and methods

Technical efficiency measurements have to do with the comparison of actual performance to optimal performance. Since the true frontier is not known an empirical approximation normally referred to as "best-practice" frontier is required. This can be done by using the parametric or the non-parametric technique (Berger and Humphery, 1997). The estimation of technical efficiency comprises two main methods, namely, the parametric approach and the non-parametric approach. However, this study employs the parametric approach. An example of the parametric approach is the stochastic frontier approach. The stochastic frontier function, an improved model of estimating technical efficiency was developed independently by Aigner, Lovell and Schmidt (1977) and Meeusen and van de Broeck (1977). The model incorporates an error term which is a component of statistical noise and technical inefficiencies. The disintegration of the error term makes this technique more preferable to others. The random errors are assumed to be independently and identically distributed. It also assumes a stochastic relationship between inputs and the output produced. Thus, it allows the assumption that deviations from the frontier are due to inefficiencies and noise in the data. However, the assumption of a-priori distributional forms for the inefficiency component and the imposition of an explicit functional form for the underlying technology is a major flaw for the stochastic frontier analysis. Literature highly recommends the use of stochastic frontier analysis in agricultural production as a result of its inherent nature of uncertainty (Ezeh, 2004)

Sample Size and Data Analysis

The simple random sampling technique was used to select 306 maize farmers from the Ejura Sekyedumase District. The analytical tools used for this study were descriptive statistics and the stochastic frontier model. The R programming software was used to analyse the data. The stochastic frontier model was estimated using the frontier package in R.

Analytical Model for Estimating Technical Efficiency

Due to the nature of agricultural production, the stochastic frontier model which was independently put forward by Aigner et al. (1977) and Meeusen et al. (1977) was used for the estimation of technical efficiency. This allows stochastic noise and producer's inefficiency to be accounted for at the same time. For cross-sectional data, the stochastic frontier function is given as:

$$Y_i = f(X_i;\beta)\exp(\varepsilon_i) = f(X_i;\beta)\exp(V_i - U_i), i = \\ = 1,2,\ldots,N \quad (1)$$

Where Y_i denotes the level of output for the i^{th} farmer; X_i denotes a vector of inputs; β denotes a vector of unknown parameters to be estimated; ε_i denotes the composed error term consisting of two independent elements V_i and U_i such that $\varepsilon_i=(V_i-U_i)$. V_i denotes the stochastic noise and other factors beyond the farmers control; U_i denotes the inefficiency error term which is non-negative. This makes it possible for all observations to lie on or below the stochastic production frontier (Coelli, Rao, O'Donnell and Battese, 2005). Furthermore, it is assumed that the two-sided error V_i is identically and independently distributed (iid) with a mean of zero and a variance of σ_v^2. Also, V_i and U_i are distributed independent of each other and of the independent variables. Following from equation (1), technical efficiency can then be specified as:

$$T_i = \frac{f(X_i;\beta).\exp\{v_i - u_i\}}{f(X_i;\beta).\exp\{v_i\}} = \\ = \mathrm{e\ \ p}\{-u_i\} \quad (2)$$

Equation 2 defines technical efficiency as the ratio of the observed output to the frontier output. Technical efficiency takes a value between zero and one. Thus, $0 \leq TE_i \leq 1$. If $u_i=0$, then the production firm is 100% efficient and if $u_i>0$, then there is some inefficiency.

Specification of the Empirical Model

The Cobb-Douglas production function was used to estimate the stochastic frontier production function. This functional form was chosen because it is flexible, self-dual and its returns to scale are easily interpreted (Bravo-Ureta and Evenson, 1994). Also, empirically, the Cobb-Douglas production function has been widely used in technical efficiency estimation (Hasssan et al., 2005; Essilfie et al., 2011). The model is specified as:

$$\log Y_i = \beta_0 + \sum_{i=1}^{6} \beta_i \log X_i + e_i \tag{3}$$

$e_i = v_i - u_i$

Where Y_i is the output of maize (kilograms) is produced in 2013 season by the i^{th} farmer; X is a set of six input categories namely: land size (acres), labour (man-days), seed (kilograms), agrochemicals (litres), Equipment (GHS), fertiliser (kilograms); β denotes the unknown parameters to be estimated; v_i denotes random shocks; u_i is the one-sided non-negative error representing inefficiency in production.

Estimation of Factors Influencing Technical Efficiency

The single stage approach was adopted for this study. This approach as in Battese et al. (1995), involves a concurrent estimation where the inefficiency effects are expressed as an explicit function of a vector of explanatory variables. Also, the choice of inputs by farmers is shaped by their level of technical inefficiency. The inefficiency model of the stochastic frontier function is given by:

$$u_i = \delta_0 + \sum_{i=1}^{9} \delta_i Z_i \tag{4}$$

Where u_i denotes farm specific inefficiency, δ denotes a set of parameters to be estimated, Z_1 denotes farmers educational level (years of schooling), Z_2 denotes age of farmer (years), Z_3 denotes sex of the farmer (1 = male, 0 = female), Z_4 denotes agricultural extension service contact (yes = 1, no = 0), Z_5 denotes off-farm work (yes = 1, no = 0), Z_6 denotes access to credit (yes = 1, no = 0), Z_7 denotes household size (number), Z_8 denotes experience (number of years in maize production), Z_9 denotes membership to farmer based organisation (yes = 1, no = 0).

Estimating the Level of Productivity

From the Cobb-Douglas production function, the elasticities of the inputs are equal to the corresponding coefficients. Based on the firms' output elasticities, it would be known whether the firm exhibits constant returns to scale, decreasing returns to scale or increasing returns to scale and its implication to the firm. The summation of all the output elasticities gives the returns to scale (RTS). Mathematically, it is specified as:

$$RTS = \sum_{i=1}^{6} \varepsilon y_i \tag{5}$$

Results and Discussion

Findings from Table 1 indicate that on average a yield of 7396.37kg was obtained. This output was obtained by combining 170.65 person-days of labour, 16.06 acres of land, 15.82 litres of agrochemicals, 140.98 kilogram of fertiliser, 5.03 kilogram of seeds and GHS15.68 of equipment. The least and highest yield obtained shows there is a large variation in maize output among farmers in the District. The wide variation in output could be attributed to differences in technical efficiency levels of farmers.

Table 1. Summary Statistics of Variables in the Frontier and Inefficiency Models

Variable	Unit	Minimum	Maximum	Mean	Std. Dev
Output	Kg	480.00	52 200.00	7396.37	6919.31
Labour	P-D	28.00	469.00	170.65	75.91
Land	Acres	2.00	60.00	16.06	10.60
Equipment	GHS	2.40	72.00	15.68	14.04
Agrochemicals	Lit.	3.00	63.00	15.82	10.65
Fertiliser	Kg	25.00	300.00	140.98	43.33
Seed	Kg	3.00	9.00	5.03	1.12
Age	Years	20.00	75.00	43.59	12.63
Education	Years	0.00	18.00	5.13	4.511
Household size	No.	0.00	25.00	6.65	4.38
Experience	Years	2.00	52.00	17.83	10.83
Extension visits	No.	0.00	5.00	0.611	1.06

Source: Field data, 2014

Further, the average age and the years of schooling of maize farmers were 44 years and 5 years respectively. It can therefore be asserted that the older people are the ones engaging in agricultural production especially in maize cultivation. In addition, averagely, the highest level of education attained by a farmer is the primary school and the average number of persons in a household was seven. The result also shows that the number of years engaged in maize production by farmers ranged from 2 years to 52 years. Respondents have much experience in maize farming as the mean experience is about 18 years. Farmers had an extension contact approximately once during the cropping season.

As shown in Table 2, the positive coefficients of labour, land, equipment and fertiliser implies that as each of these input variables is increased, output of maize also increases. There is also a significant but negative relationship between the use of agrochemicals (weedicides, pesticides, fungicide and insecticide) and maize yield. This suggests that the output level of maize would decline as the use of agrochemicals is increased. One plausible explanation for this relationship may be due to the wrong application of the input resulting in excessive use. The coefficient of seed is insignificant but has a negative relationship with output. An explanation for this result is that the quantity of maize seed used by farmers may be higher than the recommended seed rate.

It is also evident that the sigma square value is significantly different from zero, showing a good fit and correctness of the specified distributional assumption. Again, it is clear that the maximum likelihood estimate of the gamma value is 0.6324. The parameter, gamma, shows the total variation of observed output from frontier output. The value (0.6324) is significantly different from one. This means that variations in output are not only caused by inefficiencies in production but it can also be attributed to stochastic noise such as bad weather. This confirms the argument that agricultural production is characterised by uncertainties (Abedullah and Mushtaq, 2007).

Table 2. Maximum Likelihood Estimates of the Stochastic Frontier Model

Variable	Parameters	Coefficient	Std. error	z-value
Intercept	β_0	5.4713***	0.3478	15.7324
log (Lab)	β_1	0.0768	0.0646	1.1893
log (Land)	β_2	1.2862***	0.0637	20.2077
log (Equip)	β_3	0.0667**	0.0255	2.6059
log (Agrochem)	β_4	–0.1646*	0.0681	–2.4161
log (Fert)	β_5	0.0498	0.0551	0.9037
log (Seed)		–0.0931	0.0813	–1.1443
Variance parameters				
Sigmasq	σ_2	0.0935***	0.0183	5.1033
Gamma	γ	0.6324**	0.2071	3.0529
Log likelihood		–49.4088		

Source: Field data, 2014

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Drawing from Henningsen (2013), the variance of the inefficiency term *u,* is not equal to σ_u^2 rather it is equal to $Var(u)=\sigma_u^2[1-(2\square(0))^2]$. Therefore, the proportion of the total variance as a result of inefficiency cannot be explained as the estimated parameter γ. So, further analysis shows that the proportion of the total variance due to inefficiency is 0.38 or 38%.

As indicated in Table 3, the technical efficiency of the farmers is below 100% or 1, showing that all the sampled maize farmers in the District produce below the frontier. The efficiency distribution show that about 61% of the farmers had a technical efficiency below 70 percent while 39% had an efficiency level of above 70 percent. The mean technical efficiency level is about 67%. A wide range of variation exists in the technical efficiency scores of the maize farmers with 28% as the least score and 93% as the highest score. This disparity could be explained by the fact that farmers' combination of inputs yielded different output levels, all other things being equal. The average technical efficiency level of 67% shows that maize farmers could bridge the gap between their observed output and the frontier output by 33%. The implication of this is that with the same level of available resources, farmers could increase yield by 33% without employing any additional resources.

Determinants of Technical Efficiency

Estimates of the technical inefficiency model are presented in Table 4. The factors that influence technical efficiency are explained based on their coefficient signs. A positive sign indicates a decrease in technical efficiency or an increase in technical inefficiency and a negative sign shows an increase in technical efficiency or a reduction in technical inefficiency.

The coefficient of age in the inefficiency model is negative at 10% significant level. This suggests that older farmers are less technically inefficient than the younger farmers. Younger farmers are normally faced with limitations when it comes to the ownership of agricultural resources (land, labour and capital). For instance, land ownership according to the survey was mainly by rent. Therefore, the ability of the farmer to acquire

Table 3. Frequency Distribution of Technical Efficiency Scores

TE: Range (100%)	Frequency	Percentage
1–50	20	6.5
51–60	72	23.5
61–70	95	31.0
71–80	75	24.5
81–90	43	14.1
91–100	1	0.3
Total	306	100
Mean TE		66.99
Minimum		28.33
Maximum		93.09

Source: Field data, 2014

land for production depends on their capital base of which the older farmer may have an advantage because they may have accumulated wealth over the years. Again, even where family land exists for cultivation, it is normally distributed based on age. This result is in line with that of Etwire et al. (2013) and Essilfie et al (2011).

Another vital determinant of inefficiency is the variable sex. But the result is contrary to the a priori expectation because a positive and significant relationship was found between the variable sex and technical inefficiency. It was revealed that female farmers were technically efficient as compared to their male counterparts. This is much of a surprise because the social status of women in many developing countries do not allow them to have access and own resources unlike men who are not limited in their ability to own and have to access resources. Females are less likely to have easy access to credit. Also, it has been found that women as compared to men have lower access to extension service (Njuki, Kihiyo, O'ktingati and Place, 2004).

As expected, credit influenced technical efficiency positively although it was not significant. The availability of credit, whether in cash or kind reduces the constraint faced by farmers financially. This allows them to get the necessary inputs they need and implement certain management decisions on time. However, credit, in the form of cash may sometimes be diverted into other activities especially in situations where farmers are not able to access it on time. This result is similar to the study by Essilfie et al. (2011).

The estimated coefficient of off-farm work was positive and significant at 5%. Off-farm work activities reduce the technical efficiency in maize production. Thus, farmers who engage in non-farm employment are more technically inefficient than those who do not. Farmers become less technically efficient when they engage in occupational activities that gives them extra or higher income. They may therefore pay little attention to the production activities on the farm. The finding obtained corroborates the studies by Coelli, Rahman and Thirtle (2002).

Surprisingly, farmers experienced in maize farming had a negative influence on technical efficiency although it did not have a significant influence on technical efficiency. The positive sign of experience in the inefficiency model indicates that farmers with higher experience are less technically efficient in maize production. The reason for this finding may be attributed to the fact that farmers who have spent long years in farming may be less willing to adopt modern techniques of agricultural practices and new technologies. This result is similar to the study by Otitoju et al. (2010).

The benefits that we get from education and its effects on efficiency have greatly been discussed by many researchers. In principle, it is expected that education will enhance agricultural productivity. In this study, the variable education surprisingly had a positive influence on technical inefficiency but was not a significant determinant of technical efficiency. Farmers who are more educated are more technically inefficient than those who are not. Coelli et al (2002), Wadud and White (2000) in their studies also failed to obtain a significant relationship between education and production efficiency. They attributed this to the fact that the Bangladesh educational system was not agricultural oriented.

Agricultural extension is a tool through which information on new technologies and better farming practices are transmitted to farmers. Consistent with the study of Al-hassan (2012), findings of this study shows that a negative and an insignificant relationship exist between extension contact and technical inefficiency. The negative relationship means that extension contact reduces technical inefficiency. The reason is that farmers are able to apply the training they receive and also appreciate good management practices like timely planting and weed control, correct application of fertiliser, pest and disease control as well as the right amount of seed rate. This leads to the efficient use of scarce resources. A contradictory result has also been reported by Kuwornu et al. (2013) that extensions contacts negatively and significantly influence technical efficiency. They attributed this to the fact either the content of the message delivered by the extension agents were unproductive or the farmers failed to apply the training given to them.

Estimating the Productivity Level

Table 5 reports the productivity level of the maize farmers by looking at the production elasticities and returns to scale. It can be seen that the elasticity of all input are inelastic except land which is elastic. Input elasticities are inelastic if a one percent increase in input results in a less than one percent increase in output and vice versa. An elastic input elasticity means that a percentage change in input use will cause output to change by more than one percent.

Following from the result, the input with the highest elasticity is land and its relationship with output is positive. Thus, an increase in the amount of land under cultivation will significantly increase output, all other things being equal. Aside from land, agrochemical is the second most used input. A one percentage increase in the use of agrochemicals reduces out-

Table 4. Maximum Likelihood Estimates of the Inefficiency Model

Variable	Parameters	Coefficient	Std. error	z-value
Intercept	δ_0	0.4664*	0.2195	2.1246
Age	δ_1	–0.0054.	0.0033	–1.6588
Sex	δ_2	0.1093.	0.0592	1.8456
Education	δ_3	0.0005	0.0056	0.0938
Household	δ_4	–0.0023	0.0070	–0.3358
Experience	δ_5	0.0018	0.0033	0.5384
Off-farm work	δ_6	0.1199*	0.0557	2.1516
Credit	δ_7	–0.1121	0.0788	–0.1423
Extension	δ_8	–0.0185	0.0523	–0.3542
FBOs	δ_9	0.0187	0.0550	0.3409

Source: Field data, 2014

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5. Elasticity of Production and Returns to Scale (RTS)

Variable	Elasticity	RTS
Labour	0.0768	1.2218
Land	1.2862	
Equipment	0.0667	
Agrochemicals	–0.1646	
Fertiliser	0.0498	
Seed	–0.0931	

Source: Field data, 2014

put by 0.16 percent. The cause of reduction in output may reflect in the incorrect application of the input. The use of agrochemicals protects crops from pests and fungal pathogens.

The production function of the maize farmers exhibited increasing returns to scale. Thus, a proportionate increase in all inputs more than doubles output. Farmers, are therefore operating at the irrational stage of production (stage I). They could increase their scale of production efficiently by employing more inputs especially labour, land, equipment and fertiliser to expand output.

Conclusion

The study adopts a single-stage modelling stochastic frontier approach to examine technical efficiency and its determinants of maize farmers in the Ejura-Sekyedumase District of Ghana. Empirical results show that maize farmers in Ghana produce below the production frontier and are therefore technically inefficient. This gives maize farmers the opportunity to increase their yield by 33% using the same level of inputs and existing technology. Agricultural production inputs such as land and equipment had a positive and significant effect on output whilst agrochemicals had a negative and significant effect on output. Farmers were operating at an increasing return to scale. Farmer specific characteristics such as sex, age and off-farm work activities were the important determinants of technical inefficiencies in production. Based on the findings, it is recommended that the Ministry of Food and Agriculture organise educational programmes for farmers on the need to improve upon their production activities through the efficient combination of inputs given that the farmers were producing below the frontier.

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