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Estimation of Farm Level Technical Efficiency of Small-Scale Cowpea Production in Ghana

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Abstract: This study investigates the determinants of small-scale cowpea production in Ejura/Sekyedumase Municipality in the Ashanti Region using a stochastic frontier production function that incorporates inefficiency factors. Data for the study was collected from 200 randomly selected cowpea farmers within the district. A maximum likelihood technique was used to analyze the data. The results indicate that small-scale cowpea farmers were not fully technically efficient as the mean efficiency was 66%. Farm size, seed, pesticides and labour were the major input factors that influenced changes in cowpea output. The result also shows that a farmer's educational level, membership of farmer based organization and access to extension services significantly influenced their efficiency positively. The implications are that policies that would encourage cowpea farmers to join farmer based organizations and provide them with easy access to extension services are options that would improve the efficiency of the farmers.

Key words: Technical efficiency · Cowpea production · Ghana

INTRODUCTION

A key feature of Ghanaian agriculture is the dominance of smallholder farms, which constitute an important and invaluable component of the Ghanaian economy. In Ghana, over about 12 million farmers, scattered in different ecological zones, engage in the production of a wide variety of arable crops through traditional smallholder agriculture Breisinger *et al* [1]. Individually, while not exerting much influence, they collectively form an important foundation on which the nation's economy rests. It has been established that 90% of Ghana's total food production comes from small farms and at least 60% of the country's population earn their living from the small farms [2]. Therefore an effective economic development strategy will depend critically on promoting productivity and output growth in the agriculture sector, particularly among small-scale producers since they make up the bulk of the nation's agriculture.

In Ghana, cowpea is mainly produced in the Northern and Upper West regions [3] however the Upper East Region is also a major commercial cowpea growing area. Likewise parts of Brong Ahafo, Eastern, Volta and Ashanti regions savannah areas are considered cowpea growing areas [4]. The Ghanaian government policy objective for the cowpea subsector is to encourage increased production so that self-sufficiency and food security can be achieved. However, the production of the crop has fluctuated over the years partly due to climatic conditions and policy constraints.

According to the food balance sheet 2009 and 2010, the gross biological production of cowpea is 205,000 Mt [5]. The available domestic production for human consumption is 174,250 Mt from which the per capita consumption is 5.0kg (SRID, 2010). The achievable yield of cowpea under rain-fed conditions in Ghana is 1.96mt/ha with average yield currently being produced being 1.3mt/ha [4]. The average yield currently being produced in the study area is 1.02mt/ha [6]. Some of the main reasons for low productivity of cowpea among small-scale producers in Ghana are associated with the following challenges; poor access to credit, inadequate use of recommended technologies, high

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cost of inputs, lack of agricultural extension service, poor flow of information from research stations to farmers, low prices from the cowpea market resulting in lower input use, high technical and allocative inefficiency [7].

One way of bridging the gap between the achievable or potential yield of cowpea under rain-fed conditions and the current average yield level recorded so far is to increase farm output by increasing technical efficiency under the current existing technologies. In this regard, it is necessary to quantify current levels of technical efficiency so as to estimate losses in production that could be attributed to inefficiency due to difference in socioeconomic characteristics and management practices. The main objective of the study therefore is to estimate the farm level technical efficiency of smallholder cowpea production in Ejura-Sekyedumase Municipality which is a major production area in Ghana.

MATERIALS AND METHODS

Study Area: The study was carried out in the Ejura Sekyedumase Municipality in the Ashanti Region because it is one of the major cowpea production belts in Ghana. The district is located in the northern part of the Ashanti Region (7°22'30''N1°22'1.2''W) and covers a total area of 1,782 square kilometres. This is about 7.3% of the total land area of the Ashanti Region, making it the fifth largest of the twenty-one districts in the region [8]. In 2004, the population was estimated at 81,119. It is estimated that there are about 19,000 farmers in the district, of which 80% are cowpea farmers [4].

Method of Data Collection: A multistage sampling technique (purposive and random sampling technique was adopted in selecting 200 small-scale cowpea farmers from four Operational Zones (Nkyensie, Bayere Nkwanta, Ejura and Dromankuma) in the municipality. The farmers were visited on a fortnightly basis to collect information on inputs used in production as well as output of harvested cowpea. Information on socio-economic characteristics and production factors of the farmers was obtained on the visits with the use of questionnaires. Data collection was carried out between August and December 2012.

Analytical Framework and Techniques: It is hypothesised that the small-scale cowpea farmers were technically efficient in their production and that the systematic and random inefficiency effect is zero which means there is no stochastic effect.

The analytical framework used to test the above hypothesis is based on efficiency measures. According to Ajibefun and Daramola, [9] the fundamental idea underlying all efficiency measures is that the output of goods and services per unit of input must be attained without waste. There are two basic methods of measuring technical efficiency: the classical and the frontier approach. There are controversies and dissatisfaction as well as some shortcomings associated with the classical approach. This has led to the development of the advanced econometric, statistical and linear programming techniques by economist for the analysis of technical efficiency related issues. Both techniques have in common the concept of a frontier which is regarded as the measure of efficiency. Thus, efficient farms are those operating on the production frontier, while inefficient farms are those operating below the production frontier.

The amount by which a farm lies below its production frontier is regarded as the measure of inefficiency. Aigner *et al.* [10] define stochastic frontier production function as:

$$Y_i = f(X_i;\beta) + e_i \tag{1}$$

where, $i = 1,2,...N$

$$e_i = v_i = u_i \tag{2}$$

Where Yi represents the output level of the *ith* sample farm; $f(X_i;\beta)$ is a suitable function such as Cobb-Douglas or translog production functions of vector, X_i of input for the *ith* farm and a vector, β of unknown parameters [7]. e_i *is* an error term made up of two components: v_i is a random error having zero mean, $N(0;\sigma v)$ and it is assumed to be symmetric independently distributed as $N(0;\sigma\ v)$ random variables and independent of u_i On the other hand, u_i is a non-negative truncated normal, $N(0;\sigma\ v)$ random variable associated with farm-specific factors, which leads to the *ith* farmer not attaining maximum efficiency of production; u_i is associated with technical inefficiency of the farmer and ranges between zero and one.

N represents the number of farmers involved in the cross-sectional survey of the farms [7]:

$$\overline{TE}_i = Y_i / Y_i^* \tag{3}$$

Where
$Y_i^* = f\left(X_i, \beta\right) = \text{the highest predicted out of the farm}$

$$\overline{TE}_i = Exp\left(-U_i\right) \tag{4}$$

Technical efficiency $= 1 - \overline{TE}_i$

Empirical Model Specifications: The empirical stochastic production frontier model used the Cobb-Douglas specification for the analysis of technical efficiency of sole cowpea farmers. The model is specified as follows

$$ln\ Y_i = \beta_0 + \sum_{i=1}^{4} \beta \ln X_i + e_i \tag{5}$$

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

Where Y_i is the output of cowpea measured in kilograms and x_i are the inputs (Farm size, Seed, Pesticides, Labour) and the $X\ s$ are the parameters to be estimated. The efficiency model is specified as follows:

$$u_i = \delta_0 + \sum_{i=1}^{7} \delta_1 Z_i \tag{7}$$

The u_i is the inefficiency model and the variable Z_i (that is, educational level, household size, number of years of farming, access to extension services, access to credit, access to off farm income and a membership of farmer based organization) are the farm/farmer characteristics that have direct influence on the farmers' efficiency [11]. The empirical model estimated is specified as

$$In\ yield = \beta_0 + \beta_1\ In\ Farmsize + \beta_2\ Seed + \beta_3\ In\ Pesticides + \beta_4\ labor + \delta_1\ Educa + \delta_2 HHS + \delta_3 Farmexp + \delta_4 Extcon + \delta_5\ Cred + \delta_6\ Offinc + \delta_7\ Fbo + v \tag{8}$$

Where:

Yield	=	Output of cowpea measured in Metric tonnes
Farm size	=	land area measured in hectares
Seed	=	Seed input measured in Metric tonnes
Pesticides	=	measured in litters
Labour	=	measured in man-days
Educa	=	number of years in schooling (Education)
HHS	=	Household size of farmers (Numbers)
Farmexp	=	Farming experience in number of years
Extcon	=	Extension contact (1=Contact and 0= No contact)
Cred	=	credit access (1=Access and 0= No access
Offinc	=	Off-farm income in Ghana Cedi (GH¢)
Fbo	=	Farmer Based Organisation (1=Member and 0=Non-member)
V	=	Error term.

In this study, parameters of the stochastic frontier production function (β_0-β_4 and δ_0-δ_7) are estimated using maximum likelihood estimation method, using the computer programme STATA (Version 10)

RESULTS AND DISCUSSIONS

Summary statistics of the socioeconomic characteristics of the respondents are presented in Table1 and Table 2. The age of the farmers studied ranged between 22 to 60 years with an average of 45 years. The results imply that farmers in the area are relatively old, a condition that may affect their overall efficiency. The average household size of the farmers is five (5) which means, the farmers have some source of labour, since cowpea production is labour intensive. Furthermore, the average farming experience of the farmers is 16 years, implying that the farmers have an appreciable number of years of experience in cowpea production. This should enhance the farmer's productivity/ efficiency since experienced farmers have the ability to predict climatic, soil conditions and pest and disease occurrences on the field.

The average number of years of schooling (education) among the farmers is 5 years. It implies that most of the farmers had either no formal education or spent very few years schooling. This attribute of the farmers in the study area decreases production efficiency. The respondents mean off farm income is GH¢ 120 per annum. This may have double-edged implication for cowpea production. First there is the likelihood that farmers will spend their time elsewhere to gain this off-farm income, thus spending less time on their field and therefore not being able to perform all the necessary operations that would enhance production efficiency. This could then reduce technical efficiency. Secondly, other sources of income could help farmers finance their farm operations leading to enhanced production efficiency and for that matter technical efficiency.

Table 1: Summary Statistics of Age, Household Size, Farming Experience and Education of the Respondents

Variable	Mean	St. dev	Minimum	Maximum
Age	45.12	7.15	22	60
Household size	5.35	2.07	2	10
Farming experience	15.99	6.41	2	22
Education(years of Schooling)	5.38	4.22	0	12
Off-farm income	125	12.6	0	243

Table 2: Socioeconomic Characteristics of the Respondents

Variable	Frequency	Percentage
Sex		
Male(1)	148	74
Female(0)	52	26
Extension Contact		
Contact(1)	76	38
No contact(0)	124	62
Access to Credit		
Access(1)	68	34
No access(0)	132	66

Source: field survey 2012

Table 3: Summary Statistics of Variable used in the Stochastic Frontier Model

Variable	Unit	Mean	Standard deviation	Minimum	Maximum
Output	Mt/ha	0.98	65.54	0.272	1.09
Pesticides	Litres/ha	4.76	0.49	1	3
Seed	Ma/ha	0.07	1.10	0.025	0.0375
Farm size	Hectares	1.506	0.88	1	5
Labour	Man-days	68.42	6.74	45	75

The gender distribution in the study area saw males being dominant 74% of the respondents are male while only 26 are female. Most of the farmers had no extension contact pertaining to advice or information acquisition on cowpea production technologies and management practices. This is a hindrance to the farmers in getting closer to the frontier. Furthermore, the majority of the farmers had no access to credit. Credit accessibility helps farmers to acquire inputs like labour, seed and pesticides which would enhance the farmer's technical efficiency.

Summary Statistics of the Output and Input Variables: The summary of the variable used in the production function estimation is presented in Table 3. The results indicate that the mean output per farmer in small-scale cowpea production is about 0.98mt/ha. This output per hectare was relatively lower than the national mean yield of approximately 1.03mt/ha [4]. The mean labour usage was 68.42 man-days. This is expected given the tedious operations in small-scale cowpea production. The mean farm size among the farmers was 1.5 Hectares which implies that the farmers are indeed operating on a small-scale level. Seed and pesticide usage was adequately used by the farmers, since the level of output to be obtained depends on the seed rate and pest control

Estimates of the Parameters of the Production Factors: Estimates of the parameters of the stochastic frontier production model revealed that all the estimated coefficient of the variables of the production function were positive and significant (Table 4).

This implies that these inputs are very much needed in increasing the output of cowpea. Farm size is significant at 1 percent implying that, among the factors, output of cowpea is affected greatly (99 percent in terms of confidence interval) by farm size. Seed and pesticides are significant at 5 percent indicating that output of cowpea is affected (95 percent in terms of confidence interval) by seed and pesticides. Labour which is significant at 10 percent affects output (by 90 percent in terms of confidence interval).

Table 4: Estimates of Parameters of the Stochastic Production Frontier and the Inefficiency Model

Variable			
Stochastic Frontier	coef	Z-values	P> Z
Intercept	4.6792	4.29	0.000
ln Farm size	0.3812 ***	4.31	0.000
ln Seed	0.2174 **	2.21	0.015
ln Pesticides	0.5234 **	1.91	0.010
ln Labor	0.0716*	1.71	0.056
Inefficiency Model			
Education	- 0.1125**	-2.16	0.032
Household size	0.0093	0.76	0.451
Farm experience	-0.0097	-0.15	0.892
Extension contact	-0.2428**	-1.32	0.022
Credit access	-0.8682	-1.69	0.122
Off-farm income	0.3943***	3.89	0.000
Fbo member	-0.6341***	-2.07	0.007
Variance parameters			
Sigma-Squared		0.7243	
Gamma		0.7076	
Lamda		1.5540	
Log-likelihood function		62.697	
Mean Technical Efficiency		0.6621	

***, **, * are 1%, 5% and 10% significant level respectively

Table 5: Input Elasticity

Input Variables	Elasticity
Farm size	0.082
Seed	0.278
Pesticides	0.681
Labour	0.223
Return-To-Scale (RTS)	1.264

Diagnostic Statistics and Gamma Parameters: The estimated lamda (λ) and sigma-squared (σ^2) values of 1.55 and 0.72 are significant at 1%, indicating a good fit and correctness of the specified distribution assumption. The lamda is the ratio of the U and V error term and it indicates that the one sided error term U dominates the symmetric error term V, so variation in actual cowpea yield comes from the difference in farmers' specific factors rather than the random variability. Gamma (γ) is also a measure of the level of inefficiency in the variance parameters and ranges between 1 and 0. For the Cobb-Douglas model used in the study area, it is estimated to be 0.7076 or approximately 71%. This indicates that 71% of the total variations in cowpea output are due to technical inefficiency in the study area. The result of the diagnostic statistic therefore confirms the relevance of the stochastic parametric production function and the maximum likelihood estimation model employed.

Input Elasticity: Determination of elasticity is necessary for the estimation of the responsiveness of yield to inputs. All of the inputs on the stochastic frontier are statistically significant and have the expected signs. Table 5 shows results of the input elasticities for each input in the Cobb-Douglas stochastic frontier production function. A one percent increase in the acreage will increase cowpea yield by 0.28 percent (p=0.000), ceteris paribus. In addition, a one percent increase in seed rate will increase output by 0.22 percent (p=0.015) and an increase in the quantity of pesticides applied increases output by 0.68 percent (p=0.070). Furthermore, a one percent increase in the man-days of labour increases output by 0.08 percent (p=0.056)

The study also showed that yield of cowpea was most responsive to pesticides, followed by seed, labour and farm size. The prior expectation was that yield of cowpea is more responsive to pesticides. This result supports the findings put forward by International Institute of Tropical Agriculture (IITA) indicating that output of cowpea depends mostly on how pest and diseases are controlled since the crop is very susceptible to pest and diseases in the Africa continent. A total of 95 percent of the output could be lost if pre-harvest pests and diseases are not controlled well. As observed in the above results, all the inputs elasticities are inelastic; a one percent increase in each input results in a less than one percent increase in yield [12].

Scale Efficiency: Summation of the partial elasticity of production with respect to every input for a homogenous function (all resources varied in the same proportion) from Table 5 above is 1.26. This represents the Returns-To-Scale (RTS) coefficient, also called the function coefficient or total output elasticity. If all factors are varied by the same proportion, the function coefficient indicates the percentage by which output will be increased. In this case, the production function can be used to estimate the magnitude of the return-to-scale. Constant return-to-scale only holds if the sum of all partial elasticity is equal to one. If the sum is less than one, the function has a decreasing return-to-scale: If more than one, as in the case of the study, an increasing return-to-scale exists. Therefore, an increase in all inputs by one percent increases cowpea yield by 1.26 percent.

Table 6: Marginal Physical Productivity and Average Physical Productivity of the Inputs

Inputs	MPP (Mt/Ha)	APP (Mt/Ha)
Farm size	0.844(0.775bags)	0.302(2.767bags)
Seed	0.068(0.625bags)	0.310(2.840bags)
Pesticides	0.155(1.425bags)	0.228(2.095bags)
Labour	0.043 (0.400bag)	0.545(5.000bags)

1bag of cowpea =0.109mt

This indicates that farmers are operating in the stage one of the production surface which is an irrational zone and that output can still be increased by using more of the inputs.

Marginal Physical Productivity and Average Physical Productivity of the Inputs: The Marginal Physical Product (MPP) and the Average Physical Product (APP) for each of the inputs were estimated. Table 6 below shows the results of the MPP and APP values of the various inputs

Pesticides had the highest MPP: therefore an increase in the quantity of pesticides by one litre is estimated to increase output by 0.16mt/ha, equivalent to 1.4 bags per hectare. An increase in quantity of seed by one kilogram is estimated to increase output by 0.7 mt/ha. Furthermore, an additional labour, which is a person-day, is estimated to increase output by about 0.04mt/hat. An additional usage of land is estimated to increase output by 0.844mt or 0.8bag per hectare. The various APP of the inputs depicts the average output attained when the total quantity of each of the inputs is used on per acre basis. This implies that, the average productivity of land on per hectare basis is 0.30mt/ha of output. This interpretation applies to the APP values of the rest of the inputs.

Sources of Technical Inefficiency: The sources of inefficiency were examined by using the estimated δ-coefficient associated with the inefficiency effects. The inefficiency effects are specified as those relating to farming experience, education, credit access, extension contact, membership of a farmer based organization, household size and off-farm income. The estimated coefficient of farming experience, household size, credit access and off-farm income were statistically insignificant. However, only farming experience and credit access have the expected sign.

On the other hand, education, extension contact and membership of a farmer based organization were statistically significant and negatively related to inefficiency effect. The estimated coefficient of education is negative and statistically significant at 5 percent. This indicates reduction in technical inefficiency. This implies that more years of education or years of schooling brings about a decrease in technical inefficiency (increase in technical efficiency) in small-scale cowpea production. Thus, farmers with more years of formal schooling tend to be more efficient in cowpea production presumably due to their enhanced ability to acquire knowledge, which makes them closer to the frontier output. Besides, farmers who had some level of education respond readily to the use of improved technology. This results is consistent with Lockheed *et al.* [13], Ali and Byerlee [14], Ali and Flinn [15], Bravo-Ureta and Reiger [16], Abdulai and Huffman [17] and Wang *et al*. [18].

On the other hand, the estimated coefficient of extension contact is negative and statistically significant at 5 percent. The result shows that access to extension services helps to reduce technical inefficiency in cowpea production. The advice given by the extension agents helps the farmers to improve their management skills and also to acquire knowledge on new practices. This result is consistent with the finding obtained by other researchers [16, 19, 20]. This result therefore serves to emphasize the role of extension service in reducing technical inefficiency in cowpea production.

Finally, the coefficient of the dummy variable for membership in a farmer based organization is negative and statistically significant at 1 percent. Membership of a farmer based organization is part of social capital. Binam *et al.* [21] also used association membership to capture the role of social capital in providing incentives for efficient farm production. Furthermore, membership of farmer based organization affords the farmers the opportunity of sharing information on modern cowpea production practices by interacting with other farmers. This result is consistent with those of Onyenweaku [22], Effiong [23] and Okike [24] all in Nigeria.

Results of Tests of Hypothesis: The null hypothesis specifies that the small-scale cowpea farmers were technically efficient in their production and that the systematic and random inefficiency effect is zero which means there is no stochastic effect.

Table 7: Likelihood-Ratio Test

Null Hypothesis	Chi2	diff	P-value	Decision
H_0: $U=0$	32.53	17	0.000	Reject H_O

Source: Field survey 2012

The alternative hypothesis states that the small-scale cowpea farmers were not technically efficient in their production and that the systematic and random technical efficient in the inefficiency effect are not zero. The above hypothesis was tested using the log likelihood ratio test (Table 7).

The null hypothesis is rejected in favour of the alternative hypothesis that is presence of inefficiency effects.

Summary: In summary, the This study set out to provide estimates of technical efficiency of small-scale cowpea production and to explain variations in technical efficiency among farms through managerial and socio economic characteristics. Farm specific technical efficiencies were computed using cross-sectional data of small-scale cowpea production from the Ejura/sekyeodumase Municipality. A stochastic frontier approach was used to generate technical efficiency estimated using STATA 10 software. The coefficients of the inefficiency determinants were obtained using the Cobb-Douglas frontier production function through maximum likelihood estimation procedure.

Conclusion and Recommendations: The mean technical efficiency for the small-scale cowpea farmers in the study area was 0.66. The important factor inputs that increased farm output are farm size, seed, pesticides and labour. The farm specific technical distribution revealed that none of the farmers reached the frontier threshold. Thus, within the context of the efficient agricultural production, cowpea output per hectare production can still be increased by 44% with using available inputs and technology. The farmers were found to have a return-to-scale of 1.26, implying that the farmers are operating in stage one of the production surfaces.

Among the seven socioeconomic variables estimated in the inefficiency model, only three were statistically significant. These are education, extension contact and membership of farmer based organization. However, the coefficient of farmer based organisation exhibit which had a negative relationship with the inefficiency effects. It was further shown that all the input elasticities were inelastic; a one percent increase in each input results in a less than one percent increase in yield.

In order to improve efficiency, farmers need to organize themselves into groups as group membership positively influences their efficiency. Also more effort should be intensified on the part of extension agents in educating the farmers on cowpea production.

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