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TECHNICAL EFFICIENCY IN ARABLE CROP PRODUCTION IN KEBBI STATE, NIGERIA

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ABSTRACT

This paper examines the technical efficiency and the sources of inefficiency in smallholder arable crop production in Kebbi State during the 2003 cropping season using a stochastic frontier production function which incorporates a model for inefficiency effects. A sample of 96 farm households selected using the multi-stage stratified random sampling techniques were used to generate primary data via the cost-route approach. Results reveal that the major factors that affected the output of arable crops are labour, material inputs and capital. Low levels of formal education and a low capital base for investment are the major factors that influenced their level of technical efficiency. The mean technical efficiency is 0.55 (55%). The implication is that the mean technical efficiency index could be increased by 45 percent through efficient reallocation of the existing resources.

INTRODUCTION

Prior to the advent of the oil boom in the early 1970's, agriculture was the backbone of Nigeria's economy and the country was self-sufficient in food production. However, with the advent of the 'oil boom', agriculture became relegated both in attention and in contribution. Consequently, ever-growing demand for food has remained a major challenge. In 1994, food consumption accounted for approximately 50% of a households total expenditure, but the proportion increased to 72% in 1995 (Central Bank of Nigeria, 1995). A rapidly growing population exerts pressure on the increased demand for food. Yields are low as a result of inefficient production techniques manifested in technical and allocative inefficiencies, over-reliance on household resources, labour-intensive agricultural technology and rapidly declining soil productivity (Tanko, 2003). The need to improve the efficiency in food crop production so that output could be raised to meet the growing demand has become imperative.

Most studies show that aggregate food production in Nigeria has been growing at about 2.5 per cent per annum while the annual rate of population growth has been as high as 2.9 per cent (Olayemi, 1998). The reality of the circumstance is that, food supply has not kept pace with demand even though Nigeria, with a population of over 100 million people and about 93 million hectares of land has about 70 per cent of this population engaged in agriculture (National Population Commission (NPC); 1992). Consequently, greater emphasis is inevitable upon making efficient utilization of the existing resources and combining the enterprises in an optimal manner.

An attempt aimed at increasing the efficiency in food crop production could lead to the resolution of the food crisis, improvement of farm income earned by farmers, reduction in their poverty level and meeting their usually multiple goals of production. This paper investigates the technical efficiency of farmers in food crop production in Kebbi State, Nigeria.

Theoretical Framework

Previous studies on efficiency of farm can be classified broadly into the following three categories; namely, deterministic parametric estimation, non-parametric mathematical programming and the stochastic parametric estimation (Udo and Akintola, 2001). The use of non-parametric techniques are limited in efficiency measurement in agriculture despite the fact that non-parametric methodologies can be used in situation where data is more limited and where production technologies are less well understood (Llewelyn and Williams, 1996).

Econometric modeling of stochastic frontier methodology of Aigner Lovell and Schmitt (1977) associated with the estimation of efficiency has been an important area of research in recent years. Basically, the studies are mostly based on Cobb-Douglas function and transcendental logarithmic (translog) functions that could be specified either as production function or cost functions. The first application of stochastic frontier model to farm level agricultural data was by Battesse and Corra (1977). But technical efficiency of farms was not directly addressed in the work. Kalirajan (1981) estimated a stochastic frontier Cobb-Douglas production function using cross-sectional data and found the variance of farm effects to be a highly significant component in describing the variability of rice yield. Bagi (1984) used the stochastic frontier Cobb-Douglas production function model to investigate whether there were any significant differences in the mean technical efficiencies of part-time and full-time farmers. Results showed no apparent significance, irrespective of whether the part-time and full-time farmers were engaged in mixed farming or crops-in only.

Bagi and Huang (1983) estimated a translogarithmic stochastic frontier production function and found technical efficiencies to vary from 0.35 to 0.92 for mixed farms and 0.52 to 0.91 for crop farms. Kalirajan and Flin (1983) assumed a translogarithmic stochastic frontier production and by maximum likelihood estimation, the parameters were estimated and individual technical efficiencies ranged from 0.38 to 0.91. They went further to regress the predicted technical efficiencies on several farm-level variables and farm-specific characteristics. In most of the studies, it was found that the Cobb-Douglas stochastic frontier does not provide an adequate representation for describing the data given the specification of a translog model.

The analysis of efficiency is generally associated with the possibility of farms producing a certain optimal level of output from a given bundle of resources at least-cost. Farrel (1957) distinguishes between three types of efficiency:

(a) Technical Efficiency, which is the physical ratio of product output to the factor input. The greater the ratio, the greater the magnitude of technical efficiency.

(b) Allocative or Price Efficiency: A firm is allocatively efficient when production occurs at a point where the marginal value product is equal to the marginal factor cost.

(c) Economic Efficiency: Obtains where both technical and allocative efficiencies have been attained.

The achievement of either technical or allocative efficiency is a necessary but not a sufficient condition to ensuring economic efficiency. He suggested a method of measuring technical efficiency of a firm in an industry by estimating the production function of firms which are 'fully efficient' (i.e a frontier production function).

METHODOLOGY

(a) The Data

The data used for this study were mainly generated through a farm management survey of 96 farm households using the cost-route approach during the 2003 cropping season in Kebbi State. Kebbi State is located in North Western Nigeria between latitudes 10° and 13°N and longitudes 3° and 6°W. The area falls within the dry savanna agroecological zone of Nigeria with an average annual rainfall of between 650mm and 1,100mm, with distinct wet and dry seasons.

The main instrument for data collection were well-structured questionnaire administered on farm families by trained enumerators under the supervision of the researcher. Multi-stage stratified random sampling techniques were employed in the choice of respondents. Data were collected on the socio-economic characteristics of the farmers, cropping patterns, production activities in terms of inputs, outputs and their prices. The Yield Plot Method, was used to obtain the yields of crops. This involved marking out 16, 100 square metre portions (i.e 10m x 10m plots) on some of the sampled farms and the yields from these portions used to extrapolate for the other farms.

(b) Data Analysis

The econometric modeling of stochastic production efficiency frontier model independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and den Broeck (1997) extended by Jondrow *et al* (1982) was used in the analysis of data.

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

$$Y = f(X_a; \beta)\, e^E \qquad (1)$$

Where, Y = the quantity of agricultural output,
X_a = vector of input quantities,
β = vector of parameters;
e = error term and

E = stochastic disturbance term consisting of two independent elements V and U,
Where

$$E = U + V \qquad (2)$$

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 (O, $\delta^2 v$). A one-sided component $V \leq 0$ reflects technical inefficiency relative to the stochastic frontier, f (X_a; β)e^E. Thus, V = O for a farm output lying on the frontier and V < O for one whose output is below the frontier as N (O, δ^2 U) i.e the distribution of V is half – normal.

The frontier of the farm is given by combining (1) and (2) as follows:

$$Y = f(X_a; \beta)e^{(u+v)} \qquad (3)$$

Measure of production efficiency for each farm can be calculated as:

$$TE = \exp.[E\{u/E\}] \qquad (4)$$

In the efficiency analysis, the Battesse and Coelli (1995) single stage model was applied, whereby V in equation (3) is a non-negative random variable which is the efficiency associated with technical efficiency factors in production of the sample farmers. It is assumed that the efficiency factors are independently distributed and that V arises by the truncation (at zero) of the normal distribution, with mean U and variance δ^2 where V in equation (3) is defined as:

$$V = f(Z_b; \delta) \qquad (5)$$

Where,
Z_b = vector of farmer – specific factors and
δ = vector of parameters

The β and δ – coefficients in equations (1) and (5) respectively are unknown parameters to be simultaneously estimated together with the variance parameter which is expressed in the form:

$$r = \delta u^2/(\delta u^2 + \delta v^2) \qquad (6)$$

Where r – parameter has a value between zero and one.

(c) Empirical Stochastic Frontier Production Function

The Cobb-Douglas function is specified as,

$$\text{In } Y_{ij} = \beta_o + \beta_1 \text{In}X_{1ij} + \beta_2 \text{In}X_{2ij} + \beta_3 \text{In}X_{3ij} + \beta_4 \text{In}X_{4ij} + \beta_5 \text{In}X_{5ij} + V_{ij} - U_{ij} \qquad (7)$$

Where

- Y = the output of food crop in grain equivalent (in tons)
- X_1 = farm size in hectares
- X_2 = labour input in mandays
- X_3 = quantity of fertilizer used in kilogrammes
- X_4 = expenses on material inputs of seeds and agrochemicals (in Naira)
- X_5 = capital inputs measured in naira and these include depreciation charges on machinery, equipment, rent on land, interest charges on borrowed capital, tractor hiring costs and irrigation charges.
- $\beta_o - \beta_5$ = regression coefficients to be estimated
- V_{ij} = normal random errors assumed to be independently and identically distributed, having N (O, δ^2)
- U_{ij} = non-negative random variables called technical efficiency associated with the technical efficiency of the farmers involved.

U_{ij}s are the technical inefficiency effects which are assumed to be independent of V_{ij}s such that U_{ij} is the non-negative truncation (at zero) of the normal distribution with mean U_i and variance δ^2_v where U_i is defined by:

$$Ui = \delta_o + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \delta_8 D_{1i} + \delta_9 D_{2i} \qquad (8)$$

Where,

- U_i = Technical efficiency of the i^{th} farmer
- Z_1 = Age of the farmer in years
- Z_2 = Level of education in number of years spent in school
- Z_3 = Farming experience in years
- Z_4 = Household Size
- Z_5 = Extension contact (number of meetings in production season)

Z_6 = Sex, a binary variable; 1 for male 0 otherwise
D_1 = Dummy variable for credit status (1 for access to credit, 0 otherwise)
D_2 = Dummy variable for membership of Co-operative (1 for membership, Otherwise)
δ - Coefficients are unknown parameters to be estimated

These variables are assumed to influence technical efficiency of the farmers

RESULTS AND DISCUSSION

(a) Socio-economic Characteristics of Respondents

The average farm household head surveyed had seven family members, was 42 years old, male, married and had least a Quaranic level of education. Most fields were less than one hectare. An average farm household had an average of 2.50 hectares of cultivated land in scattered locations. Operating capital averaged ₦12,650.00 per farmer.

(b) Estimates of the Parameters of the Production Factors

The parameter estimates obtained and the relevant statistical test results obtained from the stochastic frontier production analysis are presented in Table 1. The regression coefficients are direct elasticities of the dependent variable with respect to the independent variables with which the depend variable is associated. The estimate of the sigma-squared (δ^2) in Table 1 is significantly different from zero at 0.01 level indicating a good fit and the correctness of the specified distributional assumptions of the composite error term. The magnitude of the variance ratio *(r)* is 0.315 which is significant at the 0.01 level, suggesting that systematic influences that are unexplained by the production function are the dominant sources of errors.

The parameter estimates of the production factors presented in Table 1 show that the estimated coefficient for labour is positive as expected and significant at 0.01 level. The 0.361 elasticity of labour implies that a 1% increase in labour employment, ceteris paribus, would lead to an increase of 0.361 per cent in the output of arable crops and vice versa. Labour is required in the accomplishment of farm operations which are time-bound. A family composed of aged people including women and children will need hired labour more than another family with able-bodied men. Another major problem that limit the contribution of women dominated communities in the Northern part of Nigeria is the practice of "Purdah" which confines women to a considerable degree to remain indoors. The coefficient for seeds/planting material is also positive and significant at 0.10 level. The 0.066 elasticity of seeds which is small in magnitude implies that a 1% increase in quantity of seeds/planting material, especially of improved varieties, would lead to an increase of 0.066 per cent in farmers' output.

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

Variable	Parameter	Coefficient	t-ratio
Production Factors			
Constant	β_o	7.146	10.347***
Farm size (X1)	β_1	0.107	0.940
Labour (X2)	β_2	0.361	4.840***
Fertilizer (X3)	β_3	-0.150	-0.321
Seeds/Planting material etc (X4)	β_4	0.066	1.619*
Capital (X5)	β_5	0.108	1.986**
Efficiency Factors			
Constant	δ_0	-5.559	-2.08***
Age	δ_1	0.029	0.012
Education	δ_2	0.213	1.781*
Farming experience	δ_3	0.331	1.581
Household size	δ_4	-0.199	-1.654*
Extension contact	δ_5	0.242	0.421
Credit	δ_6	1.64	2.40**
Membership of co-operative	δ_7	0.103	0.083
Sex	δ_8	-0.150	-0.232
Diagnostic Statistics			
Log Likelihood function	-83.680		
LR test of one-sided errors	26.280		
Sigma – squared (δ)		0.375***	(6.909)
Gamme (*r*)		0.315***	(3.216)

***, ** and * imply significance at 0.01, 0.05 and 0.10 levels respectively
Source: Summarized from computer output

Agrochemicals, a component of material input are applied to crops to mitigate the effect of crop losses and deterioration due to infestation from pests and disease incidences. Thus as expected, the coefficient is positive implying a positive effect on crop output. The estimated coefficient for capital inputs is positive and significant at 0.05 level. The amount of capital inputs per farm determines the level of investment in such a farm. Tanko (2003) observed that in traditional agriculture, capital investment on fixed assets is negligible. High level of investment however, ceteris paribus, translates to higher returns. Therefore, the 0.108 elasticity of capital implies that a 1% increase in capital inputs would lead to an increase of 0.108 percent total output.

(c) Estimates of the Parameters of the Efficiency Factors

The sources of inefficiency are examined by using the estimated δ-coefficients in Table 1. The estimated coefficient of education variable is estimated to be positive as expected and statistically significant at the 0.05 level. This implies that arable crop farmers with more years of formal schooling, tend to be more efficient in crop production which makes them operate more close to the frontier output. The ability of the farmer to cope with the complexities of new innovations increases as the level of education increases, thus enabling them produce closer to the frontier. The estimated coefficient for household size variable is negative contrary to a priori expectation and statistically significant at 0.10 level. This suggests that farmers who have more people in their households tend to be less efficient in crop production. Although it is theoretically plausible that more adults in the farmers' household means more work force and savings in labour costs, however, the amount of labour available for farmwork depends fundamentally on two factors, namely, the number of people in a family who can actually work on the farm and the length of time for which each member is prepared to work on the family farm. Consequently, what matters is not the size of the family per se, but the composition and quality of those capable of working on the farm. As expected, the estimated coefficient for credit dummy variable is positive and statistically significant at the 0.05 level. This implies that farmers who have access to credit, tend to be more efficient in arable crop production. Farmers with access to credit are more disposed to hire labour, purchase material inputs and increase farm sizes.

Overall, the technical efficiency of the sample farmers is less than 1 (100%) indicating that all the farmers are producing below the maximum efficiency frontier. The distribution of technical efficiency estimates of farmers is presented in Table 2.

Results in Table 2 reveal that the best farm has a technical efficiency of 0.94 (94%) while the worst has a technical efficiency of 0.13 (13%) implying that some farmers are operating far away from the frontier region. The mean technical efficiency is 0.55 which implies that on the average, the respondents are able to obtain a little over 55% of potential output from a given mix of production inputs suggesting a wider scope for the farmers to increase their level of technical efficiency by allocating the existing resources more optimally.

The results show that it will take an average arable crop farmer in the survey area (1 – 0.55 / 0.94). i.e 42.0% cost saving to become the most efficient arable crop farmer while the worst performing farmer would require (1 – 0.37 / 0.94) i.e 61.0% cost saving to become the most technically efficient.

Table 2: Distribution of Technical Efficiency Estimates of Arable Crop Farmers in Kebbi State, 2003

Efficiency Class Index			Frequency	Percentage
0.10 – 0.20			3	3.00
0.21 – 0.40			28	29.00
0.41 – 0.60			32	33.00
0.61 – 0.80			20	20.00
0.81 – 0.90			11	11.00
0.91 – 1.00			2	2.00
Mean = 0.55				
Total				100.00
Maximum technical efficiency	=	0.94		
Minimum technical efficiency	=	0.13		
Mean of worst 10	=	0.37		
Mean of best 10	=	0.88		

Source: Computed from MLE Results

CONCLUSION AND POLICY RECOMMENDATIONS

The maximum likelihood estimation results reveal that labour, material inputs and capital are the major factors significantly explaining changes in the output of arable crops. Food crop production is characterized by complete reliance on household resources, use of in-appropriate and labour-intensive technology, shortage of capital for agricultural investment etc., which explains why maximum technical efficiency is yet to be attained with a considerable scope for improvement. The low levels of formal education and a low capital base for investment are the major factors that influenced the level of their technical efficiency. The distribution of the technical efficiency indices reveal that the current state of technology used by the farmers is inferior and grossly inadequate to bring about significant increases in food crop production. Thus, the need for the adoption of a more superior technology.

The implication of the study is that, technical efficiency in arable crop production could be increased by 45 per cent through optimal reallocation of existing resources. A shift from the current technology to the use of improved seeds and agrochemicals, increasing the access of resources–poor farmers to agricultural credit and adequate supply of modern inputs to farmers at terms and times convenient and at fairly competitive prices could bring about the transformation in agricultural production. The incidences of unemployment necessitated by the inefficient utilization of family labour and poverty could be reduced by creating alternative employment opportunities.

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