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ASSESSING THE PRODUCTIVE EFFICIENCY AMONG SMALLHOLDER COWPEA FARMERS IN NORTHERN GHANA

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Abstract
Understanding the sources and drivers of inefficiency in Ghana's crop production systems remains an imperative. This study uses stochastic frontier modelling to investigate the technical, allocative and economic efficiency of cowpea production in Tolon, Savelugu-Nanton, and Gushegu districts of the Northern region using cross-sectional data of the 2013/14 cropping season. Technical, allocative, and economic efficiencies averages were estimated to be 91.6%, 80.7%, and 73.4%, respectively. The results suggest that there is enough potential for cowpea farmers to increase production and net profits. The results also show that, quantity of seeds, labour, and farm size exert significant positive effects on the output of cowpea, while expansion in land under cultivation decreases average costs, an observation consistent with economic theory. The study also finds that, education, land ownership, number of years in cowpea farming, and agricultural extension services were the significant determinants of technical inefficiency. The study recommends that farmer education be intensified though well-tailored agricultural extension services.

Keywords: Allocative efficiency, Cowpea, Economic efficiency, Northern Ghana, Technical efficiency

Introduction

Despite the oil find and the talk of an emerging petrochemical economy, agriculture remains a significant contributor to Ghana's Gross Domestic Product (GDP) and a growth pole for socio-economic development. Ghana's agricultural sector consists of a variety of farm products and a well-rooted industry that employs both formal and informal segment of the economy. Agriculture in Ghana accounts for more than 30% of GDP, three-quarters of export earnings. Despite growth in the service sector, the agricultural industry is still the leading source of employment, employing about 50% of the unemployed persons in Ghana (GSS Labour Force Report, 2015). The contribution of agriculture to GDP has however been declining due to growth in other sectors. Between 2005 and 2012, the share of agricultural GDP fell from 37% to 23% (MoFA, 2012). The crop sub-sector, however, remains the most substantial activity in the economy with a share of 16.9% of GDP.

The crop sector consists of major crops such as cocoa, cotton, oil palm, cashew, soybean, rice, maize, cereals, and legumes. Among the leguminous crops, the most economically-important indigenous African grain legume is cowpea, *Vigna unguiculata*. Related to common bean and chickpeas, millions of small-holder farmers cultivate this crop allocating about 8 million hectares of cultivable land in West and Central Africa (Langyintuo *et. al.* 2003). Cowpea grain is one of the few products that can be profitably produced by farmers under arid conditions and resource constraints. Cowpea has the potential to contribute to food security and poverty reduction in West Africa. The demand for cowpea in the West African region is increasing because of high population growth, mainly from the urban areas, and also because of poverty and the need for low-cost food. The high protein content of cowpea and its use as a staple in the diets of Sahelian and coastal populations makes cowpea a strategic crop for improving food security in these regions. Cowpea forage contributes significantly to animal feed mainly during the dry season when the demand for feed reaches its peak. The largest producer and consumer of cowpea in West Africa and in the world is Nigeria where a dense population and oil revenue create an enormous effective demand for cowpea. Niger is the largest cowpea exporter in West Africa (and in the world) with an estimated 215,000 MT exported annually, mainly to Nigeria. Substantial amounts of cowpea also come to Nigeria from other neighbouring countries, especially Cameroon and Chad. A significant portion of cowpea from Burkina Faso and Mali are sold into Cote d'Ivoire, and also Nigeria.

Ghana's agricultural sector remains predominantly small-scale with about 83% of the rural households producing 80% of the output using rudimentary methods that often result in poor yields and low factor productivity (FAO, 2015). Yields of most crops are low (20 – 50% below their potential levels). For example, yam yield is at 15.6 metric tonnes against a propective yield of 49 metric tonnes, the yield of paddy rice is 2.5 metric tonnes as against a potential yield of 6.5 metric tonnes (MoFA, 2012). For the legumes, groundnut yield is at 1.4 metric tonnes against a prospective yield of 2.5 metric tonnes whereas cowpea records a yield of 1.3 metric tonnes against a potential of 2.6 metric tonnes per hectare (MoFA, 2012). The current situation calls for an increase in productivity to close the yield gap to grow the agriculture sector. Agricultural growth can be attained by improving upon the use of the available resources. Though Ghana has the potential to increase cowpea productivity, just like any other agrarian subsector, cowpea production is plagued with challenges such as expensive inputs (fertilizer, chemicals, etc.), inadequate access to extension services and credit facilities. As a result, cowpea farmers, on the average produce less than the potential output making them highly inefficient in the production. However, the actual levels of efficiency and the sources of inefficiencies are less exploited in the Ghanaian agricultural literature. Measuring economic efficiency and identifying the causes of inefficiencies are necessary first steps to achieving agricultural productivity growth. The general objective of this study is to estimate the technical, allocative and economic efficiency of cowpea farmers in the northern region of Ghana, using Tolon, Savelegu-Nanton and Gushegu districts as a case study.

Materials and Methods

Study Area, Data and Sampling Approach

The data was obtained through a cross-sectional survey conducted in three districts in the Northern region during the 2013/2014 farming season. The three districts namely, Tolon district, Savelugu/Nanton municipality, and Gushegu district, all located in the North –Western part of the region. The region occupies 70,384 square kilometres, representing about 30% of the total land area of Ghana. The population is estimated at 1.8 million representing 9.6 percent of the total population of Ghana (Population and Housing Census [PHC], 2010). The Northern region is much drier than the southern areas of Ghana, due to its proximity to the Sahel and Sahara. The vegetation consists predominantly of grassland, especially savannah with clusters of drought-resistant trees such as baobab or acacias. The period between May and October is the wet season with an average rainfall of 750mm and 1050mm (30 to 40 inches). The dry season occurs between November and April. The highest temperatures are reached at the end of the dry season, between October and March, the lowest in December. Major food crops grown in the districts are cereals (maize, rice, sorghum and millet) root and tubers (cassava, yam and potatoes). Others include legumes (groundnut, cowpea, soybean, pigeon pea and Bambara beans and vegetables (Okro, tomatoes, pepper, onions, garden eggs, green melon).

The study followed a multi-stage proportionate sampling procedure in selecting districts from the region, communities from the district and households from the communities. Extensions agents assisted these selection procedures at the district departments of Ministry of Food and Agriculture (MoFA). Firstly, three districts namely Tolon, Savelegu-Nanton and Gushiegu districts were selected from the list of cowpea producing districts in the Northern region. Secondly, a proportionate random sampling was used to select six, eight and five communities from Tolon, Savelegu-Nanton and Gushiegu respectively. Finally, 15 – 22 farm households were selected from each community. In total across the three districts, 100, 100, and 140 farm households were randomly sampled from Tolon, Gushiegu, and Savelegu-Nanton respectively, making a total sample size of 342 cowpea farm households. The questionnaire was pre-tested, and some slight modifications were made to get more relevant information and improve reliability.

Theoretical and Analytical Framework

Measurement of efficiency emanated from the theory of production function. The production function is a technical relationship between inputs and outputs, given a set of technology. There are two main ways of estimating the production function for efficiency analysis namely; parametric frontier model (PFM) or statistical approach and non-parametric frontier model (NFM) or linear programming approach (Johnes 2006). In PFM, specific functional forms, as well as distributional form, are assumed but not so in NFM. One can also distinguish stochastic models from deterministic models from literature. A deterministic frontier assumes that any deviation from the frontier is attributable to inefficiency. In the stochastic frontier models, it is only factors that are within the control of production units account for inefficiency but at the same time recognizes the role of factors that are beyond the control of such production units. However, the non-parametric approach also imposes some technical restrictions such as monotonicity and convexity (Kumbakar et. al., 2000). In this study, we adopted the stochastic frontier analysis which is a parametric approach to estimate our production function.

Efficiency measurement has its root from the efforts of Farrell (1957), who suggested the two main components of efficiency, namely; technical and allocative efficiencies. Technical efficiency measures the ability of a firm to obtain maximum output from a given set of inputs while the firm's ability to optimize the use of inputs up to a level where their marginal value of productivity is equal to the marginal factor cost is called allocative efficiency. Technical and allocative efficiency constitutes economic efficiency. Figure 1 depicts a graphical illustration of TE, AE, and EE.

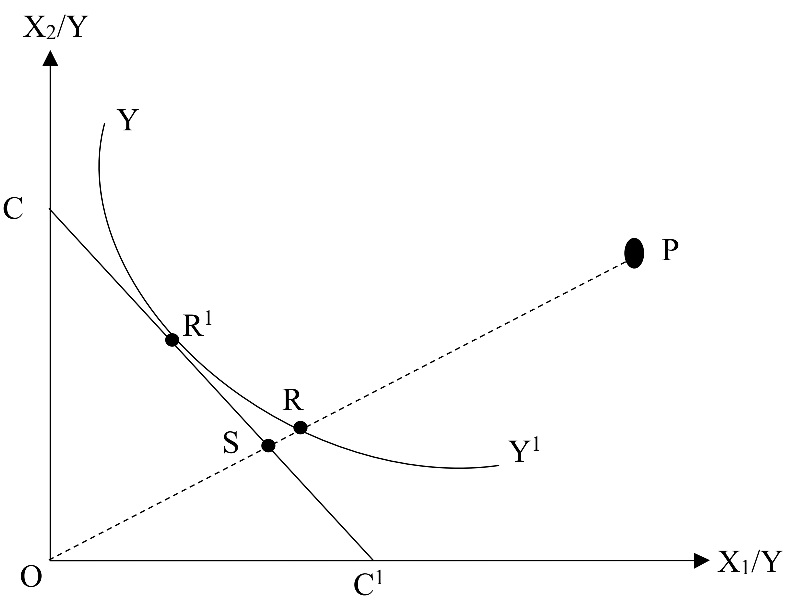

Figure 1: Technical, allocative and economic efficiency (Adapted from Coeli, 1996)

Figure 1 indicates that any firm say ***R*** that operates on the isoquant $\boldsymbol{YY^1}$ is considered as being technically efficient. However, a firm operating at ***P*** is said to be inefficient because it is operating far away from R. In this case, the distance from ***R*** to ***P*** measures the technical inefficiency of ***P***. The distance ***RP*** is the amount by which firm's inputs can be proportionally reduced without reducing output. Thus, technical efficiency of this firm is measured as ratio of distance ***OP*** to distance ***OR*** (i.e. $TE = \frac{OP}{OR}$). TE is in the range of zero and one, where one represents technically efficient and zero indicates technically inefficient. From Figure 1, the input prices are represented by the straight line CC^1 where allocative efficiency (AE) can be determined. *AE* can be specified as, $AE = \frac{OS}{OR}$, since distance *SR* represents reduction in production costs if production were to occur at technically and allocatively efficient point $\boldsymbol{R^1}$ instead point $\boldsymbol{R}$ where a firm will be technically efficient but allocatively inefficient. The product of *TE* and *AE* give us economic efficiency and can be specified as; $EE = TE \times AE$.

The Stochastic Frontier

Building on the previous works of Farrel, (1957), Aigner, et al. (1977) and Meeuseen van den Broeck (1977) developed the stochastic frontier model for the analysis of production units. According to Coelli (1995), stochastic frontier is most appropriate for the analysis of farm-level data where measurement errors and climatic conditions are likely to have a significant effect. Hence, the study adopted the stochastic frontier model. The general stochastic production model of a farm is given as;

$$Y_i = f(X_i;\beta)\exp(V_i - U_i) \qquad [1]$$

Where Y_i is the output of the i^{th} farmer; X_i is a vector of farm inputs β is a vector of parameters to be estimated; V_i measures the random variation in output due to factors outside the control of the farm, and assumed to be identically and independently distributed as $N(0,\sigma_v^2)$ independent of U_i which has a half normal non-negative distribution. The U_i are non-negative technical inefficiency effects representing factors within the control of the farmer and assumed to be independently distributed with mean u_i and variance σ^2. The coefficients of equation [1] are estimated through the maximum likelihood procedure. The overall variance of the model σ^2 is given as the summation of the variances of random errors σ_v^2 and the variances of the inefficiency effects σ_u^2, which can be specified as;

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \qquad [2]$$

The total variation of the output from the frontier attributed to technical inefficiency is also measured by the gamma γ, which is the ratio of the variance of the inefficiency effect σ_u^2 to total variance σ^2. This can be specified as;

$$\gamma = \frac{\sigma_u^2}{\sigma^2} \qquad [3]$$

The value of the γ is between 0 and 1 (Battese and Corra, 1997).

In specifying the cost function, the composite error term is changed from $\varepsilon_i = V_i - U_i$ to $\varepsilon_i = U_i + V_i$. The transformation of the production function provides the cost function specified as:

$$C_i = f(Y^*, P_i, \alpha)\exp(U_i + V_i) \qquad [4]$$

Where C_i is the minimum cost of the input of the i^{th} farm associated with the observed output Y^*, P_i is the vector of input prices, and α is a vector of parameters. V_i is a random variable assumed to be iid $iid\, N(0,\sigma_v^2)$ and independent of U_i. U_i are a non-negative variables assumed to be $iid\, N(0,\sigma_u^2)$ and considered to be responsible for the farm's cost inefficiency. It determines how far the firm operates above its cost frontier.

The economic efficiency (EE) of the i^{th} farm can specifically be calculated as the ratio of the minimum potential total production cost (C*) to the observed total production cost and can be specified as;

$$EE = \frac{C_i^*}{C_i} = \frac{f(Y^*, P_i; \alpha_i)\exp(U_i + V_i)}{f(Y^*, P_i, \alpha_i)\exp(V_i)} = \exp(U_i)$$

[5]

Where C^* is the potential production cost where cost efficiency can be achieved and C is the observed cost by the i^{th} farm. The value of economic efficiency ranges between 0 and 1. An i^{th} farm is said to exhibit economic efficiency if $C^* = C$ and economic inefficiency exists if $C^* > C$

Economic inefficiency of an i^{th} farm can also be specified as;

$$U_i = \delta Z_i + w_i \qquad [6]$$

Where Z_i is a $(1 \times m)$ vector of explanatory variables explaining the variations in farmers' economic inefficiency. δ is a vector of parameters to be estimated and w_i is an unobserved random variable.

Farrel (1957) explained that the index of allocative efficiency can be obtained by the ratio of economic efficiency to that of technical efficiency. Thus, $AE = \frac{EE}{TE}$.

To evaluate the extent to which cowpea farmers efficiently allocate their resources, we adopted marginal-value-productivity (*MVP*)- marginal-factor-cost (*MFC*) analysis. With this analysis, the MVP of each input is computed from an average response model estimated with Ordinary Least Ordinary (*OLS*), where input elasticity (β_i) and marginal physical product (*MPP*) are obtained. The *MVP* can then be calculated as follows;

$$Y = f(X_i; \beta_i) \quad [7]$$

$$\beta_i = \frac{\partial \ln Y_i}{\partial \ln X_i} \quad [8]$$

$$MPP = \beta_i (\frac{Y_i}{X_i}) \quad [9]$$

$$MVP = \beta_i (\frac{Y_i}{X_i}) \cdot P_Y = MPP \cdot P_Y \quad [10]$$

Where Y_i is the mean cowpea output of the i^{th} farm, X_i is the mean of each input used and P_Y is the mean price of output. A measurable input is allocatively efficient if it is used up to a point where *MVP* is equal to its respective *MFC* (Danso-Abbeam et. al., 2015; Abdulai et. al. 2017).

Thus, an i^{th} farm will achieve full allocative efficiency if and only if; $\frac{MVP}{MFC} = R_X = 1$

[11]

Consequently, an input is over-utilized if $R_X < 1$ and under-utilized if $R_X > 1$. In a situation where $R_X \neq 1$, then the extent of changed required in the inputs' used in order to achieve full allocative efficiency is given by: $(1 - R_X) \cdot 100$ (Nwaru and Iheke, 2010).

Empirical model of the stochastic and cost functions

In estimating the stochastic and cost function of cowpea production in the study area, we adopted the translog functional form proposed by Christensen et. al., (1973) after a preliminary test of hypothesis had suggested translog is the best fit for the data set. The translog functional form has been used in many efficiency studies in agricultural sector (Mensah and Brummer 2016; Asante et. al. 2017). The translog functional form for stochastic production function can be specified as follows;

$$\ln Y_i = \beta_0 + \sum_{k=1}^{5} \beta_k \ln X_{IK} + \frac{1}{2} \sum_{k=1}^{3} \sum_{j=1}^{3} \beta_{kj} \ln X_{ik} \ln X_{ij} + (V_i - U_i) \quad [12]$$

Where Y_i denotes the output of cowpea in kilograms, X_i is a vector of inputs representing farm size (ha), labour (man-days) and amount of seeds (kilograms). U_i is the inefficiency measure, which is half-normal distribution with mean, μ and variance, σ^2.

The stochastic cost function can also be expressed as;

$$\ln C_i = \beta_0 + \beta_1 \ln Y_i + \sum_{k=1}^{3} \beta_k \ln X_{ik} + \frac{1}{2} \sum_{k=1}^{3} \sum_{j=1}^{3} \beta_{kj} \ln X_{ik} \ln X_{ij} + (U_i + V_{ii}) \quad [13]$$

Where C represents the total cost of maize production in Ghana Cedis (GH¢), Y_i is the output of cowpea in kilograms, X_1 represents the unit price of land, X_2 is the unit price of seeds and X_3 is the unit price of seeds.

The technical inefficiency model can also be expressed as;

$$u_i = \delta_0 + \sum_{i=1}^{10} \delta_i Z_i + \varepsilon_i \qquad [14]$$

Where Z_1 is the age of farmer; Z_2 is the number of years in school; Z_3 is the household size of farming household; Z_4 is the number of years of farmer in cowpea cultivation; Z_5 is farmers belonging to farmer based organizations (categorised as 1 for belonging to FBO and 0 otherwise); Z_6 is the distance of farmer's home to farm plot; Z_7 is land ownership(1 for land ownership and 0 otherwise) and Z_8 is the type of seed (1 for hybrid and 0 otherwise); Z_9 number of agricultural extension visits and Z_{10} is farmer's access to credit (1 for access to credit and 0 otherwise) ε_i is the two-sided error term and δ_i is a vector of parameters to be estimated.

Similarly, the cost inefficiency model can be specified as;

$$u_i = \delta_0 + \sum_{i=1}^{10} \delta_i Z_i + \varepsilon_i \qquad [15]$$

All variables are earlier defined.[1]

Three main hypotheses were tested in this study, *viz*; (i). There is no production and cost inefficiency effect, (ii) the coefficients of the square values and the interaction terms in translog have zero values (appropriateness of the translog model), and (iii) exogenous factors are not responsible for the inefficiency term (μ_i). The results of the three hypotheses were tested using the generalized likelihood-ratio test statistic specified as;

$$LR(\lambda) = -2[\{\ln L(H_0)\} - \{\ln L(H_1)\}] \qquad [16]$$

Where $L(H_0)$ and $L(H_1)$ are the likelihood functions under null and alternate hypotheses, respectively. If we fail to reject the null hypothesis, then the test statistic (λ) has a chi-square distribution of the degree of freedom defined as the difference between the estimated parameters under (H_1) and (H_0). However, if the null hypothesis involves $\gamma = 0$, then the asymptotic distribution involves a mixed chi-square distribution (Coelli 1995).

Definition of Variables and descriptive statistics of the sampled farm households

Table 1 reports the definitions of the variables used in both the production and the cost function as well as the inefficiency effects model. Thus, two main categories of variables are described here, the usual conventional inputs (and the price) that enters the output and the cost model and the explanatory variables such as socioeconomic, farm-specific and institutional variables that explain the sources of variation in the inefficient effects models. The output reflects the quantity of cowpea harvested in kilograms, and on the average, smallholder cowpea farmer harvest approximately 277kg during the 2015 farming season. Labour consists of the quantity of labourers (both hired and family) that worked in the cowpea farm measured in person-days. The mean quantity of labour (in person-days) is about 196. Moreover, the mean amount of cowpea seeds (kg) used per ha was approximately 3 kg. Farm size reflects the proportion of farm households' land under cowpea cultivation. On the average, smallholder farmers across the three districts in the Northern region operate a farm size of approximately 1.5 hectares (ha).[2] The average farm size of 1.5 ha reinforce the reports by SRID of MoFA (2012) that majority (about 90%) of Ghanaian smallholder farmers operate on less than 2 hectares of farmlands, particularly in the food crop sector.

The study further revealed the mean age of 36.5 years which is an indication of economically active age group as the national description comprises of people

[1] Equations [12] and [14] are jointly estimated while [13] and [15] are also jointly estimated using the maximum likelihood function in STATA 14 software which yielded consistent and efficient estimators for $\beta, \delta, \gamma, and\ \sigma^2$ where they are defined earlier.

[2] In Ghana, farm plots are measured in acres (1 hectare = 2.47 acres). However, for consistency with international standards, farm plots in acres were converted to hectares.

within the age bracket of 15 to 60 years. This suggests a higher potential for farming in the study area if this age group (primarily youth) are well motivated.

Table 1: Definition of variables and summary statistics of sampled farm households

Variable	Description	Mean	SE
Output model			
Cowpea output	Quantity of cowpea (kg) harvested	276.9	
Labour	Hired and family labour in man-days	196.36	64.21
Cowpea seeds	Quantity of seeds (kg) used per ha	3.03	0.51
Farm size	Land under cowpea cultivation in ha	1.49	0.53
Cost function			
Price of land	Rental value per hectare of land	103.12	
Cost of seed	Amount paid per kg of seeds		
Price of labour	Amount paid for labour	30.78	
Inefficiency Model			
Gender	Dummy; 1 for male, 0 for female		
Age	Age of the household head in years	36.45	9.72
Household size	Number of members in the household	12.59	4.1
Educational status	Number of years in formal education	4.89	4.95
Access to input	Dummy; 1 if access to input, 0 otherwise	0.86	
Membership of farmer-based organization (FBO)	Dummy; 1 if member of FBO, 0 Otherwise	0.76	
Hybrid seeds	Dummy; 1 if farmer cultivates hybrid seeds, 0 otherwise	0.31	
Extension services	Dummy; 1 if farmer have access to extension services, 0 otherwise	0.41	
Access to credit	Dummy; 1 if farmer have access to credit, 0 otherwise	0.53	
Experience	Number of years in cowpea farming	8.98	6.11

The study found the average household size of about 12.6 persons per family which is almost twice the 6.59 reported in the 2010 national census reported by Ghana Statistical Service (GSS) for Northern Ghana. The average number of years in formal education was approximately five years which is similar to the one obtained by Abdulai et. al. (2017) for Northern Region of Ghana. About 86% of the sampled farm households had access to farm input while 76% were members of the Farmer-based Organization (FBO). However, only 31%, 41%, and 53% had access to hybrid seeds, extension services, and agricultural financial credit, respectively. On the average, sampled farmers have been involved in cowpea farming business for about eight years.

Empirical Results and Discussions

Test of hypotheses

The Generalised Likelihood Ratio test was used to test the appropriate functional form to fit the data and to establish the role of socio-economic indicators in explaining the technical and cost inefficiency as shown in Table 2. The results indicate that the decision to use Cobb-Douglas in both technical and cost frontier functions was rejected in favour of the translog model since the generalized likelihood statistic is significantly different from zero. This suggests that the results from the translog models are appropriate and adequately fit the data given the assumption of the stochastic frontier model. The second hypothesis also indicates that inefficiency is present in the model and that socioeconomic characteristics contribute significantly to farmers' inefficiency. Hence, the decision to use the average response model was rejected in favour of the frontier model.

Table 2: Results of Hypotheses Test

Null Hypotheses	*χ^2 Statistic*	*Critical region*	*Decision*
Technical Efficiency			
1. $H_0 : \beta_1 + ...\beta_n = 0$	240	11.91	Reject H_0: Translog appropriate
2. $H_0 : \delta_1 ......\delta_n = 0$	136	14.85	Reject H_0: Inefficiency present
Cost Efficiency			
1. $H_0 : \beta_1 + ...\beta_n = 0$	684.46	11.91	Reject H_0: Translog appropriate
2. $H_0 : \delta_1 ......\delta_n = 0$	429.93	13.40	Reject H_0: Inefficiency present

Determinants of Production Output and Cost

In this section, the study discusses the determinants of cowpea output and production cost for the study area. Table 3 presents the results of the maximum likelihood (ML) estimates of the parameters of the stochastic production frontier for the determinants of cowpea output and cost of production in the study area.[3] The sigma-squared value of 0.065 was significantly different from zero, suggesting the correctness of the specified distributional assumption of the inefficiency model. The estimated gamma (γ) value 0.682 implies that about 68% of the variation in the cowpea output was due to inefficiency in the use of inputs and other farm management practices. The remaining 32% of the deviation came from random factors. Thus, the difference between the observed and the potential (frontier) value was dominated by farmers' technical inefficiency, and therefore technical inefficiency had a significant effect on farmers' output (Wadud and White, 2000). Similarly, the gamma value for the cost inefficiency implies that farmers incurred total production cost of about 50% due to production inefficiency.

Table 3: Maximum Likelihood Estimates of the Stochastic Frontier Models

	Production Function		***Cost Function***	
Variable	*Coeff.*	*SE*	*Coeff.*	*SE*
Constant	-0.687	0.345**	1.130	0.238***
Farm size	-0.964	0.567*	0.184	0.059***
Labour	0.023	0.013*	-0.162	0.227
Seed	1.102	0.554**	0.637	0.094***
Farm size × farm size	1.325	0.673**	-0.221	0.029***
Labour × labour	0.026	0.071	-0.189	0.008***

[3] The results were obtained using the programme FRONTIER version 4.1 developed by Coeli (1996).

Seed × seed	-1.204	0.721*	-0.192	0.062***
Farm size × labour	-1.611	0.818**	0.467	0.010***
Farm size × seed	1.772	0.844**	0.594	0.120***
Labour × seed	-2.048	1.653	0.213	0.036***
Variance Parameters				
Sigma squared (σ^2)	0.037	0.003		3.31E-05
Sigma-u (σ_u)	0.001	0.108		0.000796
Sigma-v (σ_v)	0.192	0.007		4.75E-08
Gamma	0.682	0.142		
Log-likelihood	90.040			
Chibar 2 (14) =502.24				
Prob. > Chi2=0.0000				
Number of observations	342			

All the first order terms, that is, farm size, labour and seeds were positively correlated with cowpea output in the production frontier model at significant levels of 1%. The positive correlation of land size allocated to cowpea production is consistent with previous studies conducted by Diiro (2013) and Nkegbe (2012). However, studies like Danso-Abbeam et. al., (2015) and Adzawla et. al., (2013) found farm size as a decreasing function of output in relation to groundnuts, rice, and cotton respectively. The squared variables in the translog function indicate the effect of the continuous use of that variable on output while the interaction terms indicate a complementarity or a substitutability of that variable. While a significant positive interaction signifies complementarity, a significant negative interaction term suggests substitutability. The results from the table indicate that the continuous use of land, labour, and seeds all have positive effects on cowpea output. Moreover, farm size has a significant complementarity with the amount of labour used on the farm; likewise, amount of labour used and quantity of seeds sown.

With regards to the cost of production frontier, the results indicate that prices of labour and seeds have positive effects on costs. That is, an increase in the costs of labour and seeds will increase the total cost. However, a decrease in the rental price of land will decrease the total cost as evidenced by the negative effect of cost of farm size on total cost. Moreover, the negative parameter of "labour and seeds" indicates that they are substitutes for one another in production; hence, cost can be reduced by mixing them.

Determinants of Technical and Cost Inefficiency

Table 4 discusses sources of technical and cost inefficiencies. Variables with negative estimates have positive relation with efficiency (or reduces inefficiency). The opposite goes for variables with positive estimates. Seven out of ten were estimated to explain farmers' sources of technical inefficiencies. These include household size, farm experience, distance of farmers' home to farm, type of seed, extension service and access to credit. The coefficient of household size was positive and statistically significant at 1%. This indicates that farmers with larger family size were less technically efficient than their counterparts with smaller family size. Danso-Abbeam et. al. (2015) also found household size to have positive influence on technical inefficiency of cowpea farmers in Northern Region. The coefficient of farming experience was negative and significant at 1%. This indicates that farmers with more years in farming are less technically inefficient than farmers with fewer years in farming. Farming is considered as a vocational training and therefore the more years a farmer spends in the farming business, the higher his/her ability to draw from experience and improves his/her productivity. Lapple (2010) also noted that increase in farming experience gives farmers better technical and managerial knowledge about their production environment. However, Oyewo (2009) in his study on technical efficiency among maize farm households in Ogbomoso South local government area in Nigeria found farmers with many years of experience to be technically inefficient compared with their counterparts with fewer years in farming business. Similarly, the type of seed exhibits a positive function of farmers' efficiency level as it is negatively signed and significant at 1%. This indicates that farmers who use hybrid seed had higher technical efficiency levels than farmers who use local seed. This result is consistent with the findings of Tchale (2009), who found that farmers who use purchased seed (which is most likely comprised of first-generation hybrids) improve technical efficiency significantly, such that farmers who plant purchased seed gain on average 9% higher efficiency than those who do not. This may be attributed to the fact that, hybrid seeds mature early, yield heavily and are more resistant to diseases. Further, the estimated coefficient of extension service is negative and statistically significant at 1%. Thus, the results indicate that extension services provided by extension agents go a long way to reduce technical inefficiency in cowpea farming. The information and technical advice given by extension agents help the farmers to acquire knowledge or best practices, and therefore improve their management skills in cowpea production, hence increase in output.

Table 4: Determinants of technical and cost inefficiency

	Technical Inefficiency		***Cost Inefficiency***	
Variable	***Coefficient.***	***SE***	***Coefficient***	***SE***
Constant	0.092	1.102	-1.399	0.577
Age	0.044	0.027	0.002	0.016
Education	-0.057	0.052	-0.081***	0.032
Household size	0.115***	0.043	0.030	0.036
Cowpea farming experience	-0.292***	0.080	-0.027	0.030
Farm-home distance	-0.067	0.041	-0.03	0.021
Land ownership	-0.719	0.847	0.866***	0.342
Extension	-1.931***	0.703	-1.298***	0.401
Farmer-based Organization	1.074	0.843		
Access to agricultural credit	-1.758**	0.890		
Seed variety	-2.011***	0.659		

Moreover, the World Development Report (2008) stressed on the significant role of extension services in disseminating information on agrarian technologies required to be adopted by African farmers to spur agricultural productivity growth through African green revolution. Abdulai et al. (2016) indicated that research findings on agricultural technology would be meaningless if the end-users (farmers) do not accept and adopt the output of these technologies and this adoption can be spearheaded through agricultural extension services. The results are similar to studies on cowpea by Awunyo-Vitor et al. (2013) in Ghana and Rahman (2003) on rice farming in Bangladesh. Access to credit also exhibits a positive function of farmer's efficiency level as it is negatively signed and significant at 10%. The positive effect of credit on technical efficiency met the study's a priori expectation as credit facilitates a timely purchase of inputs, which help increase productivity. This result is consistent with the studies of Danso-Abbeam (2014) and Awudu and Huffman (2000). On the contrary, Haji (2006) found a negative effect of access to credit on technical efficiency.

With regards to sources of cost inefficiency, three out of the seven variables examined were statistically significant as indicated in Table 4. Thus, educational attainment, land ownership and access to extension service to the farmers were statistically significant. For instance, the coefficient of the level of education was negative and significant at 1%, implying that cowpea farmers who spent longer years in formal education were more cost or economically efficient than farmers who spent few years in school. This means that farmers with higher education are better able to reduce input related costs and hence maximize profit relative to their counterparts who have a lower educational level. As reported by Mapemba et. al., (2013), education increases farmer's managerial skills and therefore enhances their efficiency levels. Also, the coefficient of land ownership had a positive and significant effect on farmer's cost or economic efficiency level suggesting that cowpea farmers who own land for farming are less economically efficient than farmers who do not own land. Moreover, the coefficient of the extension service was negative and statistically significant at 1% level. Thus, extension services help farmers to be more cost-efficient.

Allocative Efficiency

This section of the study focuses on how farmers allocate expenditure on land, seed and labour concerning input quantities given the production technology available. This analysis was achieved by estimating an average production function from which input elasticities (*E*), marginal value products (*MVP*), marginal factor cost (*MFC)* and allocative ratios *(R*) of the inputs were calculated. The results are presented in Table 5. From the results, the allocative efficiency ratio (*R)* for land is greater than one (1). This implies that land is being under-utilized because the marginal value obtained from spending GH¢7.47 ($1.92)[4] on land is less than its marginal value product of GH¢31.96 ($8.22). It must be noted that the marginal factor cost of land is low because landowners do not sell land for farming; instead, they take a token from farmers before they release the land for agricultural activities.

Table 5: Allocative Efficiency Ratio (R) of the Various Production Inputs

Input	MVP	MFC	$R = MVP/MFC$	% change required
Land	31.96	7.47	3.28	-328
Seed	24.40	7.29	2.35	-235
Labour	11.28	21.85	0.484	+48.4

Note: (-) implies increased use is needed and (+) means reduction is needed.

To attain efficiency in land allocation, its use should be increased by 328% to achieve the point where its MVP equals its MFC. The allocative efficiency ratio (R) of seed was also greater than one (1), implying that there is need to increase the use of the input seed. The marginal factor cost of GH¢7.29 ($1.87) spent

[4] GH¢3.89 = US$1 (December, 2015)

on seed is less than its marginal value product of GH¢24.40 ($6.27) Cowpea farmers can achieve allocative efficiency in seed use, by increasing the use of seed by 235% to attain the point at which its *MVP* equals its *MFC*. On the other hand, labour has an allocative efficiency ratio of 0.484 which is less than one (1). This means that labour is being over-utilized. Therefore, cowpea farmers must reduce the number of labour by 48.4% to attain allocative efficiency given the *MVP* of GH¢11.28 ($2.89) and *MFC* of GH¢21.85($5.62).

Distribution of Efficiency Estimates

The mean technical efficiency was 91.6% with a minimum and maximum scores of 37.2% and 100%, respectively. This indicates that the average cowpea farmer in the study area produces about 91.6% of the potential output given the current technology available. That is, cowpea farmers in the study area produce at a level below 8.4% of the frontier output. Thus, in the short run, there is a scope of increasing cowpea production by 8.4% by adopting the technologies and the techniques practiced by the best cowpea farmer and efficiency combination of inputs. Similar results have been documented by Chirwa (2003), Edriss *et al.* (2004), Awunyo-Victor (2013) and Taru *et al*., (2011) who estimated the mean technical efficiency of cowpea farmers to be 65%, 55%, 66% and 89% respectively. However, this result is far higher compared with the results obtained by Ani et al. (2014) who estimated the mean technical efficiency of cowpea (or groundnut) farmers in Nigeria to be 3.78%. Furthermore, the results revealed that majority (94.4%) of the farmers operated within the technical efficiency level between 81% and 100%, while only a few (5.6%) had technical efficiency level between 31% and 80%.

Table 6: Distribution of Farm specific Technical, Allocative and Economic Efficiency Estimates.

	TE		AE		EE	
Score	Freq.	%	Freq.	%	Freq.	%
30-40	2	0.6	1	0.3	9	2.6
41-50	7	2.0	12	3.5	17	5.0
51-60	2	0.6	16	4.7	27	7.9
61-70	4	1.2	39	11.4	51	14.9
71-80	4	1.2	70	20.5	116	33.9
81-90	105	30.7	123	36.0	113	33.0
91-100	218	63.7	81	23.7	9	2.6
Total	342	100.0	342	100.0	342	100.0
Mean	91.6%		80.7%		73.4%	
Min.	37.2%		39.6%		30.9%	
Max.	100%		100%		94.8%	

Source: Author's Computation, 2015.

Allocative efficiency had similar scores ranging from 31.6% to 100%. Also, the mean allocative efficiency estimate for the sampled cowpea farmers in the study area was 80.7%. This implies that if the average farmer in the sample was to achieve the allocative efficiency level of his or her most efficient counterpart in Northern region, then the farmer should increase the allocative efficiency by 19.3%. This is consistent with similar findings by Tchale (2009) and Magreta et. al. (2013) who found the allocative efficiency of 46% and 59% respectively. The results also revealed that higher number (80.1%) of the farmers had allocative efficiency levels between 71-100% while 19.9% of the farmers fell within the range of 31-70% efficiency level.

Furthermore, farmers had a mean economic efficiency of 73%, with minimum and maximum efficiency scores of 31% and 95% respectively. The mean economic efficiency of 73% implies that farmers in the study area could raise their profitability of cowpea production by 27% through the optimum use of all the inputs. This result is also consistent with findings in similar studies by Tchale (2009) and Magreta et al., (2013) who found economic efficiency scores of 35%, 38% and 53%

respectively. The results further showed that 66.9% of the farmers achieved efficiency levels between 71-90%, while only 2.6% of the farmers operated at the highest level between 91-100%.

Conclusions and Recommendations

This study examined the economic efficiency among smallholder cowpea farmers in the northern region using three districts as a case study. The results of the study indicate that cowpea farmers in the study area are doing quite well as their average technical, allocative and economic levels are 91.6%, 80.7%, and 73.4% respectively. The discrepancy between observed and frontier efficiencies reveals that there is room to improve on cowpea productivity through efficient use of resources. The results indicate that farm size, the quantity of seeds and amount of labour used have direct correlations with the output of cowpea. Also, while increasing the amount of seeds and labour increases costs, expanding land size decreases costs. The technical efficiency of cowpea production was significantly affected by household size, cowpea farming experience, type of seed, extension service and access to credit. A farmer with more years in cowpea farming was more technically efficient than their counterparts with fewer years in farming. Therefore, opportunities such as farmer-based organizations and farmer field schools that promote farmer-to-farmer extension should be encouraged so that the less experienced could tap from the more experienced ones. Given the empirical findings, the study recommends that research and development in the seed sector as well as programmes to improve access to seeds are crucial for cowpea production in the country. Government through Ministry of Food and Agriculture (MoFA) and other development partners (NGO) into seed technology transfer should strengthen both access and production. Farmers who had access to credit were more technically efficient than those who did not, hence, credit policies to make financial credit easily accessible to farmers is highly encouraged. Finally, farmers who had access to extension service were more efficient than those who did not, hence agricultural extension systems provided by agricultural extension agents should be adequately resourced by government and other partners to provide extension service to cowpea farmers.

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