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Technical Efficiency of Smallholder Maize Farmers in Nigeria: The Stochastic Frontier Approach

[1]Oladunni, Olufemi A., [2]Aduba, Joseph J. & [3]Onojah, David

1 Director of Studies, Agriculture and Rural Management Training Institute (ARMTI), PMB 1343 Ilorin, Kwara State Nigeria.
2 Data Analyst/Statistician, National Centre for Agricultural Mechanization (NCAM), PMB 1525, Ilorin, Kwara State Nigeria,
3 Monitoring & Evaluation Officer (M&EO), Kogi State Fadama Coordinating Office, Lokoja, Kogi State

Corresponding author: [1] Oladunni, Olufemi A

Abstract
The study examined technical efficiency of maize farmers in Kogi State, Nigeria. The objective is to determine the technical efficiency of maize production and factors responsible for technical inefficiencies in maize production in the study area. Primary data were used for the study. Data collated were analyzed using descriptive statistics, ordinary regression, and stochastic frontier model. Results from the analyses revealed that 70% of the farmers were above productive age, 87.5 are male while 62.5% have the ability to read and write. The regression analysis showed that variable inputs such as fertilizer, maize seed, chemical, labour and farm size are determinant of maize production in the study area while labour does not show any significant relationship. The mean technical efficiency was 0.758 implying that maize farmers in the study area are fairly efficient in their use of existing technologies. This means that on average smallholder maize farmers in the study area incurred about 24% loss in output due to technical inefficiency. This implies that on average output can be increased by at least 24% while utilizing existing resources and technology given the inefficiency factors are fully addressed. Farmers' characteristics such as gender, membership of cooperative society, storage facilities and nearness to market are factors affecting technical inefficiency.

Key words: *Agriculture, Farmers, Maize, Stochastic, Technical Efficiency,*

Introduction

Maize (Zea Mays L.) is one of the most important cereals in the world after rice, millet and sorghum with regard to its production and cultivation and it constitute a large percentage of the world's food supply (Osagie and Eka, 1998). Maize plant produces grains that are very rich in carbohydrate contents and protein used in various form for the purpose of feeding both human and animal (Abba 2012).

Maize is also one of the major staples in Nigeria and is one of the vital concerns to agricultural policy decisions. Current maize production in Nigeria is about 8 million tonnes and its average yield is 1.5 tonnes per hectare. The average yield is lower compared to the world average of 4.3 tonnes/ha and to that from other African countries such as South Africa with 2.5 tonnes/ha (FAO, 2009). There has been a growing gap between the demand for maize and its supply. The stronger force of demand for maize relative to supply is evidenced in frequent rise in price of maize and therefore, has great implication for the food security status and economic development of the Nigerian economy (Goodness and Eric, 2010).

Despite the efforts by the Nigerian government, maize productivity still remains below expectation considering the demonstrated and potential yields of 4.5t/ha and above 5.0t/ha respectively (Remison 2005). The failure to realize increased productivity in the Nigerian maize sector raises questions about the efficiency with which maize farmers use production resources and if inefficiency is observed, could this be attributed to technological innovation and other policy factors? The answer to these policy questions will serve as justification for further investment in maize production and agricultural technology development. Economic efficiency means to increase output without using more conventional inputs. This is because the use of existing technologies at times is more cost-effective than applying new technologies if farmers cultivate their products with the existing technology efficiently (Belbase and Grabowski, 1985; Shapiro 1977). There are three main efficiency measures namely technical, allocative and cost efficiency. In microeconomic theory, the primal production frontier describes the maximum output that may be obtained from given inputs. Any deviation from the maximal output is typically considered technical inefficiency.

A firm that operates at the production frontier has a technical efficiency of 100%. Even though farmers may be technically efficient, they may not be cost efficient because they are allocatively inefficient. That is, they do not utilise the inputs in optimal proportions, given the observed input prices, and hence do not produce at minimum possible cost. Therefore, the modelling and estimation of both technical and allocative efficiency of agricultural production is often motivated by the need for a more complete representation of economic or cost efficiency of farmers implied by the economic theory of production (Aye and Mungatana 2012).

The decomposition of technical efficiency is in threefold namely; *scale efficiency* (the potential productivity gain from achieving optimal size of a farm), *congestion* (increase in some inputs could decrease output) and lastly *Pure technical efficiency* (which deals with achieving the optimum output with the available technology). Though both technical efficiency and allocative Efficiency are important to achieve the overall economic efficiency in resource use, however technical efficiency is more important for study areas like Kogi State where inputs are not necessarily from the market (Singh, 2006; 2008). Moreover, there is skepticism about the credibility of allocative efficiency estimates in the peasant economies (Barrett, 1997). While technical efficiency estimation does not require information on prices, estimation of allocative efficiency does. And given that household-specific failures in markets for input and output are the distinguishing characteristics of low-income agriculture like maize farming in Kogi State, the relevant notion of allocative efficiency might differ from farmer to farmer, with many crucial variables like fundamentally unobservable shadow prices.

The main objective of this study is therefore to measure technical gains from enhancing the efficiency of maize farmers. The analytical method of the study is to measure the technical efficiency of maize farmers in Kogi State of Nigeria by applying stochastic frontier and to identify some determinants of technical inefficiency.

Methodology

Study area

Kogi state is found in the central region of Nigeria. It is popularly called the Confluence State because the confluence of River Niger and River Benue is at its capital, Lokoja, which is the first administrative capital of modern-day Nigeria**.** The state was formed in 1991 from parts of Kwara State and Benue State. Agriculture is the mainstay of the economy and the principal cash crops. The state is known for its mass production of farm produce such coffee, cocoa, palm oil, cashews, groundnuts, maize, cassava, yam, rice and melon. According to 2005 estimate, Kogi state has approximate population of 3,595,789. Kogi state has a coordinate of 7°30′N 6°42′E and a land area 29,833 km^2

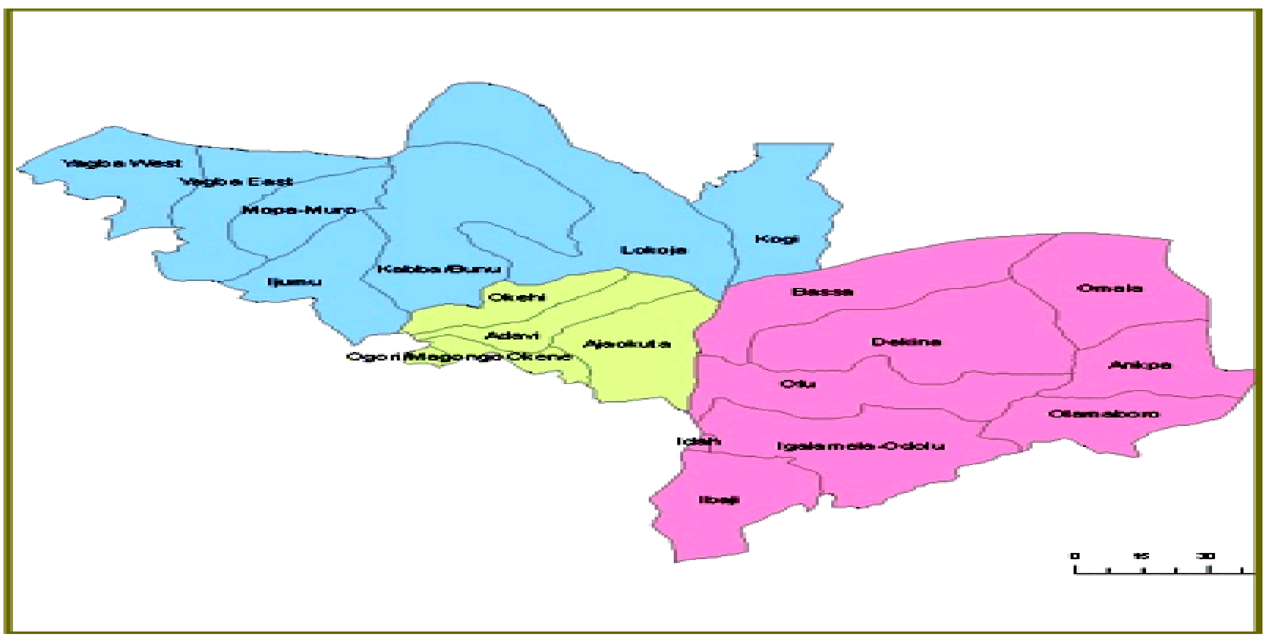

Fig. 1: Kogi State Map showing all the local governments
Source: Google Map, 2013.

Kogi State has an average maximum temperature of 33.2°C and average minimum of 22.8°C. The state has two distinct weather conditions, dry season, which lasts from November to February and rain season that lasts from March to October. Annual rainfall ranges from 1016mm to 1524mm.

Analytical Technique

The study was conducted in Kogi State of Nigeria. Farming is the major occupation of the majority of the people in the locality. The study employed multi-stage sampling technique involving a purposive selection of eight maize producing clans that are chiefly concerned with maize production as their most preferred means of livelihood in the study areas. A total of four hundred questionnaires were utilized for detailed study.

Data was collected using a well structured questionnaire and interview schedule administered on the respondents. Data collections covered one production cycle and include input-output data such as farm size, family labour, hired labour and planting material, capital, maize output as well as socio-economic characteristics of respondent. A combination of descriptive and stochastic production function model using the method of Maximum Likelihood Estimate (MLE) with the aid of computer programme stata 11 were used to analyze the data obtained from the farmers. Descriptive tools such as percentages and frequency were used to analyze the socio-economic characteristics of the farmers while Maximum Likelihood Estimate (MLE) was used to analyze the technical efficiency of the farmers.

The empirical model is expressed as

$$Y_i = \exp\ (X_{ij}\,\beta + v_i - u_i) \qquad (1)$$

Where Y_i is the output of the i^{th} farms, X_{ij} is a vector of inputs used by i^{th} farm, β is the vector of unknown parameters which will be estimated, the term v_i is a two sided ($-\infty < v_i < \infty$) normally distributed random error ($v \sim N[0, \sigma_v^2]$) that represent the stochastic effects outside the control of the farmers (whether, natural disaster and luck) measurement errors, and other statistical noise. The term u_i is a one sided ($u_i \geq 0$) efficiency component that represents the technical inefficiency of farm (Coeli et al. 2005). The distribution of ui can be half-normal, exponential, or gamma (Aigner et al. 1977; Meeusen and Boreck, 1977). u_i and v_i are assumed to be independently distributed. Under this assumption, the mean of the technical inefficiency effect ui can be specified as follows;

$$u_i = \sum \delta_k z_{ik} \qquad (2)$$

Where

z_i is a vector of observable farm specific variables hypothesized to be associated technical inefficiency,

δ is a vector of unknown parameters to be estimated.

The variance $\sigma^2 = \sigma_u^2 + \sigma_v^2$, while the ratio of the two standard errors γ is defined as;

$$\gamma - u_i^2 / v_i^2 \qquad (3)$$

Equation 3 determines whether a stochastic frontier model is warranted as opposed to simple production function.

Data Analysis

Since the Cobb Douglas functional form is preferable to other forms if there are three or more independent variables in the model (Hanley and Spash 1993), the study utilized the Cob Douglas stochastic frontier production function model with seven independent variables. The independent variables are farm size, hired labour, years of experience, family labour, fertilizer, agro chemicals and seed. This is expressed as follows;

$$\ln y = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_6 + \beta_7 lnX_7 + (v_i - u_i) \qquad (4)$$

Where

y is quantity of maize (kg),
X_1 is farm size,
X_2 is agro chemicals,
X_3 is seed,
X_4 is years of experience,
X_5 is family labour,
X_6 is hired labour and
X_7 is fertilizer.

The inefficient component u_i was modelled in terms of the factors that are assumed to affect the efficiency of production of the maize farmers such as the socio-economic characteristics of the farmers. The determinant of technical inefficiency is defined by:

$$u_i = z_0\delta_0 + z_1\delta_1 + z_2\delta_2 + z_3\delta_3 + z_4\delta_4 + z_5\delta_5 + z_6\delta_6 + z_7\delta_7 + z_8\delta_8 + z_9\delta_9 \qquad (5)$$

Where,
u is technical inefficiency,
z_1 is gender (dummy variable 1=male, 0=female),
z_2 is age (years),
z_3 is level of education (1=formal school attended, 0=no formal attended),
z_4 is membership of cooperative society (1=yes, 0=no),
z_5 is access to credit facility (1=yes, 0=no),
z_6 accessed to agric-based information (1=yes, 0=no),
z_7 is accessed to storage facility (1=yes, 0=no),
z_8 is previous annual income (1=≤N600,000, 2=≥600,000), and

z_9 is distance to market (km)
$\delta_1 - \delta_9$ *Inefficiency parameters*
These variables are assumed to influence technical efficiency of maize farmers in Kogi State. However, the technical efficiency of an individual maize farmer in the study area is defined in terms of the observed output (y_i) to the corresponding frontier output y_i^* given the available technology. Mathematically, this could be expressed as;

$$TE = \frac{y_i}{y_i^*} = \frac{Exp(x_i\beta + v_i - u_i)}{Exp(x_i\beta + v_i)}, \quad (6)$$

Where $0 \leq TE \leq 1$

Results and Discussion

Socio-economic Characteristics

From Table 1, it can be inferred that farmers between the age of 46 years old and above (80%) were more involved in maize production in the study area. The average age of the respondents was 47. Based on the World Health Organization 2003 average life span of 42 years for Nigeria, it can be inferred from the foregoing that maize farmers in the study areas are relatively old. Non project farmers are majorly male (87.5%). This can be attributed to the fact that male always have right to land as a productive resource than the female. The male domination of maize farming may also be due to high demands of time and energy required to work in such enterprise. This agrees with the study of Baiyegunhi and Fraser, (2009). The study shows that 37.5% of the farmers had no formal education, while about 62.5% farmers have one form of formal education or the other. Their educational status as it is however is enough to provide them with the ability to read and write, handle and interpret messages relating to farm input and machinery uses, and also enable them to appreciate extension services. It is an establish fact that at least 90% farmers in the study area belong to one association or the other. This suggests that these farmers already formidable can be assisted using their cooperative or associations as the intervention medium. Table 1 also show that while 89.2% of the Maize farmers depend solely on their personal saving as their source of farm credit, only a few others sourced credit from cooperatives (6.7%), bank (1.70%) and money lender (2.5%). More than 90% of the farmers are members of one cooperative society or the other. About 89.1% of the farmers have no storage facilities. This has negative implication on maize production in the study area as the quantity of maize grown may be limited because of lack of storage facilities.

Table 1: Farmers Characteristics in the study areas

Variable	Description	Frequency	Percentage
Age of Respondent	≤ 30	13.2	3.3
	31 – 45	66.8	16.7
	46 – 55	216.8	54.2
	≥55	103.2	25.8
	Total	400.0	100.0
Gender	Male	350.0	87.5
	Female	50.0	12.5
	Total	400.0	100.0
Education Status	No formal education	150.0	37.5
	Primary education	136.8	34.2
	Secondary Education	70.0	17.5
	Tertiary education	36.8	9.2
	Quaranic education	6.8	1.7
	Total	400.0	100.0
Membership of cooperative society	Yes	380.0	95.0
	No	20.0	5.0
	Total	400.0	100.0
Credit source	Personal	356.8	89.2
	Money lender	10.0	2.5
	Bank loan	6.8	1.7
	Cooperative/interv. fund	26.8	6.7
	Total	400.0	100.0
Storage Facility	Yes	13	10.9
	No	106	89.1
	Total	119	100.0

Summary Statistics of Measured Variables of Interest

The summary statistics of the variable gathered from maize farmers in Kogi State are reported in Table 2. The average yield per hectare is 14.95 maize bags. The standard deviations of 6.07 associated with these measurements indicate moderate variability in output among the maize farmers. On average, about 394.10 and man-hours per hectare were applied for one production cycle/season. This shows that the production technology existing among farming household is labour intensive (Tewodros, 2001). This is a peculiar characteristic of maize farming in developing countries where appropriate mechanized technologies are lacking.
Important farm inputs include seed, fertilizer, and agro chemicals mostly sourced from the market. There were also agricultural credit facility and subsidy on some of these farm inputs. Additional information revealed that the so called subsidies on the farm inputs were grossly below expectation/performance. For example, about 8 to 10 bags of fertilizers may be required for one hectare of maize farm, an average farmer however, indicated to have been be subsidized with as few as 2bags.

Table 2: Summary statistics for survey variables

Variable	Sample mean	Std deviation	Minimum	Maximum
Output (bag)	14.95	6.07	8.00	32.00
Farm size (ha)	1.45	0.93	1.00	8.00
Hired labour (man-0day)	394.10	198.79	56.25	1260.00
Family labour (man-days)	259.86	183.14	26.25	840.00
Fertilizer (kg)	215.22	155.84	100.00	800.00
Agro chemical (litre)	12.43	5.65	4.00	25.00
Seed(kg)	20.93	23.70	10.00	200.00

Source: field Survey, 2011

Determinant of Maize Production

Ordinary least square (OLS) estimate of the parameters which show the average performance of the maize farming households in the study area is presented in Table 3. The high value of adjusted R^2 for the study implies that about 95.69 percent of the variation in the production process was explained by the various explanatory variables/inputs employed. Some of the coefficients of the measured parameters such as farm size, labour, agro chemicals, fertilizers and seed were statistically significant and exhibited expected sign. Years of experience exhibit negative sign. This is not unconnected with the fact that most farmers in the study area are relatively old as seen earlier in farmers' characteristics.
There was no incidence of multi-collinearity in the data since the test prove otherwise. Insignificant variables were not considered for further analysis.

Table 3: OLS estimate of Cobb-Douglass production function

Variable	Parameters	Coefficient	T-ratio
Constant	β_0	-4.3835	-4.0200*
Farm size	β_1	0.7888	4.9200*
Agro chemicals	β_2	0.0586	2.2600*
Seed	β_3	0.2618	3.1300*
Years of Exp.	β_4	-0.1652	-2.0200*
Family labour	β_5	0.0206	0.3900
Hired labour	β_6	0.0493	-0.9100
Fertilizer	β_7	0.1277	-3.2100*

*R^2_{adj}=86.65, *significant at 5%*

Effect of Distributional Assumption (Comparison and Selection of the Appropriate Model)

The maximum likelihood estimates of the Cob-Douglas stochastic frontier model, was made on two different distributional assumptions on the efficiency error term namely; half normal and exponential distributions, are presented in Table 4. The table presents the estimates of the stochastic frontier which shows the best practice and efficient use of available technology.

The log likelihood functional values for the two different models are relatively the same for maize farming in the study area. The estimated values of the frontier production obtained with the two models are very similar to one another. This suggests that either of the models can be used to appropriately capture the inefficiency component if it exists.

Table 4: Maximum Likelihood Estimates of the Stochastic Frontier Production Function

Parameters	Half normal	Exponential
β_0	-3.3322* (1.3261)	-0.1011* (1.1481)
β_1	0.5337* (0.1658)	0.4498* (0.1513)
β_2	0.0598 (0.0432)	0.2804* (0.0514)
β_3	0.3066* (0.0832)	0.2520* (0.0799)
β_4	-0.1579* (0.0892)	-0.1961* (0.0587)
β_5	0.1116* (0.0630)	0.0798* (0.0468)
β_6 (drop for collinearity problem)	-	-
β_7 (drop for collinearity problem)	-	-
$\lambda = \sigma_u / \sigma_v$	8377.82 (0.0257)	2.5903 0.0360
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.1054 (0.0167)	0.0387 0.0096
Chi Square	2.24E+07	1022.21
Log Likelihood	31.94	29.533
Probability	0.001	0.001

**significant at 1% level, figures in parenthesis are standard errors.*

Parameter Estimates of Stochastic Production Function

Using the half normal assumption, we reproduce the maximum likelihood estimates of the Cobb-Douglas stochastic frontier model on Table 5 below for further discussion. From the Table, it is evident that the estimate of λ (8377.82) and σ(0.8224654) for the maize farmers are large and significantly different from zero. This indicates a good fit and the correctness of distributional assumption (Tewodros, 2001). The observed significant of σ at 1% is consistent with the findings of Sharma et al. (1997) and Hjalmarsson et al. This suggests the conventional production function (OLS) is not an adequate representation of the data. Furthermore, the estimate of $\Gamma^{\#}$0.998, implying that more 99% of the variation in the output among maize farmers in the study area are due to the differences in technical efficiencies. This result is in consonance with Coelli and Battese (1996), Kalirajan (1981) and Hjalmarsson et al, (1997). The positive significant coefficient of farm size shows the existence of economies of scale in the study area (Oyewo et al 2009, and Onuk et al. 2010)). However, given the small size of farm used by most respondents, it may not be feasible to actually exploit the economies of scale arising from farm size. Seed was currently being overused by farmers in the study area. Since most respondent indicated the use of improved/hybrid seed given as a subsidy, the overused here may suggest insufficient provision of this very important input. Agro chemical was significant. All these indicate that there is potential of increasing maize production through raising the level of these inputs.

The estimated elasticity of production which are the coefficient of the Cob-Douglas for all the inputs are less than 1, implying positive decreasing function to the factors. This suggests that the allocation of these inputs were in the stage of efficient factor usage (Singh & e t al, (2009).

Table 5: Maximum Likelihood Estimates of the Stochastic Frontier Production Function

Parameters	Half normal
β_0	-3.3322* (1.3261)
β_1	0.5337* (0.1658)
β_2	0.0598 (0.0432)
β_3	0.3066* (0.0832)
β_4	-0.1579* (0.0892)
β_5	0.1116* (0.0630)
$\lambda = \sigma_u / \sigma_v$	8377.82 (0.0257)
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.1054 (0.0167)
σ	0.8224654
Chi Square	2.24E+07
Log Likelihood	31.94
Probability	0.001
Likelihood ratio test ($\sigma - 0$)	35.95, ($p \leq 0.001$)

$\Gamma = \sigma 2 / \sigma 2$	0.997

*significant at 5% level, figures in parenthesis are standard errors.

The mean technical efficiency for the maize ranges between 0.758 and 0.187 (see Table 6). This implies that maize farmers in Kogi state are able to attain well over 70% of potential output from a given mix of production inputs. While the farmers could be said to be relatively technically efficient, in the short run, there is a scope for increasing maize production by 24% by adopting the best available technology and techniques used by the best practice maize farmers in the study area, (Tewodros, 2001).

Table 6: Summary of statistics for the efficiency score

Statistic	*Efficiency Score*
Mean	*0.758*
Minimum	*0.187*
Maximum	*0.998*
Standard Deviation	*0.218*
Kurtosis	*-0.313*
Skewness	*-0.813*

The frequency distribution of the efficiency indicates that 63.8% of maize farmers operate with efficiency score greater than 70 (Table 7), this suggest that majority of maize farmers in the study areas are taking advantage of the available technology despite their crude nature.

Table 7: Frequency Distribution of the efficiency estimate

Efficiency Score	No. of Farms	% of Farms
<50	11.00	13.75
51-60	10.00	12.50
61-70	8.00	10.00
>70	51.00	63.75

Sources of Technical Efficiency

Farmers' characteristics, demographic factors, farm characteristics and perhaps non physical factors are likely to affect efficiency (see Ali and Chaundry, 1990). The maximum likelihood estimates of the determinant of technical efficiency are summarized in Table 8.

It is believe that age is a proxy for farming experience in a traditional setting as it is the case in the study area. This means that the larger the age the greater the farming experience a farmer has, Tewodros (2001). The study however, revealed age is not a determinant of technical efficiency. This could be due to the fact that most farmers in the study area are the above productive age as seen earlier.

Gender of ownership is a determinant of technical efficiency. Since maize farming in the study area is male dominating activities, male could have made decisions concerning production activities that are favourable and technically efficient. Memberships of group/association afford farmers the privilege of enjoying interacting with one another and assessing information and agricultural credit facilities both from the government and financial institutions. This explains the positive and significant coefficient associated with cooperative society.

Farmers with storage facility tend to be more technically efficient since post harvest losses are reduced to the barest minimum. Also the incidences of fungal attack, pest and disease, theft and / or poor weather conditions associated with post harvest trauma are controlled with the aid of storage facilities. Proximity to market is another factor that account for technical inefficiency.

Table 8: Factors affecting farmers' technical efficiency

Variable	Coeficients	t-ratios
Gender	0.1660	2.0200**
Age	-0.0023	-1.3000
level_edu	-0.0449	-1.2200
coop_society	0.7956	10.5000*
Credit	-0.3587	-3.7500*
info_acces~d	0.0569	1.2600
Storage	0.2269	5.0200*
Previous Income	-0.1174	-1.4500

Market dist.	-0.0080	-2.0600**

**significant at 1% level, **significant at 5% level*

Conclusions

The study examined the technical efficiency of maize farmers in Kogi State of Nigeria. Primary data was basically used for the study and this was obtained using stratified sampling technique, and basically through interview.

The data collected were analyzed using descriptive statistics, regression analysis and the Cob Douglass production function.The study revealed that majority of the farmers 70% are above productive ages, and that maize production was mainly dominated by male and married farmers.

The study further revealed that farming is basically the primary occupation in the study area. Majority of the farmers (65%) has the ability to read and write, and able to interpret messages relating to farm. Personal saving was majorly the source of credit for farmers in the study areas (89.2)

The maximum likelihood estimate of stochastic frontier showed that farm size, agro chemicals, seed, years of experience and family labour are determinant of maize production in the study area. Although the mean technical efficiency of 0.758 suggests that maize farmers in the study areas are making optimal use of available resources and technology, however, there is still a scope for increasing maize production by 24% by adopting the best available technology for maize production in the study area. Gender, membership of group, relative distance to market, and access to credit facilities are determinant of technical efficiency in the study area (Kogi State).

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