# Analysis of Technical Efficiency Differentials among Maize Farmers in Nigeria

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# Abstract

This study analyses technical efficiency differentials and their determinants among maize farmers in Nigeria. A total sample of 300 maize farmers from Oyo and Kebbi States (150 from each) was selected, and data on input-output and socioeconomic variables were collected and analysed using descriptive statistical methods and by applying a translog frontier production function to the data.

Results show that in the two states surveyed, the sizes of farms were small, and they were mostly managed by hired labour in Oyo State, and by family labour in Kebbi State. The results also indicate that the sampled farmers are not technically efficient, with mean technical efficiencies of only 0.5588 and 0.5758 in Oyo and Kebbi states, respectively. However, there are increasing returns to scale in both states. The main determinants of technical efficiency were found to include extension services and farm distance in the two states, farming experience in Oyo State, and credit accessibility, number of other crops grown and rainfall (precipitation) in Kebbi State. Furthermore, the study found that the differences in the mean technical efficiency levels of the farmers did not emanate from the absolute differences in the individual efficiencies among the farmers in the various farming communities. Nonetheless, there were significant absolute differences in the mean efficiencies among farmers in the zones of each of the two states, and the difference in the mean technical efficiencies of the two states was found to be highly significant.

The study concludes that there is considerable room for improving the technical efficiencies in the two states. This, however, calls for the motivation of the farmers by making available more production inputs. It is suggested that these farmers are empowered with appropriate financial means to acquire these inputs and to hire more labour. In this way, farmers will be able to allocate more land to maize cultivation. When this is done, farmers' productivity will improve, resulting in maximum return of farmers' output (in quantity and value terms) per input use and, consequently, increasing their income. This will ultimately reduce hunger and alleviate poverty.

*Key words: Technical efficiency, returns to scale, Oyo and Kebbi states, Nigeria*

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# 1. Introduction

## Agricultural policy in Nigeria: A brief overview

At the time of independence in 1960, Nigeria's economy was largely dominated by the agricultural sector. It was also the main employer of labour, engaging 60% of the labour force (Akinyosoye, 2000). Agricultural exports were the greatest source of foreign exchange earnings. After independence, the Nigerian government followed an industrialization strategy aimed at replacing imports with goods produced in Nigeria, and the agricultural subsector accounted for more than half of the gross domestic product (GDP) (CBN, 2000). This industrialization was financed by export taxes levied through commodity marketing boards, which monopolized the export trade and set the official producer prices well below world market levels for major agricultural commodities such as cocoa, groundnuts, palm oil, cotton and rubber. The resulting producer price had a damaging effect on the production of export crops. In addition, the civil war that raged from 1967 to 1970 had devastating effects on the economy. Earlier, it had been discovered that agricultural activities in all parts of the economy were equally adversely affected (Lambo, 1987).

In short, the policies of the 1970–1985 period were characterized by increasing government involvement, especially at the federal level. This was made possible by the oil revenue windfall to the federal budget which resulted in a federal takeover of all state-owned agricultural research institutes in 1975. This destruction of a decentralized, cooperative joint federal state agricultural research system remains a major handicap to the national agricultural research system.

## Maize production in Nigeria

The first major effort to promote the production of maize in Nigeria was in 1974 when the federal government launched the National Accelerated Food Production Programme (NAFPP) on a pilot basis (Edache, 1999). The phenomenal growth in maize production which the nation achieved in the past decade is attributed to a number of factors, notably: A restriction on the importation of maize and, lately, wheat, rice and malted barley, which gave rise to high demand for locally produced maize as a result of its use as a substitute for some inputs in the brewery, pharmaceutical and bakery industries; good weather conditions for crop production; and, high demand for Nigerian grains in neighbouring Sahelian countries. It is not likely that the full potential for maize production in Nigeria can be realized on a sustainable basis without expanding the market. The price of maize plummeted in 1995 to below production cost due to high production and low demand (Edache, 1999). The following year, farmers shifted resources to cotton production, resulting in an oversupply in the cotton market. These were useful, but painful, experiences. Thereafter, the Federal Department of Agriculture (FDA) conducted a Rapid Rural Appraisal Survey of the grain market, following reports of a downward slide in the grain price. The study, which covered 21 markets in eight states, showed that the average price of maize in June 1999 was ₦15,172 per tonne, compared with ₦29,440 per tonne in June 1998. This is a 48% decline in price, which translates to a loss of about ₦8,700 per tonne.

The various efforts by the Nigerian government to improve food security have made it beneficial for farmers to grow such crops as maize on a scale which is larger than that for a small holding (Table 1).

**Table 1: Area and production of maize in Nigeria (1984–2006)**

| Year | Area ('000 ha) | Production ('000 tonnes) | Yield (kg/ha) |
|---|---|---|---|
| 1984 | 653 | 1025 | 1569.68 |
| 1985 | 758 | 1190 | 1569.92 |
| 1986 | 810 | 1336 | 1649.38 |
| 1987 | 3108 | 4612 | 1483.91 |
| 1988 | 3212 | 3590 | 1117.68 |
| 1989 | 3590 | 5008 | 1394.99 |
| 1990 | 5101 | 5768 | 1130.76 |
| 1991 | 5112 | 5812 | 1136.93 |
| 1992 | 5223 | 5810 | 1112.39 |
| 1993 | 5309 | 6290 | 1184.78 |
| 1994 | 5426 | 6902 | 1272.02 |
| 1995 | 5472 | 6931 | 1266.63 |
| 1996 | 4273 | 5667 | 1326.23 |
| 1997 | 4200 | 5254 | 1250.95 |
| 1998 | 3884 | 5127 | 1320.03 |
| 1999 | 3965 | 5476 | 1381.08 |
| 2000 | 3999 | 4107 | 1027.01 |
| 2001 | 4041 | 4620 | 1143.28 |
| 2002 | 4490 | 4934 | 1098.89 |
| 2003 | 4700 | 5150 | 1095.74 |
| 2004 | 4466 | 4779 | 1070.09 |
| 2005 | 3589 | 5957 | 1659.79 |
| 2006 | 3905 | 6404 | 1639.95 |

Source: FAOSTAT, 2007

Maize has continued to form an important basis for consistent income for farmers in recent times. According to the International Maize and Wheat Improvement Centre CIMMYT (1999), maize is one of the crops that will continue to dominate global food security in the present century. The CIMMYT report also states that, in the next decade, global demand for maize would rise by 47%. In Nigeria, maize production has spread from the forest zone to the savannah regions of the north, mostly through the activities of the Agricultural Development Projects (ADPs). It has also evolved from being a minor delicacy grain crop cultivated on a limited scale around the homestead to a major commercial crop (Valencia and Breth, 1999). The issues in this study are, therefore, specifically tailored towards maize as largely a monocrop for some categories of farmers that were sampled. This could provide real insight into the concept of maize production for economic and national agricultural development in Nigeria.

## Research issue

According to a report by the Raw Materials Research and Development Council (RMRDC, 2004) of Nigeria, maize is among the few staple crops grown in sub-Saharan Africa for which a fairly dependable improved technology exists. Of the three major developing regions of the world, sub-Saharan Africa is the only one in which the index of per capita food production has declined steadily and where overall food security and livelihoods are deteriorating, rather than improving (FARA, 2004). As a result, the spectre of hunger and malnutrition is perpetually looming over the countries of the continent where an estimated 35% of the population, some 140 million people of whom most are children and women, suffer from hunger and malnutrition. The report also asserts that unless the present trends are reversed, 20 years from now Africa will have the world's largest net deficit in cereals, both in absolute and in relative terms. The prospects of importing food supplies to offset these deficits are not economically feasible. The challenges facing African agriculture during the next 20 years are, therefore, immense. African agriculture must feed a population that will double in the next two decades. Meeting this challenge will require drastic increases in the productivity of the principal staples (especially maize) of the continent through, among other measures, well-articulated research and development geared towards increased maize production on a sustained and sustainable basis.

Although, the output of maize in Nigeria accounts for 45% of all the maize grown in West and Central Africa (RMRDC, 2004), most of the expansion of maize has, until recently, occurred in the dry savannah ecological zone within the states of the north-west. Questions have been raised about: (i) The reasons for the slow pace of maize expansion in other ecological zones such as the southwestern region of Nigeria, that has been known to possess suitable conditions for its production; (ii) whether the fluctuating nature of maize production can be improved upon to sustain a viable expansion programme, more so when the various non-government-funded agricultural improvement schemes have been relaxed or, in some cases, are not functioning anymore; and (iii) whether the current effort by the Nigerian government targeted towards empowering farmers to cultivate the land for national food security and for export will not be derailed by the traditionally known constraints which have so far defied appropriate solutions.

The first of these constraints is the risk-averse nature of the majority of small-scale farmers in whose hands the production of the large percentage of the food crop lie (Norman, 1973; Uwakar, 1980). The second of the major factors which constrains agricultural performance in Nigeria, according to NISER (2001), can be categorized into technical constraints, resource constraints, socioeconomic constraints and organizational constraints. The latter sets (socioeconomic and organizational constraints) of constraints form formidable obstacles to steady and consistent increases in agricultural production resulting from the technical inefficiency of farmers. In a bid to address the above problems, the Nigerian government has come up with a series of policies and programmes in various periods. However, the government at all levels has not acted consistently with these policies and programmes. There is also a lack of political will and commitment to these policies. This has resulted in the inability of maize farmers to get the maximum return from the various resources committed to their crops, especially maize production. Therefore, there is a need to carry out research that will provide an appropriate way to identify further complex factors constraining maize farmers' productivity which would ultimately generate policy statements for the improvement and sustainable expansion of the maize programme in Nigeria.

## Objectives of study

The broad objective of this study is to empirically analyse technical efficiency differentials in maize production in Nigeria. The specific objectives of the study are to:

(i) Analyse the socioeconomic and farm-specific characteristics of the farmers;
(ii) Determine and quantify the technical efficiency of maize farmers;
(iii) Analyse the determinants of technical efficiency and
(iv) Analyse the intra- and interstate differentials in the mean technical efficiency levels among the farmers.

## Significance of study

The variability in maize performance is characteristic of production systems in sub-Saharan Africa. As maize is increasingly becoming an important crop in parts of western Africa, it has been the focus of a series of government initiatives to raise productivity through the adoption of seed-fertilizer technology, input and credit subsidies, price support, and investments in marketing and infrastructure.

In spite of this, however, research geared towards increased maize production has only tended to improve soil fertility and seed quality. The literature indicates that not many studies have evaluated the technical efficiency level of maize farmers in Nigeria. One of the few studies on technical efficiency carried out in Nigeria, that of Ajibefun, Battese and Daramola (2002) typically focused on a multi-crop system. Maize is widely grown in Nigeria nowadays and many farmers are interested in producing it as a single crop. As a result, there is a need to independently measure the technical efficiency of maize producers and identify the factors that affect production, particularly in the agro-ecological zones in which the maize expansion programme is carried out. Following this, this study will identify those areas which are in need of improved productivity in order to increase the national production figures and to raise the income of farmers.

# 2. Literature review and theoretical

## framework

### Measurement of technical efficiency

The technical efficiency of an individual farm is defined in terms of the ratio of the observed output to the corresponding frontier output, conditional on the level of inputs used by the farm. Therefore, technical efficiency is defined as the amount by which the level of production for the farm is less than the frontier output (Kibaara, 2005). Technical efficiency functions can be classified into parametric and non-parametric linear programming approaches. The non-parametric approach is composed of data envelopment analysis (DEA) and the free disposal hull (FDH). The parametric approach is composed of the stochastic frontier approach (SFA), the thick frontier approach (TFA) and the distribution free approach (DFA). These methods differ mainly in the assumptions made about the functional form, whether random errors have been accounted for, and the probability distribution assumed for the inefficiency. Another important distinction is between deterministic and stochastic frontiers. Deterministic models assume that any deviation from the frontier function is due to inefficiency, so they are very sensitive to outliers (Thiam et al., 2001). However, there is no consensus among researchers about the best method for measuring efficiency.

The SFA, one of the parametric methods which this study adopts, is a linear regression model with a non-normal, asymmetric disturbance term. When measuring technical efficiency, a production function is used. A meta-analysis by Thiam et al. (2001) on 32 frontier studies using farm-level data from 15 different developing countries found that cross-sectional data exhibit significantly lower technical efficiency (TE) estimates than studies that use panel data. According to Green (1993), models relying on panel data are likely to yield more accurate efficiency estimates given that there are repeated observations for each unit. However, no a priori expectations have been developed regarding the impact of data type (i.e., cross-sectional versus panel) on the magnitude of efficiency scores. The adoption of the parametric method of the stochastic frontier for this study is based on the premise of the use of cross-sectional data.

Econometric modelling according to the stochastic frontier methodology of Aigner et al. (1977), which is associated with the estimation of efficiency, has been an important area of research in recent years. These studies are mostly based on the Cobb-Douglas function and transcendental logarithmic (translog) functions that could be specified either as production functions or cost functions. Panel data, time variant data and cross-sectional data are mostly used. The first application of the stochastic frontier model to farm-level agricultural data was done by Battese and Corra (1977), although the 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. On the other hand, Bagi and Huang (1993) 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.

The theory and specification of technical efficiency measures are also found in Aigner et al. (1977), and Meeusen and Van den Broeck (1977), who independently proposed and developed models which are thought to correct some limitations in the stochastic frontier approach of estimating efficiency. In the models it is assumed that the random disturbance has two components, that is, it is assumed that

$$e_i = v_i + m_i \tag{1}$$

The error component $\upsilon_i$ represents the symmetrical disturbance that captures, among other things, random errors and erroneous data, and is assumed to be identically and independently distributed as N~ (O, $\sigma_v^2$ ). The error component $m_i$ is the asymmetrical term that captures the technical inefficiency of the observations and is assumed to be distributed independently of $\upsilon_i$, and to satisfy that $\mu_i \leq 0$. Therefore the statistical distributions for $m_i$ must be selected for distribution only on one side.

The non-positive disturbance reflects that the output of each firm must be located on or below its frontier, $a + S^k_{j=1}\, b_i X_{ij} + v_i$. Any deviation is the result of factors within the firm's control, such as technical and allocative inefficiency, and the efforts of the entrepreneur and those of the firm's employees, among other things (Apezteguia and Garate, 1997). The estimation method proposed by Aigner et al. (1977) is the maximum likelihood estimate (MLE). Starting from the density function with the addition of a symmetrical normal variable and a half-normal variable, and supposing that the production function is linear, they elaborate the likelihood function that must be maximized. The density function of $e = v + m$ is

$$f(\varepsilon) = \frac{2}{\sigma} f^*\left(\frac{\varepsilon}{\sigma}\right) X\left[1 - F^*\left(\varepsilon\lambda\sigma^{-1}\right)\right], -\infty \leq \varepsilon \leq +\infty \tag{2}$$

where $s^2 = s_u^2 + s_u^2$, $\wedge = s_u/s_v$ and f* (.) and F*(.) are the density and distribution functions of a standard normal.

The log likelihood function, if there are N observations, can be written as:

$$\ln L(y/\beta,\lambda,\sigma^2) = N\ln\frac{\sqrt{2}}{\sqrt{2}} + N\ln\sigma^{-1} + \sum_{i=1}^{N}\ln\left[1 - F^*\left(\varepsilon_i\lambda\sigma^{-1}\right)\right] - \frac{1}{2\sigma^2}\sum_{i=1}^{N}\varepsilon_i \qquad (3)$$

Once l and s are obtained, $s_u$ and $s_v$ can be calculated. If the asymmetric error term is distributed as an exponential, the density function of S is:

$$f(\varepsilon) = \frac{1}{\phi}\left[1 - F^*\left(\frac{\varepsilon}{\sigma_\mu} + \frac{\sigma_v}{\phi}\right)\right]\exp\left[\frac{\varepsilon}{\phi} + \frac{\sigma^2}{2\phi^2}\right] \qquad (4)$$

The log likelihood function to be maximized is:

$$\ln L(y/\beta,\sigma,\phi) = N\left[\ln\frac{1}{\phi} + \frac{1}{2}\left(\frac{\sigma_v}{\phi}\right)^2\right] + \sum_{i=1}^{N}\left[\ln F^*\left(\frac{-\varepsilon_i}{\sigma v} - \frac{\sigma_v}{\phi}\right) + \frac{\varepsilon_i}{\phi}\right] \qquad (5)$$

An implication of this model is that the efficiency of each observation can be estimated by the ratio $y_i / A * \pi^k{}_{i=1} X_j^{\beta_j} * e^{v_i}$, instead of by the ratio $y_i / A * \pi^k{}_{j=1} X_j^{\beta_j}$.

The MLEs are computed using a computer program, Frontier Version 4.1 (Coelli, 1994). The Frontier program provides estimates b, a, s and the average technical efficiencies and farm-level efficiencies.

## Determinants of technical efficiency

In addition to predicting the technical efficiencies of farm-firms, a number of empirical studies have determined the sources of technical efficiency. Studies such as those by Pitt and Lee (1981) and Kalirajan (1981) have investigated the determinants of technical inefficiency variations among firms in an industry using a two-stage method. However, some studies, including those by Kumbhakar et al. (1991), Reifschneider and Stevenson (1991), Huang and Liu (1994), Battese and Coelli (1995), note that this approach is theoretically inconsistent. They specify stochastic frontier models in which the inefficiency effects are made an explicit function of the firm-specific factors. In these models, all the parameters are estimated in a single-stage maximum likelihood (ML) procedure. The present study considers the single-stage maximum likelihood procedure of the stochastic frontier specifications, which incorporate models for the technical inefficiency effects and simultaneously estimate all the parameters involved.

The technical inefficiency effects are expressed as:

$$m_i = Z_i d \qquad (6)$$

where *i,z* is a vector of observed explanatory variables for firm-farm, and d is a vector of unknown parameters. Thus, the parameters of the frontier production are simultaneously estimated with those of an inefficiency model in which the technical inefficiency effects are specific as a function of other variables, including socioeconomic conditions, demographics, farm characteristics, and environmental and non-physical factors.

## Previous research on technical efficiency in African agriculture

Using the stochastic frontier approach to conduct technical efficiency research on African agriculture has found wide acceptance in the literature because of the consistency with theory, and its versatility and relative ease of estimation. In Nigeria, Ajibefun and Daramola (1999) and Ajibefun, Battese and Daramola (2002) applied the stochastic frontier production function to investigate the sources of technical inefficiency in poultry egg production in Ondo State and to determine technical efficiency in smallholder food crop farming. They concluded that in poultry egg production, technical efficiencies of the egg producers ranged from 49% to 85%, with a mean technical efficiency of 68%. The results also indicated that the coefficients of feed, total number of layers, labour, and drugs are positive and highly significant in egg production. Ajibefun, Battese and Daramola (2002) found that, among the smallholder food crop farmers, on average, farmers have high levels of technical efficiencies which clustered around a range of 0.8 and 0.9. They also found that the inefficiency of the farmers was not significantly related to the size of farming operations for the farmers involved. Also in Nigeria, Ogundele and Okoruwa (2006) analysed the technical efficiency differentials of two (traditional and improved) rice production technologies using the stochastic production frontier. Findings from this study showed that farm size was the most significant determinant of technical efficiency. Average technical efficiency in each of the two production technologies was about 90%. The study concluded that, in spite of low yields in each case, compared with their counterparts in other African countries such as Côte d'Ivoire and Senegal, there was little opportunity for increased technical efficiency in either group.

Elsewhere in Africa, Seyoum et al. (1998) measured the technical efficiency of maize producers in eastern Ethiopia. One of the key conclusions from this study was that younger farmers were more technically efficient than older farmers. Awudu and Huffman (2000) analysed the economic efficiency of rice farmers in northern Ghana using a normalized stochastic frontier profit function and concluded that the average measure of inefficiency was 27%, which suggested that about 27% of the potential maximum profit was lost due to inefficiency. They estimated that this corresponded to a mean loss of 38,555 Ghanaian cedi per hectare and, consequently, they asserted that the discrepancy between the observed profit and frontier profit was due to both technical and allocative efficiency. A study by Mochebelele and Winter-Nelson (2002) on smallholder farmers in Lesotho used a stochastic production frontier to compare technical efficiencies of farmers who had sent migrant labour to the South African mines and those who had not. They concluded that farmers who had sent migrant labour to South Africa were closer to the production frontier than those who had not. Gautam and Jeffrey (2003) used the stochastic cost function to measure efficiency among smallholder tobacco cultivators in Malawi. Their study revealed that larger tobacco farms were less cost-efficient. The study uncovered evidence that access to credit retards the gain in cost efficiency from an increase in tobacco acreage. This suggested that the method of credit disbursement was faulty. Generally, the use of the stochastic frontier approach to compare the technical efficiencies of farmers in different agro-climatic conditions and by employing related farmers' characteristics (inputs and socioeconomic variables) in the model will enable one to know the direction of the effects of the differences in these agro-climatic conditions on the farmers to produce crops efficiently. This is the focus of this study.

# 3. Research methodology

Based on the theoretical establishment of the technical efficiency measures (see previous section), this study adopts the one-step approach of estimating individual farmers' technical efficiency indexes. The inefficiency effects are also determined represents

$$E_j = \delta_0 + \sum_{i=1}^{12} \delta Z_j \tag{10}$$

The inefficiency effects are estimated through a truncated normal distribution, which is a non-neutral frontier model (Huang and Liu, 1994). Therefore the model in Equation 10 can be explicitly written as:

$$\mu = d_0 + d_1 Z_{1j} + d_2 Z_{2j} + d_3 Z_{3j} + d_4 Z_{4j} + d_5 Z_{5j} + d_6 Z_{6j} + d_7 Z_{7j} + d_8 Z_{8j} + d_9 Z_{9j} + d_{10} Z_{10j} + d_{11} Z_{11j} + d_{12} Z_{12j} \tag{11}$$

where$\mu$ represents the technical inefficiency effects and $d_s$ are the unknown parameters to be estimated. The $Z_s$ are variables that determine technical efficiency among the farmers. The $Z_s$ include $Z_1$ (age in years); $Z_2$ (schooling in years); $Z_3$ (farm experience in years); $Z_4$ (total farm size in hectares); $Z_5$ (number of respondent's household members); $Z_6$ (credit access dummy); $Z_7$ (membership of mutual group dummy); $Z_8$ (number of extension visits to farmer); $Z_9$ (distance from the farmer's home to the farm); $Z_{10}$ (number of crop type grown by farmer); $Z_{11}$ (number of risk management dimension practised by the farmer); and $Z_{12}$ (precipitation in millimetres).

Tests of differences in the means of the technical efficiencies among the farmers within each state and between the two states were also carried out. These were achieved through an analysis of variance (ANOVA) by computing the F-statistics and carrying out a t-test.

## Measurement of variables

Two main data types were collected: Agricultural production data, which included among other things, seed use, land use, labour (family, hired and contractual), tractor hiring, various types of fertilizers, and other agrochemicals (such as insecticides, herbicides, fungicides). These were obtained either in quantity or in value terms. Data were also collected on other crops grown, farming systems, quantity of maize produced, quantity consumed and quantity marketed.

Socioeconomic data were also collected. These are data on age, gender of farming by using the maximum likelihood procedure (Huang and Liu, 1994; Battese and Coelli, 1995). The model, adopted from Nchare (2007) is of the following form:

$$\ln Y_j = \beta_0 + \sum_{i=1}^{6} \beta_i \ln X_j + \frac{1}{2} \sum_{i=1}^{6} \sum_{k=1}^{6} \beta_k \ln X_{jk} + V_j - \mu_j \tag{7}$$

where ln denotes the natural logarithm; subscripts i and j represent the inputs i used by farm-firm j, and Y represents total quantity of maize harvested in tonnes, $X_s$ represents the input variables used in the model, where $X_1$= seed used in kilogramme/hectare; $X_2$ = cultivated maize area in hectare; $X_3$ = fertilizer use in kilogrammes; $X_4$ = pesticide use in litres; $X_5$ = family labour in man-days; and $X_6$ = hired labour in man-days. The $\beta_s$ represents the input coefficient for the resources used in maize production and Ý stands for summation while $v_j$ represents the random variable with zero mean and unknown variance, $\sigma_v^2; \mu_j$ represent the non-negative random term ($\mu_j \geq 0, \forall_j$) representing the technical inefficiency in production of farm j.

The estimated model in Equation 7 could be explicitly written as:

$$\begin{aligned} \text{Ln } Y_i = {} & b_0 + \text{Ln } b_1 X_1 + \text{Ln } b_2 X_2 + \text{Ln } b_3 X_3 + \text{Ln } b_4 X_4 + \text{Ln } b_5 X_5 + \text{Ln } b_6 X_6 \\ & + \text{Ln } b_7 X_1^2 + \text{Ln } b_8 X_2^2 + \text{Ln } b_9 X_3^2 + \text{Ln } b_{10} X_4^2 + \text{Ln } b_{11} X_5^2 + \text{Ln } b_{12} X_6^2 \\ & + \text{Ln } b_{13} X_1 X_2 + \text{Ln } b_{14} X_1 X_3 + \text{Ln } b_{15} X_1 X_4 + \text{Ln } b_{16} X_1 X_5 + \text{Ln } b_{17} X_1 X_6 \\ & + \text{Ln } b_{18} X_2 X_3 + \text{Ln } b_{19} X_2 X_4 + \text{Ln } b_{20} X_2 X_5 + \text{Ln } b_{21} X_2 X_6 + \text{Ln } b_{22} X_3 X_4 \\ & + \text{Ln } b_{23} X_3 X_5 + \text{Ln } b_{24} X_3 X_6 + \text{Ln } b_{25} X_4 X_5 + \text{Ln } b_{26} X_4 X_6 + \text{Ln } b_{27} X_5 X_6 \\ & + V_i b U_i \end{aligned} \tag{8}$$

where Y, b, $X_1$, $X_2$, $X_3$, $X_4$, $X_5$, $X_6$, V, U are as defined earlier.

From the stochastic production function specified in Equation 7, the technical efficiency of farm j is

$$TE_j = \exp(-m_j) \tag{9}$$

$TE_j$ is measured on a scale of 0 to 1. A value of 1 indicates that farm j displays complete technical efficiency while a value of less than 1 indicates a level of inefficiency. $TE_j$ is, in effect, an expression of the farmer's capacity to achieve results comparable to those indicated by the production frontier. Technically efficient farms are those that operate on the production frontier and the level by which a farm lies below its production frontier is regarded as the measure of technical inefficiency. The equation can be represented as follows:

as millet and sorghum, are equally widely grown. These crops are drought-tolerant and farmers in the area devote a major portion of the available dry land to them.

**Table 2: Area ('000 hectares) and production ('000 tonnes) of maize in Oyo and Kebbi (2000–2006)**

| | | Oyo | | | Kebbi | | | Nigeria | |
|---|---|---|---|---|---|---|---|---|---|
| Year Yield | Area | Prod- | Yield | Area | | Prod- | Yield | Area | Prod- |
| | cropped | uction | | cropped | uction | | cropped | uction | |
| 2000 | 120.55 | 203.80 | 1690.59 | 22.20 | 22.60 | 3999 | 1018.02 | 4107 | 1027.01 |
| 2001 | 136.45 | 232.24 | 1702.02 | 22.20 | 37.40 | 4041 | 1684.69 | 4620 | 1143.28 |
| 2002 | 160.93 | 286.46 | 1780.03 | 22.50 | 39.10 | 4490 | 1737.78 | 4943 | 1098.89 |
| 2003 | 148.34 | 277.40 | 1870.03 | 22.50 | 22.50 | 4700 | 1000.00 | 5150 | 1095.75 |
| 2004 | 156.45 | 294.13 | 1880.03 | 27.00 | 28.10 | 4466 | 1040.74 | 4779 | 1070.09 |
| 2005 | 168.97 | 304.14 | 1799.96 | 31.50 | 36.00 | 3589 | 1142.85 | 5957 | 1659.79 |
| 2006 | 138.11 | 177.66 | 1286.37 | 32.40 | 37.08 | 3905 | 1144.44 | 6404 | 1639.95 |

Sources: (i) (OYSADEP) Oyo State Agricultural Development Programme, case summaries, 2000–2006

(ii) (KARDP) Kebbi State FADAMA Development Office (FADAMA II Project)

The main sampling method that was employed in this study was the multistage stratified random sampling procedure. This involved four stages for each state. The two states (Oyo and Kebbi) were adequately stratified based on the characteristic features of the crop growing belts of the Agricultural Development Programme (ADP) zones of each of the two states. In the second stage, two ADP zones were selected from each state, of which 20 (10 from each of the two ADP zones in each state) blocks were proportionately selected. The third stage involved obtaining the list of villages for each of the selected blocks, from which 10 villages/farm settlements were randomly selected. The fourth, and last stage, involved the following steps: House listing in the selected villages; (ii) household listing in each listed house with the address of each household to facilitate recall; and (iii) systematic selection of households from the list of households by a random start. The listing of the households was done with the assistance of the ADP extension officers covering the ADP zones. A total sample of 300 (150 from each state) farmers was used for the study. The selection of the 300 was predetermined to ensure adequate coverage and representation of units in the sampling procedure. This was based on the proper listing of the farming households from the sampling frame.

# 4. Results

## Descriptive statistical analysis of variables in stochastic frontier model

household heads, farming experience, distance from the farmer's home to the farm, marital status, household type (whether monogamous or polygamous), household size, type of production enterprise, educational level, non-farm activities, possession of assets (e.g., houses, motorcar and processing tools), membership of cooperatives and other social groups, and access to farming inputs. Rainfall figures were collected and used as a variable which could influence technical efficiency. The estimation of a water budget (a measure of water status in the environment of any locality or water areas throughout the year) per water area is described in Kowal and Kassam (1978). For the purpose of consistency, however, the water budget per respondent's plot for the survey period was estimated as a proportion of the estimate of the locality and this was used in the model. Information on extension services (measured in number of extension visits to the farmer per cropping season) was also collected. Data on risk management dimensions (measured in number of specific number of risk management strategies that the farmer practises, e.g., income spreading, debt management, and seed/feed management) were also collected. The variables are essentially independent of the inefficiency factors and those that are hypothesized to influence the farmers' technical efficiency.

## Data sources and collection methods

The study makes use of primary data sources. The primary data for the study were collected with the aid of well-structured and coded questionnaire responses obtained through interviews, focus group discussions and personal observation. The questionnaires were pre-tested which allowed some modifications to be effected. After modifying the questionnaire, it was standardized and recoded to ensure consistency of data collection from the households. The data used for this study are cross-sectional and they were collected to represent the 2006/07 cropping season (production cycle) from two states of Nigeria: Oyo and Kebbi. These states are independently located in two main agro-ecological zones of Nigeria. Oyo State cuts across the rainforest and the derived savannah belts of southwestern Nigeria. Kebbi State falls into the dry savanna ecological zone of northwest Nigeria. These two states were chosen because of two main reasons. First, in Nigeria, the area of maize cultivation is expanding across the agro-ecological zones. The most notable expansion is occurring in the north (particularly in the dry savannah of the northwest) where maize is replacing sorghum and is grown under irrigation, replacing wheat and vegetables (Ado et al., 1999). In the southwest, particularly along the derived and guinea savannah belts, maize cultivation has also lately started to expand. As a result, Oyo State (in the derived and Guinea savannah belts of the southwest) and Kebbi State (in the dry savannah of the northwest) were purposively chosen. Apart from the fact that maize-growing activities are usually prominent in these two states during the yearly cropping season, data availability was thought not to pose any problem because of the well-coordinated irrigation (FADAMA) programmes.

The second reason why these states were selected is that there is a need to compare the technical efficiencies and the differences of the maize farmers in these two states that fall in major agro-ecological zones, so that a clear comparison of the findings will be possible. This will, in turn, allow for an aggregate national policy statement. Table 2 presents the production figures and cropped areas for the two selected states in the period 2000–2006. The total production figures and area cropped in Nigeria are also shown in Table 2. Noticeably, the area of land cropped by maize in Oyo State is much more than that in Kebbi State. This is because in Kebbi State other cereals and grain crops, such

| | Oyo | Kebbi | Oyo | Kebbi | Oyo | Kebbi | Oyo | Kebbi |
|---|---|---|---|---|---|---|---|---|
| Output (tons) | .07 | .01 | 3.20 | 4.70 | .75 | 1.49 | .63 | 1.04 |
| Seed (kg) | 1.20 | 2.00 | 45.00 | 30.00 | 8.81 | 13.92 | 6.89 | 7.85 |
| Land (ha) | .10 | .25 | 2.00 | 7.00 | .587 | 1.85 | .40 | 1.43 |
| Fertilizer (kg)/ha | 50.00 | 50.00 | 200.00 | 400.00 | 45.50 | 177.00 | 57.67 | 109.65 |
| Pesticide (litre)/ha | 1.00 | 1.00 | 8.00 | 10.00 | 1.37 | 3.19 | .97 | 1.88 |
| Fam. labour (md) | 1.00 | 1.00 | 35.00 | 35.00 | 12.88 | 14.08 | 7.32 | 6.48 |
| Hrd. labor (ld) | 1.00 | 1.00 | 26.00 | 40.00 | 14.21 | 5.91 | 6.35 | 4.29 |
| Age (yrs) | 28.00 | 20.00 | 78.00 | 70.00 | 48.34 | 40.16 | 10.05 | 11.00 |
| Schooling (yrs) | .00 | .00 | 15.00 | 23.00 | 4.62 | 8.57 | 4.37 | 7.34 |
| Experience (yrs) | 1.00 | 1.00 | 52.00 | 50.00 | 24.64 | 14.40 | 14.58 | 10.53 |
| Farm size (ha) | .20 | .50 | 13.50 | 12.00 | 3.08 | 3.33 | 2.74 | 2.53 |
| Hhsize (no) | 1.00 | 1.00 | 8.00 | 10.00 | 3.71 | 4.20 | 1.61 | 2.02 |
| Credit (dummy) | .00 | .00 | 1.00 | 1.00 | .38 | .17 | .49 | .38 |
| Mutualgr (dummy) | .00 | .00 | 1.00 | 1.00 | .25 | .45 | .43 | .50 |
| Ext. visit (no) | .00 | .00 | 5.00 | 5.00 | 1.77 | 1.17 | 2.00 | 1.30 |
| Fardista (km) | 1.00 | .50 | 15.00 | 20.00 | 5.23 | 4.73 | 2.82 | 3.52 |
| Noofcrop (no) | 1.00 | 1.00 | 5.00 | 5.00 | 2.21 | 1.95 | .94 | 1.02 |
| Riskmgtd (no) | .00 | .00 | 10.00 | 21.00 | 3.40 | 8.43 | 2.05 | 5.09 |
| Rainfall (mm) | 1200.00 | 500.00 | 1300.00 | 750.00 | 1250.00 | 625.00 | 70.71 | 176.78 |

Source: Data analysis, 2007

## Analysis of stochastic frontier production function estimates

The translog production function was adopted for analysis in this study. The translog function shows some interactions among variables and it is also known to have several possible interpretations (Sankhayan, 1988). It can also approximate arbitrary twice continuously differentiable functions (Chambers, 1994). As a result, recent advances in econometric theory and in applied production economics explain its popularity.

The frontier function was estimated using the MLE procedure in Frontier 4.1. The procedure estimates the variance parameters in terms of $\sigma_s^2 = \sigma_2 + \sigma_v^2$ and $\gamma = \sigma^2 + \sigma_s^2$ (Coelli, 1994). The individual coefficients of the explanatory variables in the translog function are not directly interpretable but the important measures to be discussed are either the elasticities of the mean output with respect to the inputs which are functions of the second-order coefficients of the translog frontier, and the levels of inputs, or the elasticities of output with respect to the inputs at the data point. The output elasticities with respect to the inputs for the specified translog function in this study are evaluated at the sample mean. (The estimation procedures for elasticities based on the specified translog function are described in Appendix B). This is based on Awudu and Eberlin,

Table 3 presents the summary statistics of the variables included in the frontier model. They include the minimum and maximum values, the sample means and the standard deviations of each of the variables for the two survey states (Oyo and Kebbi).

The farms included in the survey are relatively small with mean maize farm sizes of 0.5870 hectares for Oyo, and 1.8522 hectares for Kebbi. Average total farm sizes (for all crops grown) cultivated by farmers are 3.0757 hectares and 3.3287 hectares for Oyo and Kebbi states, respectively. The smaller proportion of farm size allocated to maize in Oyo State relative to Kebbi State is due to the fact that the sampled farmers in Kebbi State own more maize farms when the total number of crop farms are considered. Mean maize outputs per hectare are 0.75 tonnes and 1.49 tonnes for the Oyo and Kebbi states' farmers, respectively. The mean maize outputs recorded are commensurate with the average size of maize farmland cultivated in each of the two states. Another reason for this wide disparity is that in Kebbi State grain crops (of which maize is important) are the major staple food crops grown. Therefore, maize is more intensively grown in Kebbi State than in Oyo State. The farms are mostly managed by hired labour in Oyo State, while in Kebbi State family-managed farm units are predominant. Mean family and hired labour for Oyo State constitute about 13 and 14 man-days, respectively, and about 14 and 6 man-days, respectively, for Kebbi State. In Oyo State, intensive use of labour is more common than in Kebbi State because specialized types of family labour abound among the rural dwellers (known simply as aaro), where a rotational labour agreement is collectively reached among extended family members. The amount of hired labour is also higher in Oyo State because weeding (which requires more labour) is an important farm operation for most of the rainy period and is done about two or three times before harvesting. In Kebbi State, weeding is done probably only once before harvesting. This explains why Oyo State farmers, in spite of cultivating smaller maize farms, recorded higher total labour use than farmers in Kebbi State. In both states, the absence of mechanized inputs such as tractors, ploughs, harrows, planters, harvesters and threshers is evident, and the few farmers who find them indispensable queue up in either the farmers' cooperative or mutual group settings to secure their use. Because farmers have to depend heavily on scarce hired labour, most of the farm activities are accomplished with the help of family (labour) members. This situation has resulted in farmers cultivating smaller (less than anticipated) parcels of land. This has also resulted in low use of seed, fertilizer and chemicals, as indicated in Table 3. In Oyo State, mean pesticide use per hectare was 1.37 litres, while in Kebbi State it was 3.19 litres. These are below the recommended rates of between four and six litres per hectare for maize. The mean fertilizer use per hectare in Oyo and Kebbi states is 45.50kg and 177.0kg, respectively, and is below the recommended rates of between 220kg and 240kg per hectare. Rainfall (precipitation) is also known to affect agriculture, particularly smallholder production in sub-Saharan Africa. For the period of the survey, average annual rainfall estimates for Oyo State was 1,250mm and 625mm for Kebbi State.

**Table 3: Summary statistics of variables in stochastic frontier model**

| Variable | Minimum | Maximum | Mean | Standard deviation |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| | (0.999) | | (5.004) * | |
| Age | 0.0110<br>(0.0643) | 0.1708 | -0.0948<br>(0.0732) | -1.2949 |
| Schooling | -0.1272<br>(0.130) | -0.9792 | -0.03875<br>(0.0821) | -0.4720 |
| Experience | 0.07976<br>(0.0426) *** | 1.8705 | -0.0399<br>(0.0703) | -0.5681 |
| Farm size (total) | 0.2277<br>(0.238) | 0.9551 | 0.0948<br>(0.269) | 0.3513 |
| Household size | -0.3985<br>(0.687) | -0.5799 | 0.1494<br>(0.241) | 0.6192 |
| Credit accessibility | -0.7836<br>(0.988) | -0.7931 | 4.0010<br>(1.104)* | 3.6214 |
| Mutual aid group | 0.0961<br>(0.995) | 0.0966 | 0.6913<br>(0.047) | 0.6599 |
| Extension services | -1.066<br>(0.612) *** | -1.7435 | 0.9126<br>(0.415) ** | 2.2011 |
| Farm distance | -0.3117<br>(0.172) *** | -1.8116 | 0.4693<br>(0.107)* | 4.3736 |
| Crops (other than maize) | 0.2912<br>(0.957) | 0.4089 | -1.4273<br>(0.433) * | -3.2967 |
| Risk management dimension | 0.0072<br>(0.739) | 0.0098 | -0.0356<br>(0.105) | -0.3404 |
| Rainfall (precipitation) | -0.0028<br>(0.0036) | -0.7835 | -0.0295<br>(0.0037)* | -8.0568 |

*; ** and *** indicate variables significant at 1%, 5% and 10%, respectively.
Figures in parentheses are standard errors.

In technical efficiency analyses, a positive coefficient of the determinant of technical efficiency indicates by how much a farmer's level of technical efficiency decreases as a result of a unit or percentage increase in the explanatory variable. On the other hand, a negative coefficient indicates an increasing level of technical efficiency as a result of a unit or percentage increase in the explanatory variable. In Oyo State, years of experience in maize farming, extension services and farm distance significantly affect the farmers' efficiency levels. The positive coefficients of the years of experience in maize farming imply that farmers with longer years of experience in maize farming are more technically inefficient than those with fewer years of experience. This could be explained in terms of the adoption of modern technology. Farmers who have been growing maize for years may tend to be conservative, while younger and new maize farmers may be more receptive to modern and newly-introduced agricultural technology. Although age was not significant, the positive coefficient implies that older farmers in Oyo State are less efficient. However, it is possible for maize farming experience and age to be correlated and to produce the results in this study. This is an important possibility (correlation between two explanatory variables), as similar results were reported by Ajibefun, Battese and Daramola (2002). The results of this study indicate that extension services (visits) play a significant role in determining the technical efficiency of maize farmers in the two states. Increased extension visits to the farmers improve efficiency in Oyo State, while

(2001) and adopted by Kibaara (2005). See also details of related estimation procedures in Ajibefun, Battese and Daramola (2002) and Ajibefun, Battese and Kada (2002). The estimates of the parameters are presented in Table A1, which also describes the diagnostic statistics.

The estimates of the partial elasticities of the two sets of variable inputs are presented in Table 4. Individually, the partial elasticity of maize output with respect to fertilizer in Oyo State and with respect to land in Kebbi State are 0.008 and 0.009, respectively, and these constitute the smallest of the six main elasticities. On the other hand, the partial elasticities of pesticide in the two states (Oyo and Kebbi) are 1.186 and 0.532, respectively, which are the highest partial elasticities. The partial elasticities of seed, pesticide, family and hired labour in Oyo State are 0.041, 1.186, 0.120 and 0.132, respectively, while in Kebbi State, the partial elasticities of seed, fertilizer, family and hired labour are 0.084, 0.017, 0.156 and 0.230, respectively. The partial elasticity values obtained indicate the relative importance of the individual factor used in maize production. In Table 4 it can be seen that in Oyo State pesticide is an important factor in maize production, followed by land, hired labour, family labour, seed and fertilizer. In Kebbi State, pesticide is also an important factor, followed by hired labour, family labour, seed, fertilizer and land. The results in this study indicate that agrochemicals, either in the form of insecticides, fungicides or herbicides (generally known as pesticides), are very important and necessary farm inputs in maize production in the study area.

The scale coefficients, e.g., 1.801 for Oyo and 1.258 for Kebbi, are both greater than one, which indicate increasing returns to scale in the respective states. This implies that proportional increases of all factors of production lead to more than proportional increases in production. This is a further confirmation that maize farmers can benefit from the economies of scale linked to increasing returns in order to boost production. Related results are found in Nchare (2007).

**Table 4: Partial elasticities and returns to scale of maize inputs**

| Sets of variables | Elasticities | |
|---|---|---|
| | Oyo | Kebbi |
| Seed | 0.041 | 0.084 |
| Land | 0.314 | 0.009 |
| Fertilizer | 0.008 | 0.017 |
| Pesticide | 1.186 | 0.532 |
| Family labour | 0.120 | 0.156 |
| Hired labour | 0.132 | 0.230 |
| Returns to scale | 1.801 | 1.258 |

The estimated coefficients of the factors that determine technical efficiency in maize production are depicted in Table 5.

**Table 5: Determinants of technical inefficiencies**

| Variables Kebbi | Oyo | | | |
|---|---|---|---|---|
| | Coefficients | t-ratio | Coefficients | t-ratio |
| Constant | -0.000002 | -0.000002 | 21.0615 | 4.2083 |

| | Oyo | Kebbi | Oyo | Kebbi |
|---|---|---|---|---|
| 10<20 | 6 | 7 | 4.0 | 4.7 |
| 20<30 | 12 | 13 | 8.0 | 8.7 |
| 30<40 | 10 | 8 | 6.7 | 5.3 |
| 40<50 | 19 | 21 | 12.7 | 14 |
| 50<60 | 24 | 14 | 16 | 9.3 |
| 60<70 | 23 | 26 | 15.3 | 17.3 |
| 70<80 | 17 | 16 | 11.3 | 10.7 |
| 80<90 | 17 | 14 | 11.3 | 9.3 |
| 90<100 | 22 | 31 | 14.7 | 20.7 |
| Total | 150 | 150 | 100.0 | 100.0 |

## Differences in technical efficiencies

The sampled maize farmers from each of the two states were grouped into five farming communities in four subzones. This was done on the basis of the geographical spread of the farmers. The mean technical efficiencies of each of the farming communities and from each of the subzones were employed as variables in an ANOVA test. This was done to compute the F-statistics and to determine the intra-state differences in the farmers' technical efficiency levels. A t-test was also carried out to determine the difference in the mean technical efficiencies of the farmers in the two states.

Results show that in each of the two states there are no significant inter-community differences in the farmers' technical efficiencies. However, differences which are significant were found to exist among the subzones of each of the two states (F=5.108075; significant p <5% for Oyo State and F=7.079246; significant p <1% for Kebbi State). The differences in the technical efficiencies among the subzones reflect the variations which exist in the use of productivity enhancing inputs which are at the disposal of the sampled farmers in the smaller farming units of each state.

The results of the t-test show a highly significant difference in the mean technical efficiencies between the two states (*t=3.552; significant p <1%*). The mean technical efficiencies, which are 0.5588 for Oyo State and 0.5758 for Kebbi State, seem to suggest a situation where more farmers in Kebbi State tend towards technical efficiency than their counterparts in Oyo State. A cursory examination of the ranges of technical efficiency also indicates that in Kebbi State approximately 21% of the farmers are almost technically efficient, while in Oyo State only about 15% are in this category. This is a confirmation of the differences in the technical efficiency levels of the farmers in the two states.

# 5. Summary

This study analysed the technical efficiency differentials among maize farmers in Nigeria, using Oyo and Kebbi States as case studies. Data were analysed using the translog stochastic frontier production function. The predicted technical efficiency levels were explained by socioeconomic factors, as well as farmers' and firms' characteristics. The absolute differences in the predicted technical efficiency levels were efficiency is reduced in Kebbi State. The unexpected sign on the extension variable in Kebbi State could be due to a variable which may be excluded from the data.

Farm distance also has a significant influence on the technical efficiency of the maize farmers in the two states. However, the negative coefficient of farm distance in Oyo State implies reduced inefficiency as maize farms tend to be further away from home. This could be explained in terms of the farmers having to own many farms on scattered plots. The availability of these plots of maize farms means more output which may result in the farmers being more technically efficient. The variables on schooling, household size, credit accessibility and rainfall in Oyo State all have expected negative signs, but these variables do not impact significantly on farmers' technical efficiency. Total farm size and the number of crops grown by the farmers have unexpected positive signs and are insignificant for Oyo State farmers. This could be due to the non-inclusion of other variable types which would have complemented the effect of these variables.

For Kebbi State farmers, the number of other crops grown and rainfall are significant, with expected negative signs. This means that an increase in the number of other crops grown by the farmers and the amount of rainfall will increase technical efficiency. Credit accessibility, extension services and farm distance (with expected positive signs) are also significant for Kebbi State farmers. The significant positive coefficient of farm distance for Kebbi State farmers implies that maize farms which are further away from farmers' homes will result in farmers being less efficient.

## Technical efficiencies

The individual technical efficiencies obtained with the estimated stochastic frontier models show that the predicted technical efficiencies differ substantially among the farmers. They range from 0.1047 to 0.9997 in Oyo State, and from 0.1000 to 0.9923 in Kebbi State, with the mean technical efficiencies estimated as 0.5588 for Oyo State and 0.5758 for Kebbi State. The frequency distribution of the technical efficiencies is presented in Table 6 to give a clearer indication of the distribution of the technical efficiencies. The frequencies of the occurrence of the predicted technical efficiencies indicate that the highest number of farmers in Oyo State have technical efficiencies of between 50% and 60%, while in Kebbi State the highest number of farmers have efficiencies of more than 90%. The results here imply that farmers are not efficient. For example, in Oyo State only about 15% and in Kebbi State only about 21% have efficiencies of 90% and above. Given the great variation in the level of technical efficiency, there appears to be more than considerable room for effecting greater improvement in the technical efficiencies of the farmers in the two states.

**Table 6: Distribution of farmer-specific technical efficiencies**

| Efficiency | Number of farms | Percentage |
|---|---|---|

annual cropping season, especially from the middle belt region of the country. During this period farm activities, especially land clearing, planting, weeding and harvesting, reach their peak and there is always the need to employ extra hands in the form of hired labour when farmers make use of the rainy season to cultivate more land.

Given the specification of the translog function, the results of the stochastic frontier production function showed that the farmers are not efficient. However, the great variation in technical efficiency suggests that there is considerable room for effecting greater improvement in the technical efficiencies in the two states. Although the farmers were not efficient, an expansion in the use of available resources would result in more than a proportionate increase in their output, as maize farmers achieved increasing returns to scale. The factors which were found significant in determining technical efficiency were: Farming experience in Oyo State, number of extension visits and farm distance in the two states, credit accessibility, number of other crops grown and rainfall in Kebbi State. The determinants of technical efficiency in Oyo State were barely significant (all at 10%), while in Kebbi State they were highly significant (at 1%). This indicates that the influence of the determinants of technical efficiency was more pronounced on Kebbi State farmers than on their counterparts in Oyo State. Results of the F-test revealed that differences in the mean technical efficiency levels did not emanate from the absolute differences of the individual technical efficiencies among the farmers in the various farming communities. There were, however, significant absolute differences in the mean technical efficiencies among farmers in the zones. This is a reflection of the actual variations which exist in the use of productivity-enhancing inputs that are at the disposal of the farmers in different agro-ecological zones.

The result of the t-test showed a highly significant difference in the absolute mean technical efficiencies between the two states. The result of the t-test is a confirmation that farmers in Kebbi State are slightly more efficient than their counterparts in Oyo State, as up to 21% of the farmers in Kebbi State tend towards technical efficiency, whereas in Oyo State only about 15% are in this category.

# 6. Conclusion and policy implications

The generally relatively low level of maize production evidenced in this study may not augur well for the current policy of the government to increase food crop production through the expansion of output, which should follow the activities of the various programmes being put in place. In Oyo State, hired labour increased maize output, while seed, fertilizer and hired labour were identified as the major inputs that increased maize output in Kebbi State. These variables have positive coefficients and determined by analysing variance (F) and t-tests. The analysis of the socioeconomic characteristics showed that the farms included in the survey were relatively small in size. This is typical of smallholder farming in sub-Saharan Africa. The small sizes of farms allocated to maize production are, however, relative to the abundant agricultural land which the smallholder farmers allocate to other arable and cash crops, depending on their agro-ecological location. The farms are mostly managed by hired labour in Oyo State, while in Kebbi State family-managed farm units are predominant. This is because Oyo State, and most states in southwestern Nigeria, experience an influx of labour during the

In lieu of the use of more agrochemicals, however, and because of their negative impact on the environment, adequate training on integrated pest management (IPM) should be given to extension agents and farmers. IPM is more environmentally friendly and can gradually replace the use of some agrochemicals which are damaging to the environment. Increased accessibility of the farmers to credit would also empower them financially to purchase hybrid seed and fertilizer and to hire more labour in order to meet the need to expand their area of crop (maize) production. There is also a need to strengthen the extension systems of the various organs of government (extension services was a significant determinant of technical efficiency), e.g., ministries and parastatals. This will enable the farmers to adequately adopt and apply appropriate farm techniques for expected increased maize output. Another variable which was a highly determined technical efficiency in Kebbi State was rainfall. This is expected, because maize is heavily dependent on rainfall, and in the northern zone of Nigeria (where Kebbi State falls), irrigation in any form is seen as a veritable policy issue. Kebbi State is currently one of the states participating in the World Bank-assisted irrigated agriculture (FADAMA) project in Nigeria. Policy should be geared towards encouraging and empowering maize farmers to be actively involved in irrigation agriculture for increased maize output.

Finally, the low level of efficiency among maize farmers in the study area does not prevent them from increasing their scope of production at present. What is called for is proper and adequate motivation of the farmers. In fact, findings from this study show that there is considerable room for achieving technical efficiency as returns to scale were increasingly being achieved in the two states. This means that making available more production inputs to the farmers would result in more than a proportionate marginal increase of the maize output. The government, policy makers and other stakeholders should seriously consider implementing policies affecting agricultural and economic development. When this is done, farmers' productivity will increase, resulting in increased income which will, in turn, reduce hunger and alleviate poverty.

# 7. Suggestions for further research

A major part of the findings of this study is that some critical determinants of technical efficiency either did not have a significant influence or expected signs. This did not allow for specific comments to be made on the differences in the technical efficiencies between the two states. For example, the number of extension visits to farmers increased technical efficiency in Oyo State but not in Kebbi State. This suggests that perhaps there are quality differences that have not been captured by the data. In Kebbi State, the credit accessibility (dummy) variable was a significant influence, but did not provide a positive contribution to farmers' efficiency. Farmers certainly need are significant (see Table A1). The focus of government and stakeholders should be on policies to make available more seed (high-yielding seed varieties) and fertilizer. There is a crucial need to encourage farmers to follow the recommended practices of fertilizer application; low levels of fertilizer and pesticide application were recorded in the two states and this could be one of the reasons for the low yield. Availability of agrochemicals (pesticides) is also a major policy issue which should attract the attention of stakeholders (pesticide was discovered to be the direct input to which maize output mostly responded in the two states). Agrochemicals are very expensive and are within limited reach of resource-poor farmers such as those in the study areas who are, in most cases, financially constrained. A credit scheme that would help provide these agrochemicals to farmers could be instituted to lessen the burden of the maize farmers (where the use of these agrochemicals is indispensable).

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some form of credit to boost their production and thereby increase their efficiency level. In terms of credit, quality differences could exist that were not captured by the data set. For example, the variable on credit could be conceptualized from three points of view: (i) The farmer can have access to physical cash or inputs, which could be measured in dummy terms; (ii) the farmer can access credit in the form of monetary loans, measured in actual or value terms; and (iii) farmers can access credit in the form of inputs that are monetized, based on contractual agreements with credit and/or government agencies. If these variables were included in the data, further research could certainly show the importance of credit in improving farmers' levels of efficiency. A variable which represents a proxy for credit in kind, e.g., supplying seed, agrochemicals, fertilizer, tractors and working animals on farmers' plots on credit basis, can increase production and raise farmers' efficiency levels. Another avenue for further research is to pool the data and re-estimate the models for the two states and carry out appropriate statistical analyses to highlight the sequence of the importance of the variables. This could be achieved if the scope of this study is increased.

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# Appendix A: Maximum likelihood estimates of translog of frontier model for Oyo and Kebbi states' maize farmers

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| | | | | |
|---|---|---|---|---|
| Ln (seed) X Ln (pest) | 1.652* | 4.382 | 1.692* | 17.735 |
| Ln (seed) X Ln (falab) | 0.777* | 2.680 | 0.730* | 16.743 |
| Ln (seed) X Ln (hrlab) | -0.539* | -2.093 | -0.492* | -7.078 |
| Ln (land) X Ln (fert) | 0.293* | 2.539 | 0.272* | 8.667 |
| Ln (land) X Ln (pest) | -2.336* | -5.083 | -2.635* | -15.905 |
| Ln (land) X Ln (falab) | -0.100 | -0.3305 | -0.360* | -3.687 |
| Ln (land) X Ln (hrlab) | 0.0948 | 0.453 | -0.102** | -2.173 |
| Ln (fert) X Ln (pest) | 0.085 | 0.313 | 0.141** | 2.316 |
| Ln (fert) X Ln (falab) | -0.028 | -0.341 | -0.0179 | -1.244 |
| Ln (fert) X Ln (hrlab) | 0.150*** | 1.652 | 0.119** | 10.074 |
| Ln (pest) X Ln (falab) | -0.170 | -0.354 | 0.119 | -1.208 |
| Ln (pest) X Ln (hrlab) | -0.233 | -1.167 | -0.191* | -2.686 |
| Ln (falab) X Ln (hrlab) | 0.0870 | 0.510 | 0.116* | 3.705 |
| Sigma-squared ($\sigma^2$s) | 5.209* | 7.190 | 9.624* | 10.403 |
| gamma ($\gamma$) | 0-999 | | 0.999 | |
| Ln (likelihood) | -127.393 | | 128.191 | |

*; ** and *** indicate variables significant at 1%, 5% and 10%, respectively

# Appendix B: Estimation procedure for output elasticities

Taking seed ($X_1$), for example, from the estimated translog function, the following can be deduced:

$$Ln\ Y_i = b_0 + Ln\ b_1 X_1 + Ln\ b_2 X_2 + Ln\ b_3 X_3 + Ln\ b_4 X_4 + Ln\ b_5 X_5 + Ln\ b_6 X_6$$

Sigma-squared ()

Table A1 shows the maximum likelihood parameter estimates of the production frontier, Equation 7, for the two categories of farms in the study area. The estimates (5.209 and 9.624) for Oyo and Kebbi States' farmers, respectively, are very large and significantly different from zero, each at (0.01). This indicates a good fit and the correctness of the specified distributional assumption of the composite error term. Further, the estimates of the variance ratio, defined as $\gamma = (\delta_u^2 / \delta_u^2 + \delta_v^2)$, are as high as 99.9% for each of Oyo and Kebbi States, respectively. This suggests that the systematic influences which are unexplained by the production function are the dominant sources of random errors. In other words, the presence of technical inefficiency among the sampled farms explains more than 99% (close to 100%) of variations in the output level of maize farms in Oyo and Kebbi States. This confirms that in the specified models a one-sided error component is present, which implies that the effect of technical inefficiency is significant and that a classical regression model of the production function based on an ordinary least square estimation would be an inadequate representation of the data. Therefore, the results of the diagnostic statistics confirm the relevance of the stochastic parametric production frontier and maximum likelihood estimation.

**Table A1: Maximum likelihood estimates of translog of frontier model for Oyo and Kebbi states' maize farmers**

| | Oyo | | Kebbi | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **t-ratio** | **Coefficient** | **t-ratio** |
| Constant | 6.570* | 8.124 | 6.689* | 22.751 |
| Ln (seed) | 0.317 | 0.670 | 0.559* | 4.058 |
| Ln (land) | -0.592 | -1.331 | -0.0138 | -0.073 |
| Ln (fert) | 0.108 | 0.534 | 0.137* | 3.229 |
| Ln (pest) | -1.311** | -2.143 | -1.555* | -7.511 |
| Ln (falab) | -1.081*** | -1.637 | -1.042* | -14.857 |
| Ln (hrlab) | 1.239* | 3.435 | 1.032* | 8.892 |
| $[\text{Ln (seed)}]^2$ | 0.043 | 0.283 | -0.110** | -2.316 |
| $[\text{Ln (land)}]^2$ | -0.770* | -7.490 | -0.703* | -17.094 |
| $[\text{Ln (fert)}]^2$ | -0.0037 | -0.0528 | -0.0298** | -2.236 |
| $[\text{Ln (pest)}]^2$ | -0.0805 | -0.353 | -0.0945** | -2.171 |
| $[\text{Ln (falab)}]^2$ | 0.012 | 0.0744 | -0.0366*** | -1.947 |
| $[\text{Ln (hrlab)}]^2$ | -0.510* | -3.0305 | -0.458* | -13.989 |
| Ln (seed) X Ln (land) | 0.326*** | 1.638 | 0.357* | 9.5111 |
| Ln (seed) X Ln (fert) | -0.208*** | -1.744 | -0.152* | -6.728 |

$+ Ln\, b_7 X_1^2 + Ln\, b_8 X_2^2 + Ln\, b_9 X_3^2 + Ln\, b_{10} X_4^2 + Ln\, b_{11} X_5^2 + Ln\, b_{12} X_6^2$
$+ Ln\, b_{13} X_1 X_2 + Ln\, b_{14} X_1 X_3 + Ln\, b_{15} X_1 X_4 + Ln\, b_{16} X_1 X_5 + Ln\, b_{17} X_1 X_6$
$+ Ln\, b_{18} X_2 X_3 + Ln\, b_{19} X_2 X_4 + Ln\, b_{20} X_2 X_5 + Ln\, b_{21} X_2 X_6 + Ln\, b_{22} X_3 X_4$
$+ Ln\, b_{23} X_3 X_5 + Ln\, b_{24} X_3 X_6 + Ln\, b_{25} X_4 X_5 + Ln\, b_{26} X_4 X_6 + Ln\, b_{27} X_5 X_6$

$1/yield * \partial yield / \partial X_{1=}\ b_{1/} X_1 + 2b_{7/} X_1 + b_{13/} X_1 + b_{14/} X_1 + b_{15/} X_1 + b_{16/} X_1 + b_{17/} X_1$

The slope is calculated as follows:
$\partial yield / \partial X_{1=}\ (b1 + 2b_7 + b_{13} + b_{14} + b_{15} + b_{16} + b_{17}) * yield / X_1$

The equation below shows the calculation of elasticities evaluated at the mean: $e_{seed} = (b1 + 2b_7 + b_{13} + b_{14} + b_{15} + b_{16} + b_{17}) * yield/X_{1*} X_1/*yield),$

The output elasticities with respect to land, fertilizer, pesticide, family and hired labour are estimated using the procedure above.

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