ANALYSIS OF FARM LEVEL TECHNICAL EFFICIENCY IN MAIZE PRODUCTION IN KOGI STATE, NIGERIA: A STOCHASTIC FRONTIER APPROACH

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ABSTRACT
The technical efficiency, determinants of production and the sources of inefficiency in maize production in Kogi State were investigated using the stochastic translog production function which incorporates a model for inefficiency effects. Data were generated using the multi-stage random sampling techniques. A total of 240 farm households from three agricultural zones were randomly selected. Farm size and labour inputs were the major factors associated with changes in the output of maize-based production in the study area. The technical efficiency of the farmers ranges from 40.2% – 96.4 % with mean efficiency of 83.9 %. Age of the farmer, level of education, farming experience, household size, credit status and membership of co-operative societies were the factors that significantly accounted for the observed variation in efficiencies among farmers. Expansion of farm holdings, acquisition of formal education and strengthening of the existing extension services were recommended.

Keywords: Stochastic frontier, Technical Efficiency, Maximum likelihood estimate

INTRODUCTION

FAO (2001) reported that maize is the most important cereal crop after wheat and rice respectively. It is produced across the country right from the mangrove regions in the south to the sahel savannah in the north. Maize was the dominant staple food crop for early civilization of the western hemisphere and today, it still plays an important role in the diets of millions of people because of its capacity to produce a large amount of dry matter per hectare, it's ease of cultivation, versatile food uses and storage characteristics. It was estimated that more than a hundred million people in the world consume maize in the form of thin round unleavened cakes or as porridge (Samson, 2005).

Maize has a great potential and can play a crucial role in contributing to food and nutritional security, income generation, poverty alleviation and socio-economic growth of Nigeria. The significance of maize to the modern society is first and foremost clearly reflected in the importance of the crop in the diet of man and animals throughout the world (FAO, 2001). All over Nigeria, the selling of roasted and boiled maize is a thriving business that provides employment for hundreds of thousands of young girls and women though the nature of employment is part time and seasonal (Samson, 2005). Maize is traditionally used as animal feeds and for the production of maize meal, flour, guts, starches, sweeteners as well as alcoholic beverages.

In view of the potentials of maize as a staple food crop and it's economic importance in feed industries and agro-allied industries in the country, it is important to find ways of increasing its production. Studies have been conducted to ascertain the resource use efficiency of arable crop farmers in Nigeria using the ordinary least square (OLS) estimation technique (Onoja 2001, Onia, 2005, Joe, 2005). The use of OLS estimation technique however, makes it difficult to determine farm level efficiency as it provides only an average function (Bravo-ureta and Pinheiro, 1997). To overcome these short comings of OLS, the stochastic frontier function was developed and has been used by several researchers to estimate efficiency in agricultural production. (Umoh, 2006; Shehu and Mshelia, 2007; Tanko, and Jirgi 2008;).

The study of this nature can help in enlightening farmers on the sources of production inefficiency and also suggest ways to improve their technical efficiency in production. It can also provide researchers, extension agents and the government with useful information on optimal resource allocation in production. This will aid in proper formulation of good policies for agricultural production. Specifically, this study intend to provide useful information that will improve technical efficiency of maize production in the study area, which, will go a long way to generating employment opportunities for thousands of Kogi State indigenes in particular and Nigerians in general. The hypothesis tested in this study is that the inefficiency effects in the stochastic frontier production function are not stochastic i.e. $H_0 = \gamma = 0$

Theoretical Framework: Following Ajibefun (2002) considering a farmer using inputs $X_1 X_2, \ldots, X_n$ to produce output Y, efficient transformation of inputs into output is characterized by the production function f(X), which shows the maximum output obtainable from various input vectors. The stochastic frontier production is defined as

$Y_i = f(X_i, \beta)\exp(V_i - U_i)$; = 1,2.....n ----(1)

Where Y_i = Farm output for the i^{th} farmer

X_i = Vector of input quantities of the i^{th} farmer

β = Vector of unknown parameters of the i^{th} farmer

V_i = Random error associated with random factors not under the control of the farmer e.g. weather

U_i = Inefficiency effects (one-sided error with $U \geq 0$) i.e. U_i's are non-negative with technical inefficiency in production.

$(V_i - U_i)$ = Composite error term

The symmetric component, V, account for factors outside the farmer's control such as weather and diseases. It is assumed to be independent and identically distributed as N~ (0, δ^2V). A one-sided component V = O reflects technical inefficiency relative to the stochastic frontier, $f(X_i; \beta)\exp(V_i - U_i)$. Thus V = O for a farm output which lies on the frontier and V<O for one whose output is below the frontier as N~ (O, δ^2U), i.e. the distribution of V is half-normal. Thus, the stochastic production frontier model can be used to analyze cross-sectional data. The model simultaneously estimates the individual technical efficiency of the respondents as well as determinants of technical efficiency (Battesse and Coelli 1995).

The technical efficiency of an individual farm is defined in terms of the ratio of the observed output (Yi) to the corresponding frontier output (Yi*) given the available technology conditional on the level of inputs used by the farm (Amaza and Maurice, 2000) the technical efficiency of farm (i) will be as follows.

$$TE = Y_1 / Y_1^* = \frac{f(x_i;\beta)\exp(V_i - U_i)}{f(x_i;\beta)\exp V_i} = \exp(-U_i) \quad \text{---2}$$

Where TE = technical efficiency

Y_i = Observed output

Y* = Frontier output

$V_i - U_i$ = Composite error term

β = Vector of unknown parameters

X_1 = Vector of input quantities of the ith farm

Given the density function of U_i and V_i, the frontier production function can be estimated by the maximum likelihood technique. The value of the technical efficiency has between zero and one. The most efficient farmer will have value one, whereas the least efficient farmer will have value lying between zero and one.

METHODOLOGY

This study was conducted in Kogi State. Kogi State is located in the North Central part of Nigeria. It lies between longitudes 5^0 40′E and 7^0 49′N; and latitudes $6^0$33′N and 8^0 44′N. It is bounded to the South by Anambra and Edo States; to the North by Niger, Nassarawa and the Federal Capital Territory; to the East by Benue and Enugu States. On the Western flank, it shares a common border with Ondo, Ekiti and Kwara States. (KG ADP, 2003).

Kogi State is divided into four agricultural zones namely: Koton/Karfe, Anyigba, Aloma and Ijumu zones. It consists of 21 Local Government Areas (L.G.A's). Kogi state has a population of about 3,278,487 representing 2.34% of the total Nigerian population consisting of 1,691737 males and 1,586,758 females. (KG ADP, 2003).

Christianity, Islam and African Traditional Religion are the principal forms of faith in the area. Igala, Ebira, Okun, Nupe, Kakanda, Yoruba, Hausa and Bassa are the major languages in the state. The people of Kogi state are predominantly farmers. According to Kogi ADP (2003), different kinds of arable crops can be grown in Kogi State such as maize, cassava cocoa yam, millet and groundnuts. There are also abundant palm produce in the area. Livestock such as goat, sheep and poultry are also reared in the state.

Sampling Techniques: The study was conducted in the predominant maize producing areas of Kogi State. The study adopted the multi stage random sampling techniques. The state was stratified into four in accordance with the four existing agricultural zones, namely: Koton/Karfe, Anyigba, Aloma and Ijumu zones. Out of these four agricultural zones, three were selected purposively because maize based cropping systems pre-dominate the farming system in these zones. This forms the first stage. From each agricultural zone, two Local Government Areas were selected randomly, namely; Kogi and Lokoja Local Government areas for Koton/Karfe zone, Dekina and Ankpa local government areas for Anyigba zone and Igala Mela/Odolu and Ofu local government areas for Aloma Agricultural Development Project zones respectively. This was the second stage. In the third stage, two communities were randomly selected from each of the selected local government areas. Agbeji and Egume were selected from Dekina local government area. Enjema and Odugomu were selected from Ankpa local government area. Gegu and Orehi were selected from Kogi local government area. Owara and Gaude were selected from Lokoja local government area. Akpayan and Odolu were selected from Igala mela/Odolu local government area and finally, Aloji and Ochadamu were selected from Ofu local government area. Twenty (20) maize farmers were randomly selected from each of the communities given a total of two hundred and forty (240) respondents.

Empirical Translog Stochastic Frontier Production Function: The implicit form of the transcendental logarithmic empirical stochastic frontier production function is written as

$$\ln Y_i = \beta_0 + \sum_{K=1}^{5} \beta_K \ln X_{Ki} + \frac{1}{2} \sum_{K=1}^{6} \sum_{i=1}^{6} \beta_{K1} \ln X_{Ki} \ln X_{i1} + V_i - U_i \quad 3$$

Where:
In = Natural logarithm
i = i^{th} farmer
Y_i = farm output for the i^{th} farmer
X's = input variables
β_i = the input coefficients for the resources used in production.

Following Parikh and Shah (1994), Onus *et. al.* (2000) and Tanko and Jirgi (2008), the explicit form of the translog empirical stochastic frontier production function is specified as

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \tfrac{1}{2}\beta_{11} \ln X_1^2 + \tfrac{1}{2}\beta_{22} \ln X_2^2 + \tfrac{1}{2}\beta_{33} \ln X_3^2 + \tfrac{1}{2}\beta_{44} \ln X_4^2 + \tfrac{1}{2}\beta_{55} X_5^2 + \beta_{11} \ln X_1 \ln X_2 + \beta_{12} \ln X_1 \ln X_3 + \beta_{13} \ln X_1 \ln X_4 + \beta_{14} \ln X_1 \ln X_5 + \beta_{15} \ln X_2 \ln X_3 + \beta_{16} \ln X_2 \ln X_4 + \beta_{17} \ln X_2 \ln X_5 + \beta_{18} \ln X_3 \ln X_4 + \beta_{19} \ln X_3 \ln X_5 + \beta_{20} \ln X_4 \ln X_5 + V_i - U_i \text{ ---(4)}$$

Where:
In = Logarithm to base e
Y = Output of maize (kg)
X_1 = Farm size (in hectare)
X_2 = Labour input (in Mandays)
X_3 = Quantity of fertilizer used (kg)
X_4 = Other inputs expenses. These includes cost of agro chemicals and seeds (in Naira)
X_5 = Capital inputs (in naira); these include: depreciation charges on machinery, equipments rent on land and interest charges on borrowed capital.
β_0 = Intercept/constant term
$\beta_1 - \beta_{20}$ = Parameters to be estimated
V_i = Normal random errors assumed to be independently and identically distributed, having N ~ (0, δ^2)
U_i = Non-negative (Zero mean and constant variance) random variable called technical inefficiency effect associated with the technical efficiency of the ith farmer. Uijs are the technical inefficiency effects which are assumed to be independent of Vijs such that Uij's is the non-negative truncation (at zero) of the normal distribution with mean U_i and variance $\delta^2 V$. Where U_i is defined as

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 i + \delta_3 Z_3 i + \delta_4 Z_4 i + \delta_5 Z_5 i + \delta_6 Z_6 i + \delta_7 Z_7 i + \delta_8 Z_8 i \text{ --- (5)}$$

Where:
Ui = Technical inefficiency of the i^{th} farmer
Z_1 = Age of the farmer (in years)
Z_2 = Level of education (number of years spent in school)
Z_3 = Farming Experience (in years)
Z_4 = Household size (Number)
Z_5 = Extension contact (Number of meetings with the extension agents during the cropping season)
Z_6 = Sex, (Binary variable, 1 for male, 2 for female)
Z_7 = Dummy variable for credit status (dummy variable, whereby 1 for access to credit, 0 otherwise)
Z_8 = Membership of Co-operative society (dummy variable, whereby 1 for membership, 0 otherwise).
$\delta_1 - \delta_8$ = Unknown parameters to be estimated.

The parameters of the translog stochastic frontier production function were estimated by the method of maximum likelihood using the computer programme FRONTIER version 4.1 (Coelli, 1995).

RESULTS AND DISCUSSIONS

Table 1: Summary Statistics of the Variables in the Stochastic Frontier Model

Variables	Minimum	Maximum	Mean	Stan De
Maize output (kg)	300.00	30,000	3870.69	438
Farm size (Ha)	0.50	11.00	2.43	1.7
Labour (man-days)	20.00	578.00	101.80	77.
Fertilizer (kg)	0.00	850.00	121.67	169
Other inputs cost (₦)	600.00	143,000.00	25140.21	276
Capital input cost (₦)	258.30	80483.00	7899.51	146
Age (years)	23.00	65.00	44.49	10.
Education (years)	0.00	19.00	6.58	5.5
Years of experience	5.00	50.00	25.04	10.
Household size	1.00	33.00	9.44	6.5
Extension contact	0.00	3.00	0.81	0.9

Source: Field Survey, 2009

The results in Table 1 indicate that the mean output of a typical maize farmer was 387069kg with a standard deviation of 4389.92. A typical farmer cultivated 2.43 hectares usually of several plots in scattered locations. An average farmer utilized 101.80 mandays of labour indicating that maize farmers in the study area relied heavily on human labour to accomplish most of their farming operations. A typical farmer utilized 121.67kg of fertilizer, expended ₦25,140.21 and ₦7,899.51 on other inputs and capital inputs respectively. These findings seem to exemplify the nature of subsistence farming which dominates agricultural production in Nigeria.

Table 2: Maximum Likelihood Estimates of the Determinants of Technical Efficiency in Maize Production in Kogi State

Variables	Parameters	Coefficients	t-ratios
Production Factors	β		
Intercept	β_0	7.027***	3.764
Farm size (X_1)	β_1	2.710***	3.168
Labour (X_2)	β_2	3.552***	3.377
Fertilizer (X_3)	β_3	1.179	1.336
Other Inputs Cost (X_4)	β_4	-0.004	-0.009
Capital inputs (X_5)	β_5	-0.364	-0.669
Squared Terms			
Farm size x farm size	β_6	0.603**	2.165
Labour x labour	β_7	10.586***	3.148
Fertilizer x fertilizer	β_8	0.102	0.576
Other costs x other cost	β_9	0.103	1.644
Capital x capital	β_{10}	0.067	1.089
Interaction Among Inputs			
Farm size x labour	β_{11}	-0.308	-1.318
Farm size x fertilizer	β_{12}	0.168	0.989
Farm size x other cost	β_{13}	-0.084	-0.812
Farm size x capital	β_{14}	-0.149	-1.244
Labour x fertilizer	β_{15}	0.242**	2.557
Labour x other cost	β_{16}	0.036	0.385
Labour x capital	β_{17}	0.141	1.297
Fertilizer x other cost	β_{18}	-0.083	-1.341
Fertilizer x capital	β_{19}	0.020	0.406
Other cost x capital	β_{20}	-0.075	-1.078
Inefficiency Factors			
Constant	Z_0	-6.624**	-2.436
Age	Z_1	0.073**	2.296
Level of education	Z_2	-0.087**	-2.138
Farming experience	Z_3	0.037**	2.344
Household size	Z_4	-0.048**	-2.144
Extension contact	Z5	-0.181	-1.349
Sex	Z_6	0.993	1.882
Credit status	Z_7	0.797**	2.319
Co-operative	Z_8	-0.493*	1.846
Diagnostic Statistics			
Likelihood Ratio		-77.924	
LR test		49.020	
Sigma Squared	δ^2	0.543***	3.905
Gamma	γ	0.859***	19.677

Source: Computer Print out of FRONTIER 4.1
***, **, * Implies significance at the 0.01, 0.05 and 0.10 Probability Levels Respectively

Table 2 shows the maximum likelihood estimates of the translog stochastic frontier production function for maize production in the study area. The results indicate that the estimated sigma squared is 0.543 which is relatively large, statistically significant and different from zero at 0.01 probability level. This indicates a good fit and the correctness of the specified distributional assumptions of the composite error term. Tanko and Jirgi (2008), and Kebede (2001), in their separate investigations obtained similar results. Table 1 also indicates that the variance ratio, defined as that is gamma, $\gamma = \delta u^2/(\delta u^2 + \delta v^2)$is estimated to be as high as 85.9% suggesting that systematic influences that are unexplained by the production function are the dominant sources of random errors.

In addition, the coefficient of farm size and labour inputs carried the expected positive signs and were significant at the 0.01 probability level. The estimated elasticities of mean output with respect to farm size and labour were 2.710 and 3.552 respectively. This means that for every 1% increase in farm size, the output will increase by 2.710%. Similarly a 1% increases in man day of labour, will increase output by 3.552%. This result agrees with previous works of Amaza and Olayemi (2002), and Ojo *et al.* (2009).

Results also shows that the estimated coefficient of the joint effect of labour and fertilizer which is 0.242 is statistically significant at the 0.05 probability level and is positively related to the output attained. This shows that there would be an increase in the output level by 0.242% when labour is increased by 1 unit, given a unit increase in fertilizer. Tanko and Jirgi (2008) obtained similar.

Level of education, household size and membership of co-operative societies were negative -0.087, -0.048 and -0.493 respectively and were significant at the 0.05, 0.05 and 0.10 probability levels respectively. The negative sign of the level of education implies that farmers who had one form of formal education or the other tend to be more efficient in maize production activities due to enhanced technical competence which enables them to produce close to frontier level. Household size was also negatively related to technical inefficiency and was found to be significant at 5%. This implies that as the number of households increases, technical efficiency increases. The reason for this may be because of increased number of adult who are strong enough to handle the tedious nature of farm work and thereby cope with labour demand during peak periods of labour requirement for the accomplishment of farm operations. This result conforms with previous work by Omotosho *et al.* (2008).

On the other hand, the MLE estimate for farmer's age (0.073) was significant at 5% and is positively related to technical inefficiency. This implies that as the farmers grow older, the level of technical inefficiency also increases. This could be attributed to decline in strength. More so, elderly farmers are risk-averse (Samson, 2005) and may not embrace improved technology which breeds efficiency, reduces farm drudgery and ensures timeliness in the accomplishment of farm operations. The coefficient of farming experience was found to be positive and significant at 5%. This implies that rather than increase the efficiency with which the farmers carries out their production activities, farming experience reduces it. This is contrary to a-priori expectation. Experience is expected to aid the farmer chart better courses of action by setting realistic targets.

Technical Efficiency Estimates of the Farmers

Table 3: Distribution of Respondents According to Levels of Technical Efficiency

Efficiency Class Index	Frequency	Percentage
0.31 – 0.40	1	0.42
0.41 – 0.50	3	1.25
0.51 – 0.60	8	3.33
0.61 – 0.70	10	4.17
0.71 – 0.80	26	10.83
0.81 – 0.90	136	56.67
0.91 – 1.00	56	23.33
Total	240	100.00
Mean	0.839	
Maximum value	0.964	
Minimum value	0.402	

Source: Computed from MLE Results

Table 3 indicates that technical efficiency of maize farmers in the study area ranges from 0.40 – 0.96 indicating that a wide gap exist between the efficiency of best technically efficient farmers and that of the average farmer. The mean technical efficiency of the farmers is 0.839. This implies that an average farmer in the study area was able to obtain a little over 84% of potential maize-based crop output from a given mix of production inputs. The results therefore indicated that, although farmers were generally relatively efficient, they still produced below the frontier level.

Test of Hypothesis

Table 4: Generalized Likelihood Ratio Test of Hypothesis for Parameters of the Translog Emperical Stochastic Frontier for Maize Farmers in Kogi State

Hypothesis	H_0: =0
Likelihood Ratio	-77.924
Number of Restriction	7
Critical value	14.07
Decision	Rejected

Source: Computed from MLE Results

The null hypothesis ($H_0 : \gamma = 0$) which specifies that the inefficiency effect in the stochastic frontier production function are not stochastic is also hereby rejected. Since the X_{cal} value of -77.924 is greater than χ^2 critical, (14.07).

CONCLUSION AND RECOMMENDATIONS

This study has shown that despite the fact that the farmers in the study area produced below the frontier level, they were relatively efficient with mean technical efficiency of 0.839. Although, farm size and labour inputs were positive as expected and significantly influenced farmer's efficiency levels at 1% respectively, farm resources were not optimally utilized suggesting a scope for improvement. The policy implication of this study is that there is a scope for raising the level of technical efficiency of maize production in Kogi State in particular and Nigeria in general given the wide variation in the level of technical efficiency. In other words, mean technical efficiency of 0.839 could be increase by 16.1% if efforts are put in place to reduce the level of inefficiency in production. This would serve as mitigating measure against possible food crisis that may result in Nigeria.

Based on the findings of this study, it is recommended that since size of land holding was positive and significantly influenced farmers' efficiency. The need for emphasizing the expansion of area under cultivation becomes imminent as there are advantages of having large sized farms. In addition, it is recommended that the Land Use Act of 1978 should be restructured to accommodate a policy that will allow for establishment of land markets. In addition, farmers should be encourage to acquire formal education as this will go a long way to improve their farm level technical efficiency and profitability.

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