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## Technical Efficiency of Maize Production in Nigeria: Parametric and Non-Parametric Approach

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### Abstract

The study was carried out to provide empirical evidence on technical efficiency of maize production in Nigeria using parametric and non-parametric approaches. The study employed annual secondary data on maize production in Nigeria from 1971 to 2010. Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) were used to estimate the technical efficiency of maize production. The results revealed that, the mean technical efficiency scores were 64.1%, 77.8% and 87.7% for technical efficiency under stochastic frontier analysis, technical efficiency of DEA constant return to scale and technical efficiency of DEA variable return to scale assumptions, respectively. These showed that the efficiency scores obtained from DEA are higher than those obtained from SFA. The results implied that, the country can expand its scope of output production by 35.5%, 22.2% and 12.3% for technical efficiency under stochastic frontier analysis, data envelopment analysis constant return to scale and variable return to scale, respectively. It is concluded that under the two methods used farmers can still expand their scope of output production through appropriate combination and use of production inputs at the given technology.

**Keywords:** Efficiency, data envelopment analysis, stochastic frontier analysis, constant return to scale, variable return to scale, maize

### Introduction

Maize is a cereal staple food crop that is popularly grown in many of the Sub-Saharan countries of Africa of which Nigeria inclusive, with per capital consumption of 40kg/year (FAOSTAT, 2003). The crop has big impact in the economics of developed and developing countries. According to National Bureau of Statistics (NBS) 2012 in Nigeria, over 60% of the population is employed by

agriculture. This sector contributes about 40% to the Nigerian Gross Domestic Product (GDP). Despite the economic importance of the crop to the country, yet its supply to meet the demand of the teeming population is not met. In Nigeria population is estimated to be growing at 3.2% per annum (NPC, 2006) while agricultural production is growing at 2.5% per annum (Ogundari and Ojo, 2007). Hence, this creates demand-supply imbalance of food in the country.

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According to USDA (2012) in 2011, 5.15 million hectares were cultivated to maize, with a production of 9.25 million tons per

annum, giving a yield of 1.8 tons per hectare. Ojo (2003) reported that factors such as price fluctuation, diseases and pests, poor storage facilities have been associated with low maize production in the country. In Nigeria the food demand-supply deficit has caused the country to increase its import bill from ₦160.2 billion in 2001 to ₦290.7 billion in 2007 (CBN, 2007). By the same token, maize domestic demand of 3.5 million tons outstrips supply of 2.0 million tons per annum. Hence, poultry producers and feed millers are unable to get sufficient corn supplies from local sources and are therefore looking to imports. Because of the need to import maize in order to meet the local demand, import ban on corn was lifted in 2008 and allowed at 5% tariff (USDA, 2012). Price of maize is increasing because demand outpaced the supply by 400 dollar per ton in 2011/12, up from 366 dollar per ton in 2010/11.

In an attempt to increase food production in Africa, during African head of states summit on food security and poverty reduction in Abuja Nigeria, December 2006, the African heads of states and government identified maize, among other crops as a strategic commodity for achieving food security and poverty reduction (AUC, 2006). Based on the resolutions reached, they called upon all member states to adopt strategic plans for increasing maize production in the area through measures such as research and development, access to production inputs and appropriate use of farm resources.

In order to increase food production in the country successive and present government adopted some strategic agricultural policies and programs such as Operation Feed the Nation (OFN) program of 1975-1980. The program aimed at increasing local food production through increasing more cultivable land in the country. Green Revolution (GR) program was established in 1980 to ensure self-sufficiency in food production and to introduce modern technology in to the Nigerian agricultural sector through the introduction of modern inputs such as high yielding variety of seed,

fertilizer and tractors. The policy was supported by projects such as 11 River Basin Development Authority and agro-service centres in order ensure all year round farming and efficient production inputs distribution. The Structural Adjustment Program (SAP) was introduced in 1986 in the country with the aim of increasing food production and rural incomes and to reduce her dependence on petroleum exports; eliminate distortions and rationalize consumption and expenditure patterns, through restructuring the economy's productive base.

During the same period Directorate for Foods, Roads and Rural Infrastructure (DFFRI) program was also established, aimed at developing rural and agricultural infrastructures including roads, agro-facilities, and electricity to improve rural productivity, employment and incomes. A year later, Better Life Program (BLP) for rural women was established to improve rural and agricultural women's incomes and welfare through productivity enhancing measures, skills and capacity development. In 1989 Peoples' bank was established to ease access to low-cost credit in the informal sector including farmer groups and producer's associations. Agriculture in the 7-Point Agenda Program was launched in 2007 to ensure food security, access to credit, land reform, agricultural extension, research and training, appropriate technologies etc. geared towards increases in agricultural productivity (Okoro and Ujah, 2009).

Despite the various government's agricultural policies and programs developed and implemented the sector suffers years of mismanagement, and inconsistency in the government policies and the era of huge oil revenue has as well contributed in the neglect of the agricultural sector (Umar and Zubairu, 2012). It was asserted that, lack of proper policy formulation, implementation and evaluation lead to policy failure in the agricultural sector in Nigeria. Socio-political and economic factors contribute to agricultural

policy failure in Nigeria (Olaye, 2010). The president of all farmers association of Nigeria (AFAN) Adamu (2010) said successive government policies on agriculture failed because of lack of proper monitoring mechanism

As part of policy measures to increase maize production research works on maize conducted by National Agricultural Research Institute (NARI) and International Institute for Tropical Agriculture (IITA) have developed and introduced a range of improved maize varieties that are disease resistant and high yielding. Consequently maize production in West and Central Africa including Nigeria has since the mid-1980s increased more than tripled. The new varieties have not only double the yield but also shortened the harvesting period to 80 days after planting. The development of rapid maturing varieties has enabled maize production to expand into the Sudan Savannah Zone of Nigeria because the zone has short duration of rainy season (Abdul-Karim *et al.*, 2004).

The rapidly increasing population which leads to demand increase for maize for human consumption and use as animal feed in the country, requires avenues for raising the maize production. This increase in output can be ascertained through this type of research of analyzing the maize production technical efficiency in the country. The finding could be useful to farmers to make adjustment in the use of farm resources and by government to introduce developmental project for farmers to raise their production output. Policy makers can also use the finding as a guide to come up with policy strategies for improving maize production.

Even though government adopted a lot of agricultural policies and programs with a view to increasing maize production in Nigeria, not much was explored on maize production technical efficiency using several techniques. However, the few researches on maize production technical efficiency measures were in most cases on states basis

or regional basis and have not used several methods at the same time to explore technical efficiency measurement.

Among the studies visited include Amaza *et al.* (2006) who researched on identification of factors that influence technical efficiency of food crop production in West Africa adopted a stochastic frontier production function, using the maximum likelihood estimation (MLE) technique. The results revealed that the mean farmers' technical efficiency index was 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. Fasasa (2007) studied on technical efficiency in food crop production in Oyo State, Nigeria. The author used stochastic frontier production (Maximum Likelihood Estimation) methodology to estimate the technical efficiency of 100 farmers in the study areas. The mean score of technical efficiency was 70 percent. Furthermore, the results showed Age of farmers, Farming experience and Level of education were factors that significantly influenced the level of technical efficiency. Sekhon *et al.* (2010) also used stochastic frontier production function to estimate individual farms technical efficiency of crop production at a region level. The result showed that the average technical efficiency has been found maximum in the central region (90 per cent), and the main drivers of inefficiency have been identified as experience in agriculture and age of a farmer.

Other studies reviewed include Shanmugam and Atheendar (2006) that researched on technical efficiency in agricultural production and its determinants: an exploratory study at the district level by employing stochastic frontier function methodology. They found that the mean efficiency of raising agricultural output was 79 per cent and therefore there was a scope for increasing output by 21 per cent without additional resources. Furthermore, the result indicated that, health, education, and

infrastructure are powerful drivers of efficiency at the district level. However the determinants of efficiency across districts depend greatly on environmental factors, such as agro-climatic zones, technological factors, and crop mix. Shumet (2011) reported on analysis of technical efficiency of crop producing smallholder farmers in Tigray, Ethiopia using descriptive and econometric methods. The mean technical efficiency of farmers was 60.38% which implied that output in the study area can be increased by 39.62% at the existing level of inputs and current technology by operating at full technical efficient level. The analysis further revealed that all determinants (except households' sex, farm size, participation in irrigation, and member to association) have significant effect on efficiency of farmers.

In their work Omonona *et al.* (2010) researched on farmer's resource-use and technical efficiency in cowpea production in Nigeria. The authors used stochastic production frontier, budgetary and resource-use efficiency analyses. The enterprise economic efficiency was 1.17. This means that for every N1 spent by the farmer on cowpea production, 17 kobo was realized as profit. Farmers' average technical efficiency is 87%, which implied an appreciable use of inputs in productivity. farm size, seed, hired labour, family labour, fertilizer and pesticides are significant at 1%. At the same time, to bit regression analysis indicated that some socio-economic variables were found to be significantly different from zero at 1% for cooperative membership and farming experience. Huynh and Mitsuyasu (2011) reported in their study on technical efficiency analysis of rice production in Vietnam. The authors used stochastic frontier analysis employing Cobb-Douglass production function to analyze Vietnam household living standard survey 2005-2006, yielding the mean of technical efficiency of 81.6%. Intensive labour, irrigation and education had positive impact on technical efficiency while agricultural policy did not help farmers cultivate rice more efficiently.

This showed that, most of the studies reviewed explored technical efficiency on regional or state basis using stochastic frontier analysis. Thus, data envelopment analysis was not much used to explore technical efficiency and none have used both SFA and DEA to explore technical efficiency in the country. The current study is to evaluate maize production technical efficiency in Nigeria using both Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). Using the two techniques will help to acknowledge and highlight the strength of the each technique in evaluating technical efficiency measurement. Learner and Lecnard (1983) reported that using several analytical techniques to analyze an economic phenomenon could serve as a cross verification for the robustness of the results.

## Methodology

The current study employed the two most commonly used methods based on the pioneer work of Farrel and his efficiency measures (Farrel, 1957). The two approaches employed are the Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) in order to determine and acknowledge the strength of the two techniques based on the technical efficiency levels generated. Even though these approaches were tried by other researchers regarding efficiency measurements until now no consensus was reached to which method should be used (Bauer *et al.*, 1998). The preference of using a particular method is given by the distribution of the data set. The use of the two methods to analyze technical efficiency could serve as a cross verification for the robustness of the results (Learner and Leonard, 1983).

The Stochastic Frontier Analysis used in the current study was developed by Aigner *et al.*, (1977). The parametric approach requires that the shape of the frontier be guessed beforehand by specifying a particular function relating output to input.

SFA involves econometric estimation of parametric frontier. Using this approach one can account for noise and conduct hypothesis test. Its disadvantage compared to DEA includes the need to specify a functional form. It is also more difficult to accommodate multiple outputs. The basic stochastic frontier production function model is specified as follows:

$$Y = f(X_i; \beta) + \varepsilon, i = 1, 2, \dots, n \dots \dots \dots (1)$$

Where y represents farm's output, X<sub>i</sub> is a vector of inputs used by the farm; ε is a composite error term. This ε decomposed to give V-U. V represents random variable which is assumed to be N~(0, δ<sup>2</sup><sub>v</sub>). This component of the error term accounts for the stochastic effects that are beyond farmers' control. Examples of these effects include natural disaster, weather, measurement error and statistical noise. U is a non-negative random variable which represents inefficiency of the producing farm (Coelli *et al.*, 2005). U is assumed to be independent of V. β represents parameter to be estimated.

To determine physical relationship between inputs and output, several functional forms were adopted. Based on Hanley and Spash (1993) that when there are three or more independent variables in the model it is more appropriate to apply Cobb-Douglass production function model. To determine technical efficiency using Cobb-Douglass stochastic frontier analysis, the empirical model is specified as follows:

$$\ln Y = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + V-U \dots \dots \dots (2)$$

Where Y represents quantity of maize output in tons, X<sub>1</sub> represents area harvested in hectares, X<sub>2</sub> represents quantity of seed in tons, X<sub>3</sub> represents fertilizer quantity in tons, X<sub>4</sub> represents labor in no. male and female economically active in agriculture and X<sub>5</sub> represents number of tractors in use in no., V represents random variable which is assumed to be N~(0, δ<sup>2</sup><sub>v</sub>). U is a non-negative random variable which represents inefficiency term. β<sub>1</sub>-β<sub>5</sub> represent unknown

parameters to be estimated. β<sub>0</sub> represents the intercept term.

The Data Envelopment Analysis (DEA) was developed by Charnes, Cooper, and Rhodes (1978). It involved the estimation of non-parametric frontiers. Other than comparing efficiency across Decision Making Units (DMUs) within an organization, DEA has also been used to compare efficiency across firms. This approach does not require price data, and if price data are available, then allocative efficiency can be calculated. Charnes *et al.* (1978) used this approach in their study to estimate an empirical production technology frontier. DEA with the most basic being CCR based on Charnes *et al.* (1978) address varying returns to scale, either CRS (constant returns to scale) or VRS (variable return to scale). In the DEA methodology, formally developed by Charnes *et al.* (1978), efficiency is defined as a ratio of weighted sum of outputs to a weighted sum of inputs, where the weights structure is calculated by means of mathematical programming and constant return to scale (CRS) are assumed.

In 1984, as an improvement to the analytical technique, Banker *et al.* developed a model with variable returns to scale (VRS). Technical efficiency (TE) reflects the ability of (DMUs), such as firms to obtain maximal output from a given set of inputs (Farrell, 1957). When using the DEA model, there is no need to specify the functional form. In addition, there is no need to specify the distributional form for the inefficiency term (Coelli *et al.*, 1998). It is assumed that a maize farm or DMU produce a quantity of maize (y<sub>i</sub>) using multiple of inputs (x<sub>i</sub>), such as land, labour, seed, fertilizer and rainfall. To determine technical efficiency for the i-th maize DMU in the linear programming (LP) problem in an output-oriented DEA, the model was solved as follows:

$$\begin{aligned} &\text{Maximize } \theta \lambda \quad \theta \\ &\text{Subject to: } -\theta y_i + Y \lambda \geq 0 \\ &X_i - X \lambda \geq 0 \quad \lambda \geq 0 \dots \dots \dots (3) \end{aligned}$$

Where  $y_i$  is the maize quantity for  $i$ -th DMU,  $x_i$  is  $N \times 1$  vector of input quantities for  $i$ -th DMU,  $Y$  is  $1 \times M$  vector of maize quantities for all the country,  $X$  is  $N \times M$  matrix of input quantities for all country,  $\lambda$  is  $M \times 1$  vector of weight and  $\theta$  is a scalar. The above specified theoretical empirical linear programming model was specified based on constant return to scale (CRS). For variable return to scale (VRS) equation (3) is altered by adding the convexity constraint,  $\sum \lambda_i = 1$ . The study used variable return to scale assumption. When using variable return to scale assumption, it helped to access both technical efficiencies under variable return to scale and constant return to scale, and as well access scale efficiency measurements. The model was previously

calculated under CRS and VRS assumptions (Coelli *et al.*, 1998; Coelli & Rao, 2003).

**Data and variables**

Annual data for the period from 1971- 2010 was used. The data comprise of quantity of maize output (QP) in tons; quantity of maize seed (QSD) in tons; area harvested (AH) in ha; quantity of fertilizer (FTQ) in tons; labor (LAB) in No. male & female economically active in agriculture and number of tractors in use (TU) in No. The study used data retrieved from FAOSTAT and National Bureau of Statistics (NBS). Table 1 shows descriptive statistics of the variables.

**Table 1: Descriptive statistics of the variables**

	QP	AH	QSD	FTQ	LAB	TU
Mean	3944492.	2815114.	1114683.	287602.6	11543213	14350.35
Median	4949000.	3309430.	1275812.	179200.0	12464000	14175.00
Maximum	7676850.	5472000.	2297980.	4022223.	12870000	24800.00
Minimum	488000.0	425000.0	162543.9	9245.000	4342500.	3450.000
Std. Dev.	2539284.	1684964.	660924.2	626929.6	2257164.	6660.631
Observation	40	40	40	40	40	40

**Empirical results**

In this section results of technical efficiency using Stochastic Frontier Analysis and Data Envelopment Analysis are presented and discussed. Some hypothetical tests were

conducted to ascertain the presence or absence of some properties of the data. To test for the stationary of the data, unit root test was conducted using Augmented Dickey Fuller Unit Root Test, and the results are present in Table 2

**Table 2: Augmented dickey fuller (ADF) unit root test result**

Variable	Level		1 <sup>st</sup> Difference	
	Test statistic	Test critical value	Test statistic	Test critical value
QP	-0.346632 <sup>ns</sup>	-3.610453	-5.501367***	-3.615588
LAB	-0.933801 <sup>ns</sup>	-3.610453	-4.867627***	-3.615588
FTQ	-6.143761***	-3.605593	-8.581218***	-3.610453
AH	-0.850919 <sup>ns</sup>	-2.606857	-4.926555***	-3.610453
TU	-0.165859 <sup>ns</sup>	-2.611531	-6.074618***	-3.639407
QSD	-0.562617 <sup>ns</sup>	-2.606857	-3.559573**	-2.938987

It can be deduced from Table 2 that most of the variables were not stationary at level. In order to have the variables in the same order 1<sup>st</sup> difference of the entire variables were taken. The variables were all stationary at 1<sup>st</sup> difference. It can be observed from the

Table 2 that at 1<sup>st</sup> difference the value of test statistic is greater than the test critical value. That implied the null hypothesis of non-stationary is rejected. The test helps to avoid spurious result. Furthermore, to check if there could be a long run relationship of the

variables co-integration test was conducted using Johannes co-integration test and the results are presented in Table 3

**Table 3: VAR unrestricted Johannes co-integration rank test (Trace) 1to 1 lags interval**

Hypothesized		Trace	0.05	
No. of CE(s)	Eigen value	Statistic	Critical value	Prob.**
None *	0.742501	147.1171	95.75366	0.0000
At most 1 *	0.568984	98.27450	69.81889	0.0001
At most 2 *	0.504264	67.97655	47.85613	0.0002
At most 3 *	0.425944	42.71494	29.79707	0.0010
At most 4 *	0.316973	22.73393	15.49471	0.0034
At most 5 *	0.221415	9.009963	3.841466	0.0027

It can be observed from Table 3 that the trace statistic values are greater than the critical values and all probability values are significant at less than 5%. That implied a rejection of null hypothesis of no co-integration of the variables. Table 4 shows

percentage frequency distribution of maize production technical efficiency under constant and variable return to scale, and technical efficiency estimated by stochastic frontier analysis in Nigeria.

**Table 4: Percentage frequency distribution of maize production technical efficiency under constant and variable return to scale and technical efficiency under stochastic frontier analysis in Nigeria from 1971-2010**

Efficiency scores (%)	Frequency TE CRS	% TE CRS	Frequency TE VRS	% TE VRS	Frequency TE SFA	% TE SFA
21.0-30.0	-	-	-	-	1	2.5
31.0-40.0	1	2.5	-	-	9	22.5
41.0-50.0	2	5	-	-	2	5
51.0-60.0	4	10	2	5	1	2.5
61.0-70.0	6	15	3	7.5	8	20
71.0-80.0	10	25	8	20	12	30
81.0-90.0	5	12.5	5	12.5	4	10
91.0-99.0	6	15	7	17.5	3	7.5
100.0	6	15	15	37.5	-	-
Total	40	100	40	100	40	100
Mean		77.8		87.7		64.1
Minimum		40.4		52.5		29.3
Maximum		100.0		100.0		99.9

Table 4 shows the percentage frequency of maize production technical efficiency scores by DEA under constant return to scale and variable return to scale; and technical efficiency under stochastic frontier analysis(SFA) in Nigeria from 1971-2010. The result showed that, under SFA the country has the lowest technical efficiency scores that ranged from 21% to 30% at frequency of one, and this represents at 2.5%. The lowest technical efficiency score under DEA constant return to scale ranged

from 31% to 40% at frequency of one, and it stood at 2.5%. While the lowest technical efficiency score under DEA variable return to scale ranged from 51% to 60% at frequency of two, or 5% of the observation. It is revealed from the result that, technical efficiency level under stochastic frontier analysis ranged between 29.3% to 99.9%.The results indicated that, technical efficiency score under DEA with constant return to scale assumption ranged between 40.4% to 100%. While technical efficiency



score under DEA variable return to scale are between 52.2% to 100%. It can be deduced that the country did not register full technical efficiency level under stochastic frontier analysis during the period studied. Under DEA constant return to scale, the country registered full technical efficiency level at frequency of six (6), and it stood at 15% of the total observations. While under variable return to scale the country registered full technical efficiency level at frequency of fifteen (15), or 37.5%. The result revealed that, mean technical efficiency scores were 64.1%, 77.8% and 87.7% for technical efficiency under stochastic frontier analysis; technical efficiency DEA constant return to scale; and technical efficiency DEA variable return to scale, respectively. Even though in majority of the time the country did not recorded full technical efficiency levels, the result implied that, under technical efficiency DEA variable return to scale, the country stood more chances of being technically efficient in maize production. That is the technical efficiency scores obtained under DEA are higher than those obtained from SFA. Under DEA variable return to scale assumption farmers have more chances of moving from one level of production to another to attain suitable frontier level. This revealed the

extent at which DEA particularly under variable return to scale assumption showed the capability to capture and address variability and imperfection in issues related to efficiency measurements which could not be captured and addressed by other analytical techniques. The results further implied that, the country can expand its scope of output production by 35.5%, 22.2% and 12.3% under technical efficiency stochastic frontier analysis, data envelopment analysis constant return to scale and variable return to scale, respectively. Amaza *et al.* (2006) observed the mean of farmers' technical efficiency index was found to be 0.68, this implied 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. Omonona *et al.* (2010) observed the farmers' average technical efficiency was 87%, which implied that, output can be increased by 13% using the same inputs level at the given technology. Table 5 shows the average 5 years of maize production technical efficiency under constant and variable return to scale assumptions, and the technical efficiency under stochastic frontier analysis in Nigeria.

**Table 5: Average 5 years of maize production technical efficiency under constant and variable return to scale and technical efficiency under stochastic frontier analysis in Nigeria from 1971-2010**

Year	% TE crs	TE crs (% OIQ)	% TE vrs	TE vrs (% OIQ)	%TE SFA	TE SFA (% OIQ)
1971-1975	84.2	15.8	90.5	9.5	95.7	4.3
1976-1980	95.1	4.9	100.0	0.00	9.26	7.4
1981-1985	97.4	2.6	99.4	0.6	91.0	9
1986-1990	93.7	6.3	98.8	1.2	94.6	5.4
1991-1995	96.4	3.6	100.0	0.0	97.5	2.5
1996-2000	93.6	6.4	98.7	1.3	97.3	2.7
2001-2005	97.3	2.7	100.0	0.00	99.0	1
2006-2010	96.5	3.5	98.0	2	98.6	1.4

OIQ= output increasing quantity

Table 5 shows average 5 years of maize production technical efficiency under constant and variable return to scale

assumptions and technical efficiency under stochastic frontier analysis. It can be deduced from the Table that from 1971 to 1975 on average the country's technical efficiency scores were 84.2%, 90.5% and

95.7% for technical efficiency under DEA constant return to scale, variable return to scale and technical efficiency under stochastic frontier analysis, respectively. This implies that, under the two approaches the country can increase its output by 15.5%, 9.5% and 4.3% under DEA technical efficiency constant return to scale, variable return to scale and technical efficiency under stochastic frontier analysis, respectively using the same inputs levels at the given technology. Huynh and Mitsuyasu (2011) observed 81.6% technical efficiency; thus, there was 18.6% scope to increase output using the same inputs levels at the given technology. Shumet (2011) also observed the mean technical efficiency of farmers was 60.38% which implied that output in the study area can be increased by 39.62% at the existing level of inputs and current technology by operating at full technical efficient level.

From 1976-1980 on average the country registered full technical efficiency under DEA technical efficiency variable return to scale. That means the farmers were able to use as few inputs as possible to produce maximum output. While under technical efficiency DEA constant return to scale and technical efficiency under stochastic frontier analysis efficiency score stood at 95.1% and 92.6%. That means through appropriate use of farm resources the country still can explore more output by 4.9% and 7.4% under technical efficiency DEA constant return to scale and technical efficiency under stochastic frontier analysis, respectively, at the given technology. From 1986-1990, under DEA technical efficiency constant return to scale, variable return to scale and technical efficiency via stochastic frontier analysis, the efficiency scores were respectively 93.7%, 98.8% and 94.6%. The country stood a chance to expand its output production by 6.3%, 1.2% and 5.4% under DEA technical efficiency constant return to scale, variable return to scale and technical efficiency under stochastic frontier analysis, respectively. Shanmugam and Atheendar (2006) observed the mean efficiency of raising agricultural output was 79 per cent

and therefore there was a scope for increasing output by 21 per cent without additional resources.

From 1991-1995 the country was technically efficient in maize production under DEA estimation with variable return to scale assumption. This implied that, the farmers used as fewer inputs as possible to produce maximum output in maize production. While under constant return to scale assumption efficiency score was 96.4%. However the SFA indicated the maize production in the country experienced a 97.5% efficient. This implied that, through better use of farm resources, the country can increase its output production by 3.6% and 2.5% under the former and later approaches, respectively. Later in the period of 2001-2005 the country once again registered full technical efficiency under DEA technical efficiency variable return to scale. However the technical efficiency under constant return to scale was 97.3%. In contrast, the technical efficiency score under stochastic frontier analysis was 99%. These efficiency scores indicate that, given the amount of input used, the maize production can still be increased by 2.7% and 1% respectively, in the period of analysis. Table 5 depicts the country's maize production efficiency from 2006-2010, were 96.5%, and 98% under DEA technical efficiency constant return to scale and variable return to scale, respectively. Interestingly to observe that, the technical efficiency score under stochastic frontier analysis is almost equal to the score obtained from DEA at variable return to scale assumption that is 98.6%. Through better use of farm resources the country can still increase its scope of output production by 3.5%, 2% and 1.4% under DEA technical efficiency constant return to scale, variable return to scale and technical efficiency under stochastic frontier analysis, respectively. Luke *et al.* (2012) observed that the average technical efficiency of the sample farms was 77.26%, implying that output can be increased by 22.74% using the same inputs levels at the given technology. Sekhon *et al.* (2010) observed average technical efficiency 90%, indicating that

with the present technology there was still room for a 10 percent increase in output production.

## Conclusion

Even though the technical efficiency scores obtained from DEA in most cases were higher than those obtained from SFA, the two approaches used show strengths in evaluating maize production technical efficiency in Nigeria. That means the use of the two methods is justified in evaluating technical efficiency. This implied that, the choice between the two methods depends on the preference of a researcher which is guided by the distribution of data set. It is concluded that, under the two approaches employed; stochastic frontier analysis and data envelopment analysis farmers can still expand their scope of output production through appropriate combination and use of production inputs at the given technology. It is recommended that the two techniques can be adopted as analytical techniques for evaluating technical efficiency measurements.

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