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Identification of Factors that Influence Technical Efficiency of Food Crop Production in West Africa: Empirical Evidence from Borno State, Nigeria

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Abstract
The objective of this study was to examine the determinants of food crop production and technical efficiency in the guinea savannas of Borno State, Nigeria. A stochastic frontier production function, using the maximum likelihood estimation (MLE) technique was applied in the analysis of data collected from 1086 sample farmers in 2004. The MLE results reveal that farm size; fertilizer and hired labour are the major factors that are associated with changes in the output of food crops. The effect of land area on output is positive and the coefficient found to be significant ($p = 0.01$). Fertilizer and hired labour have positive effects on output and their coefficients are significant ($p = 0.01$). Mean farmers' technical efficiency index was found to be 0.68. Farmer-specific efficiency factors, which comprise age, education, credit, extension and crop diversification, were found to be the significant factors that account for the observed variation in efficiency among the farmers. The implication of the study is that technical efficiency in food crop production could be increased by 32 percent through better use of available resources, given the current state of technology.

Keywords: stochastic frontier, productivity, technical efficiency, food crops, farmers

1 Introduction

The Guinea savanna zone of West and Central Africa covers a large area of sub-Saharan Africa. Most of the countries in the zone have low per capita income and are characterized by high incidence of poverty and food insecurity. The rapid increases in human population and exploitative use of non-renewable resources have exacerbated food supply. Hence, providing adequate food supplies is a major challenge.

It is estimated that the annual food supply in Nigeria would have to increase at an average annual rate of 5.9 per cent to meet food demand and reduce food importation significantly (Federal Ministry of Agriculture, 1993). Most studies show that aggregate food production in Nigeria has been growing at about 2.5 percent per annum in recent years. But the annual rate of population growth has been as high as 2.9 percent

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(Olayemi, 1998). The reality is that Nigeria has not been able to attain self-sufficiency in food production, despite increasing land area put into food production annually. The constraint to the rapid growth of food production seems to mainly be that of low crop yields and resource productivity. This is revealed by the actual yields of major food crops, compared with their potential yields (Federal Ministry of Agriculture, 1993). The low yield of crops may also be attributed to a relative decline in rainfall in recent years. Studies by Jagtap (1995) showed that annual rainfall in Nigeria during 1981-90 declined from that in 1961-70. The greatest change occurred in the onset of the rainy season and the extent of early rainfall, which resulted in a reduction by nearly one month in the growing season. There were fewer wet days and higher rainfall intensities in most of the country. The rainfall series showed prolonged dry periods, especially since 1970. The rainfall decline is unprecedented in duration; spatial, temporal character and seasonal expression (Kamara *et al.*, 2006) Thus, drought is one of the major causes of yield loss in the guinea savannas. This has aggravated the food supply situation in the area resulting in low food security index (Federal Republic of Nigeria, 2002).

This paper examines the determinants of food crop production and technical efficiency in the Guinea savannas of Nigeria. A pre-requisite for enhanced efficiency is the identification of those factors which prevail at the farm-level and which affect efficiency of production. Thus, it will help in providing information for the formulation of appropriate policies.

2 Materials

The study used primary data obtained through a farm management survey of farm-families in Borno State of Nigeria. The State is demarcated in four ecological zones: southern and northern guinea savannah in the south, Sudan savannah in the south and central, and the sahel in the north.

Farming is the predominant occupation in the study area, where rain-fed food crop farming and livestock rearing characterize the major land-use pattern. The cropping system is largely determined by both the amount and the duration of the rainy season (Amaza and Gwary, 2000).

The main instruments for data collection were well-structured questionnaires administered on farm-families. Multi-stage, random sampling techniques were employed in the selection of a sample of 1086 food crop farmers by 30 trained enumerators. The range of data collected covered those on household's farm activities. These include material input (input purchase cost); family and hired labour supply and use, sources of credit, tenurial arrangement, farm size, quantities of farm outputs and their farm gate and market prices. In addition, data were collected on household socio-economic variables, such as age, level of education, household size, and so on.

3 Methods

The stochastic efficiency frontier model independently proposed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) was applied in the analysis of data. The approach has the advantage because it accounts for the presence of measurement error in the specification and estimation of the frontier production function. The stochastic frontier function differs from the traditional production function in that the former consists of two error terms. The first error term accounts for the existence of technical efficiency and the second accounts for factors such as measurement error in the output variable, weather and the combined effects of unobserved inputs on production.

In the literature, the econometric approach has generally been preferred in the empirical application of stochastic frontier production model in agriculture. This is probably due to a number of factors. First, the assumption that all deviations from the frontier arise from inefficiency, as assumed by data envelopment analysis (DEA) is difficult to accept, given the inherent variability of agricultural production due to uncontrollable factors such as weather, pests and diseases.

Second, because many farms are small, family-owned enterprises farm records are seldom kept. Consequently, available data on production are likely to be subject to measurement errors.

3.1 The Stochastic Frontier Production Model

The frontier production model is based on the stochastic efficiency model by PARIKH and SHAH (1994), which in turn, derives from the composed error model of AIGNER *et al.* (1977), MEEUSEN and VAN DEN BROECK (1977) and FORSUND *et al.* (1980).

The frontier production model begins by considering a stochastic production function with a multiplicative disturbance term of the form:

$$Y = f(X_a; \beta)\, \varepsilon(v, u) \tag{1}$$

Where:

Y	is the quantity of agricultural output;
X_a	is a vector of input quantities;
β	is a vector of parameters and
ε	is a stochastic disturbance term consisting of two independent elements u and v, where

The symmetric component, v, accounts for random variation in output due to factors outside the farmer's control, such as weather and diseases. It is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$. u is a one-sided component, where $u \leq 0$ reflects technical inefficiency relative to the stochastic frontier, $f(X_a; \beta)e^{\varepsilon}$. Thus, $u = 0$ for a farm output which lies on the frontier and $u < 0$ for one whose output is below the frontier as $|N(0, \sigma_u^2)|$, i.e. the distribution of u is half-normal.
The variance of σ^2 is, therefore

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \tag{2}$$

The ratio of two standard errors[1] is defined by

$$\lambda = \sigma_u + \sigma_v \tag{3}$$

[1] BATTESE and CORRA (1977) define γ as the total variation in output from the frontier and which is attributable to technical efficiency i.e. $\gamma = \sigma_u^2/\sigma^2$ so that $0 \leq \gamma \leq 1$

JONDROW *et al.* (1982) have shown that measures of efficiency at the individual farm level can be obtained from the error terms $\varepsilon = u + v$. For each farm, the measure is the expected value of u conditional on ε, i.e.

$$E(u|\varepsilon) = \frac{\sigma_u \sigma_v}{\sigma} = \left[\frac{f(\varepsilon\lambda/\sigma)}{1 - F(\varepsilon\lambda/\sigma)} - \frac{\varepsilon\lambda}{\sigma}\right] \qquad (4)$$

Where f and F are the standard normal density function and the standard normal distribution function evaluated at $\varepsilon\lambda/\sigma$. Estimated values for ε, λ and σ are used to evaluate the density and distribution functions. Measures of efficiency for each farm can be calculated as:

$$TE = exp\left[E(u|\varepsilon)\right] \qquad (5)$$

A number of empirical works (PARIKH and SHAH, 1994; LLEWELYN and WILLIAMS, 1996) and recently AMAZA and OLAYEMI (2002) have investigated the determinants of technical efficiency among firms in an industry by regressing the predicted efficiencies, obtained from an estimated stochastic frontier on a vector of farmer-specific factors such as age of the farmer, educational level of the farmer, access to extension, and so on, in a second-stage regression. The identification of those factors, which influence the level of technical efficiencies, is a valuable exercise because the factors are significant for policy formulation.

It is assumed that the inefficiency factors are independently distributed and that u arises by the truncation (at zero) of the normal distribution with mean μ and variance σ^2, where u in equation (5) is defined as:

$$u = f(Z_b; \delta) \qquad (6)$$

Where Z_b is a vector of farmer-specific factors, and
δ is a vector of parameters

The β- and δ- coefficients in equations (1) and (6) respectively are unknown parameters to be simultaneously estimated, together with the variance parameters which are expressed in terms of:

$$\sigma_s^2 = \sigma_v^2 + \sigma^2 \text{ and} \qquad (7)$$

$$\gamma = \sigma^2/\sigma_s^2 \qquad (8)$$

Where the γ- parameter has a value between zero and one. The parameters of the stochastic frontier function are estimated by the method of maximum likelihood, using the computer program FRONTIER version 4.1 (COELLI, 1994)

4 Results and Discussions

The estimated stochastic frontier production function is presented in Table 1. All the coefficients in the model have the expected *a priori* signs and are mostly significant.

The estimated coefficient for land is positive, which conform to *a priori* expectation, and significant at 1-percent level. The magnitude of the coefficient of land, which is 0.07, indicates that the output in food crop production is inelastic to changes in the

Table 1: Maximum likelihood estimates of the parameters of the stochastic frontier function.

Variable	*Parameter*	*Coefficient*	*Standard error*
Production factors			
Constant	β_0	8.282	0.159**
Farm size (X_1)	β_1	0.073	0.033 **
Fertiliser (X_2)	β_2	0.204	0.012**
Hired labour (X_3)	β_3	0.063	0.003**
Family labor (X_4)	β_4	0.001	0.014
Seeds (X_5)	β_5	0.0009	0.008
Inefficiency effects			
Constant	δ_0	-9.904	2.581**
Age (Z_1)	δ_1	-2.042	0.417**
Education (Z_2)	δ_3	-0.221	0.059**
Credit (D_1)	δ_4	-0.380	0.092**
Extension (D_2)	δ_5	-0.24	0.050**
Crop diversification (Z_3)	δ_6	0.076	0.041*
Diagnostic Statistics			
Likelihood ratio = 161.42			
Sigma-squared (σ^2)	7.059	1.022**	
Gamma (γ)	0.897	0.015**	

**,* significant at the 1% and 5% level respectively

level of cultivated land area. The 0.07 elasticity of land implies that a 1-percent increase in cultivated land area, *ceteris paribus*, would lead to an increase of 0.07 percent in the output of food crops, and vice versa. This suggests that land is a significant factor associated with changes in crop output.

The production elasticity with respect to inorganic or chemical fertilizer is positive as expected and statistically significant at 1-percent level. The significance of the fertilizer variable derives from the fact that fertilizer is a major land fertilizing input and improves the productivity of existing land by increasing crop yields per hectare.

The magnitude of the coefficient of hired labour, which is 0.06, indicates that output in crop production is highly inelastic to changes in the amount of hired labour used. Thus, a 1-percent increase in hired labour would induce an increase of only 0.06 per cent in the output of crops, and vice versa. Farmers who have the main objective of income maximisation in food crop production would tend to allocate resources more efficiently, including the allocation of hired labour (Amaza and Gwary, 2000). On the other hand, farmers whose main objective is household food security would be more concerned with maximising their output per unit of resource used, especially family labour; that is, they tend to emphasize technical efficiency.

The inefficiency parameters are specified as those relating to farmers' specific socio-economic characteristics. These include the age, educational levels, access to credit, access to extension advice and their degree of crop diversification. The coefficient of age variable is estimated to be negative and statistically significant at 1-percent level. This indicates that farmers who are older are relatively less efficient in food crop production and vice versa. Thus, because food crop production in the study area is relatively labour intensive, especially weeding and harvesting operations, younger farmers tend to be more productive. Also, the younger farmers are likely to be more progressive and, hence more willing to adapt new practices, thus leading to higher efficiencies in food crop production.

The coefficient of education variable is estimated to be negative as expected and statistically significant at the 1-percent level. This finding agrees with comparable findings by Battese *et al.* (1996), Coelli and Battese (1996) and Seyoum *et al.* (1998). The implication is that farmers with formal schooling tend to be more efficient in food crop production, presumably due to their enhanced ability to acquire technical knowledge, which makes them move close to the frontier output. It is very plausible that the farmers with education respond readily to the use of improved technology, such as the application of fertilizers, use of pesticides and so on, thus producing closer to the frontier.

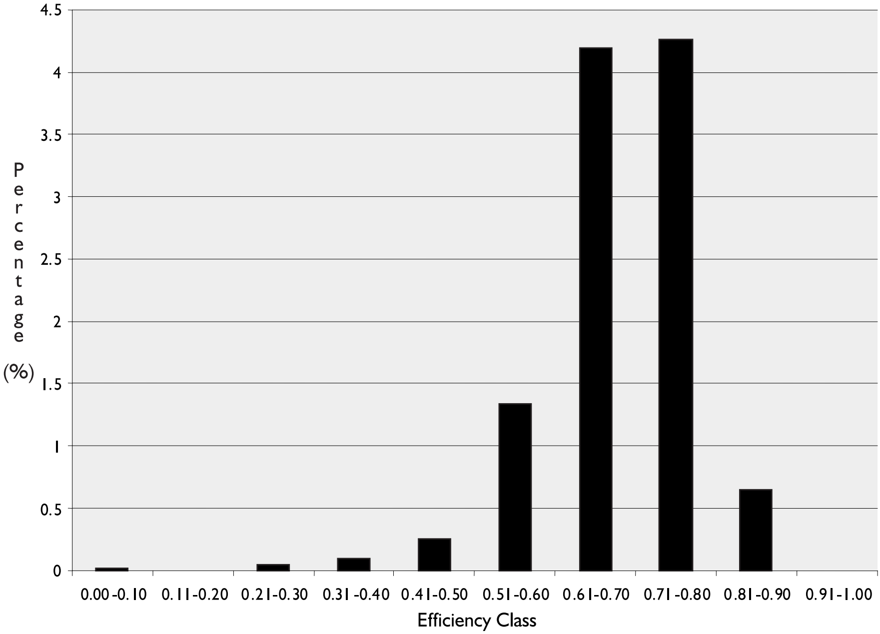
The coefficient of credit variable is estimated to be negative as expected and statistically significant at 1-percent level. This suggests that farmers who have greater access to credit tend to be more efficient in food crop production. Because food crop production is heavily labour-intensive, substantial part of the credit is used to hire labour, especially for weeding and harvesting operations. Also, the availability of credit helps to finance purchased inputs, especially fertilizer, which has positive effect on the productivity of farmers.

The coefficient of the extension variable is estimated to be negative and statistically significant at the 1-percent level. This indicates that increased extension services to farmers tend to increase technical efficiency in food crop production. The significance of extension in this study corroborates the findings of Seyoum *et al.* (1998) who reported positive influence of extension contact on efficiency in their study of technical efficiency and productivity of maize farmers in eastern Ethiopia.

The crop diversification variable in the model is negative and statistically significant at 5 percent level. As diversification decreases and fewer crops are grown, efficiency increases. The implication is that lesser diversification is associated with higher relative efficiency. The consideration for risk minimization is a major factor accounting for the practice of mixed-cropping (Norman, 1974; Just and Candler, 1985). A study by Abalu (1976) on crop mixtures in Northern Nigeria contends that crop mixtures are employed by farmers primarily as risk-minimizing precautions and that the immediate objective of farmers is not only one of profit maximization but also of stability of income.

A significant characteristic of the stochastic frontier production model is its ability to provide farm-specific measures of technical efficiencies. The distribution of farmers' technical efficiency indices derived from the analysis of the stochastic production function is provided in Figure 1.

Figure 1: Distribution of farmers' technical efficiency indices.



The technical efficiency of the sampled farmers is less than 1 (or 100 %), indicating that all the farmers are producing below the maximum efficiency frontier. A range of technical efficiency is observed across the sample farms where the spread is large. The best farm has a technical efficiency of 0.90 (90 %), while the worst farm has a technical efficiency of 0.02 (2 %). The mean technical efficiency is 0.68 (68%). This implies that, on the average, the respondents were able to obtain a little over 68 percent of optimal output from a given mix of production inputs.

The distribution of technical efficiency of the farmers reveals that only 7 farmers representing 0.64 percent had a technical efficiency of less than 30 percent, while 491 farmers, representing approximately 45.3 percent had a technical efficiency of above 70 per cent.

The picture that emerges from this analysis is one of generally average technical efficiency in food crop production in the study area. The magnitude of the mean technical efficiency of the farmers is a reflection of the fact that most of the sample farmers carry out food crop production under technical conditions, involving the use of inefficient tools, unimproved seed varieties and so on. The low production technology adopted by the majority of the farmers and their low levels of formal education are major factors that have influenced the level of their technical efficiency.

The distribution of the technical efficiency suggests that potential gain in technical efficiency among the sample farmers is large. The mean technical efficiency of approximately 68 per cent implies that, in the short-run, there is the scope for increasing technical efficiency in food crop production in the study area by 32 per cent. This can be achieved through improved farmer-specific efficiency factors, which include improved farmer education, access to credit, access to improved extension services and less crop diversification

5 Conclusion and Policy Implication

The study reveals that farm size; fertilizer and hired labour are the major factors that are associated with changes in the output of food crops. The effect of land area on output is positive and the coefficient found to be statistically significant ($p = 0.01$). Chemical fertilizer and Hired labour have positive effects on output and their coefficients are statistically significant ($p = 0.01$).

The model for the inefficiency effects in the frontier function includes age, education, access to credit, access to extension and crop diversification. All the farmer-specific variables were significant in accounting for the observed variation in efficiency among the farmers. The policy implication of the study is that technical efficiency in food crop production could be increased by 32 percent through improved use of available resources, given the current state of technology. This can be achieved through improved farmer-specific efficiency factors, which include improved farmer education, access to credit, access to improved extension services and less crop diversification.

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