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Technical Efficiency of Ginger Production in Kaduna State, Nigeria: 
The Stochastic Frontier Approach

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Abstract
The main purpose of this study was to analyze the technical efficiency of Ginger producers in Kaduna State Nigeria to provide information for effective application and management of farm inputs and policy recommendation by using a stochastic production frontier function. Data for the study were obtained from 180 farms using a multi-stage sampling procedure through the administration of structured questionnaire. About 79.44% of surveyed farmers had technical efficiency scores of 0.82. The technical efficiency computed shows a mean efficiency of 62.09 percent. This implies that considerable inefficiency exists among the ginger farmers under study. The results further indicated that a significant potential for the farmers to sustainably increase output using the available inputs and existing technology exists. The sum of elasticities of the factors included in the production function was 1.045, which was more than one, implying that the farmers were operating in the increasing returns to scale; therefore, they are inefficient in the use of their resources. The study recommends that the respondents’ technical efficiency should be increased so as to improve Ginger production in the study area.

Keywords: elasticity, ginger, resource use, technical efficiency, returns to scale,

Introduction
Agriculture has suffered from years of mismanagement, inconsistent, poorly conceived government policies, and the lack of basic infrastructure. Still, the sector accounts for about 33% of Gross Domestic Product, GDP, and two-thirds of employment. Agriculture provides a significant fraction about 10% of non-oil growth (Nigeria Economy, 2010). Agriculture in the context of the economy is tied with the various sectors and is essential for generating broad-based growth necessary for development. Agriculture is fundamental to the sustenance of life and is the bedrock of economic development, especially in the provision of adequate and nutritious food very vital for human development and industrial raw materials for industry.

Nigeria produces a wide range of agricultural commodities, which could serve as raw materials for industrial production, among them are spices, which are high value and export oriented commodity crops, like ginger, which play an important role in the agricultural economy of the country. Ginger (Zingiber officinale) is majorly produced in the Savannah belt with Kaduna State as the largest producer. FAO (2009) recorded that Nigeria’s production in 2008, 2007 and 2006 was estimated to be 140,000, 138,000 and 134,000 metric tonnes respectively. Out of this production, an average of 10 per cent is locally consumed as fresh ginger, while 90 per cent is dried and 20 percent of this is consumed locally for various uses while the remaining is exported (Ojeme, 2007).

Nigeria is the 6th largest producer of ginger and 3rd largest exporter in the world. According to the World Trade Promotion Export/Import Limited, Nigerian ginger is highly valued in international markets for its aroma, pungency and high oil and oleoresin content (Ojeme, 2007), which have food and medicinal value. Generally, it is one of the most important export spices in the market, where it is found fresh, dehydrated, preserved powdered and other forms (Owu and Okafor, 2002). However, with the current drive for the diversification of the country’s export base, ginger is presently the most important root crop for export in Nigeria (Aliyu and Lagoke, 2001).

Agricultural production requires resources that are limited in supply. The availability of these resources and various combinations determine the quantity of output produced. The cost-revenue relationship of the entire production process is influenced by how technically efficient the resources are utilized (Udoh and Akpan, 2007). Technical efficiency in production is the physical ratio of output to the factor input used.

The crucial issue in the Nigerian agriculture is that of low productivity. The problem of declining crop productivity in Nigeria is important. Farmers output must therefore be expanded with existing levels of conventional inputs and technology. More than ever, farmers will have to produce
more efficiently. That is, produce maximal output from a given mix of inputs or use the minimum levels of inputs for a given level of output (Bamidele, 2008). However, ginger farms just like the other crop farms in Nigeria are the small-scale types which are characterized by very low productivity. Nwaizu, (2010) observed that the performances of smallholders’ farmers in Nigeria are unsatisfactory and in developing agricultural economies, efficiency is a salient determinant of productivity growth as well as stabilizing production.

Heady (1982), states that optimum productivity of resources implies an efficient utilization of resources in the production process. That is, attainment of a production goal without waste. Use of farm resources is an important part of agricultural sustainability. One way peasant farmers can achieve sustainability in agricultural production is to raise the productivity of their farms by improving efficiency within the limit of existing resource base and technology. Efficient use of resources is a prerequisite for optimum farm production since inefficiency in resource use, can distort food availability and security (Udoh and Akintola, 2001; Etim, 2003). The agricultural problem in Nigeria therefore centers on the efficiency with which farmers use resources on their farms. It also borders on how the various factors that explain farm efficiency could be examined so as to improve the crop production in the country. This quest therefore raises research questions as to how technical efficient are the ginger farms in Kaduna State? What are those factors that significantly influence ginger farm-level productivity in the study area? To what extent do these factors improve crop production? Based on the economic importance of agricultural sector with specific emphasis to ginger contribution, therefore, there is need to measure the technical efficiency of resource use and determined factors contributing to inefficient use of resources among ginger farmers in the study area.

Efficiency measurement is very important in that, it is a first step in the process that might lead to substantial resource savings. These resource savings have important implications for both policy formulation and farm management. Also, during financial stress, efficiency gains are particularly important because efficiency farms are more likely to generate higher incomes and thus stand a better chance of surviving and prospering. Equally, in any economy where technologies are lacking, efficiency studies show the possibility of raising productivity without increasing the resource base or developing new technology (Ajewole and Folayan, 2008).

Conceputal framework of Stochastic Frontier

According to Battese and Coelli (1992), Stochastic frontier production function has been a significant contribution to the econometric modeling of production and the estimation of technical efficiency of firms. Stochastic frontier is an econometric analytical technique, which allows for variation in output of individual producer from the frontier of maximum achievable level to be accounted for by factors which cannot be controlled by the firm. This model, they say, involves two random components, one associate with the presence of technical inefficiency and the other being a traditional random error. They defined technical efficiency as the ratio of its mean production (conditional on its level of factors input and firm effects) to the corresponding mean production if the firm utilized its level of inputs most efficiently. Technical efficiency has also been defined by Heady (1982) as the measure of a firm’s success in producing maximum output from a given set of inputs. Battese and Coelli (1988) expressed stochastic production frontier implicitly as:

\[ Y = X_n \beta + E_n \]

Where:

\[ E_n = V_n - U_n \]

\[ X_n = \text{exogenous variables associated in the firm production} \]

\[ Y_n = \text{appropriate function of the production for the n-th sample firm in the n-th time period} \]

\[ \beta = \text{vector of the coefficients for the associated independent variables in the production function} \]

\[ U_n = \text{one sided component, which captures deviation from frontier as a result of inefficiency of the firm} \]

\[ V_n = \text{effect of random stocks outside the farmer’s control, observation and measurement error and other stochastic (noise) error term. Thus, V_n allows the frontier to vary across enterprises or over time for the same enterprise and therefore the frontier is stochastic.} \]

The technical inefficiency effect, \( U_n \) in the stochastic frontier model (2) is specified by Battese and Coelli (1995) as:

\[ U_n = Z_n \delta + W_n \]

\(-3\)
Where the random variable, $W_n$, is defined by the truncation of the normal distribution with zero mean and variance, $\sigma^2$, such that the point of truncation is $-Z_\alpha \delta$, i.e., $W_n \geq Z_\alpha \delta$. These assumptions are consistent with $U_n$ being a non-negative truncation of the $N(0, \delta, \sigma^2)$ distribution. The $W_n$ - random variables are not identically distributed nor are they required to be non-negative. Further, the mean, $Z_\alpha \delta$, of the normal distribution, which is truncated at zero to obtain the distribution of $U_n$, is not required to be positive for each observation.

The stochastic production frontier as an econometric method of efficiency measurement in production systems is built round the premise that a production system is bounded by a set of smooth and continuously differentiable concave production possibilities (Sharma, 1999). It has the advantage of allowing simultaneous estimation of individual technical efficiency of the respondent farmers as well as determinants of technical efficiency (Battese and Coelli, 1995). Following Zaihet and Dharmapala (1999), the stochastic production function is of the form:

$$Q_i = (X_{ik} \beta \epsilon_i^k, i = 1, \ldots, n; k = 1, \ldots, k)$$

Where:
- $Q_i$ is the output of the $i^{th}$ enterprise,
- $X_{ik}$ is a vector of $k$ inputs used by the $i^{th}$ enterprise,
- $\beta$ is a vector of parameter to be estimated; and
- $\epsilon_i$ is the enterprise specific composition residual term comprising of a random error term $v_i$ and an inefficiency component $u_i$.

$$\epsilon_i = v_i + u_i, \quad i = 1, \ldots, n$$

the two components $v$ and $u$ are assumed to be independent of each other, where $v$ is the two-sided, normally distributed random error $v_i \sim N(0, \sigma^2_v)$, and $u$ is one-sided efficiency component with a half-normal distribution $u_i \sim N(0, \sigma^2_u)$ (Dawson, 1990; Sharma, 1999). According to Battese and Corra (1977) gamma, $\gamma$, is the total output attained at the frontier which is attributed to technical efficiency. $\gamma = \sigma_u^2 / \sigma^2$, so that $0 \leq \gamma \leq 1$. Similarly, $1 - \gamma$ measures technical inefficiency of the farmers. The individual farmer’s level of technical efficiency ($TE_i$) is then calculated as

$$TE_i = \exp(-E[\epsilon_i / E]) \quad i = 1, \ldots, n$$

Such that $0 \leq TE \leq 1$

Materials and Methods

The study is conducted in Kaduna State. The state is situated between latitude 09°30’N and longitude 08°30’E in Northern Guinea Savannah. The study location has two distinctive seasons, a dry season (November – April) and a rainy season (May – October). The soil is rich and suitable for the cultivation of a wide range of crops such as ginger, cassava, potatoes, sorghum, cowpea, soya bean, cocoyam and maize. Kaduna state is the main producing zone of ginger with over 95% of the country’s total production (Okafon, 2002).

A multi stage random sampling technique was adopted. Three Local Government Areas, namely: Kachia, Jaba and Zango Kataf were purposively selected due to their high level of involvement in ginger production. 60 ginger farmers were randomly selected from 3 villages in each Local Government Area, giving a total of 180 ginger farmers which were used for the study. Data were collected from December, 2010 to January, 2011 through the administration of structured questionnaire and interview. The data focused on socio-economic characteristics of farmers, inputs used and output of ginger. The data was analyzed using Cobb-Douglas stochastic frontier production function which is specified as follow:

$$\ln Qty = \beta_0 + \beta_1 \ln (FS) + \beta_2 \ln (Fert) + \beta_3 \ln (lab) + \beta_4 \ln (PM) + \gamma i - U_i$$

Where:
- $Qty$ = Total output of ginger harvested (Kilogram, Kg)
- $FS$ = Farm size (hectare)
- $Fert$ = Quantity of fertilizer used (Kilogram, kg)
- $Lab$ = Labour (Man days)
- $PM$ = Quantity of planting materials used (Kg)
- $V$ and $U$ are as defined in equation (2)

The inefficiency model based on Battese and Coelli (1995) specification was:

$$U_i = \xi_0 + \xi_1 \ln (Edu) + \xi_2 \ln (Exp) + \xi_3 \ln (Age) + \xi_4 \ln (HHS) + \xi_5 \ln (Ext) + W_i$$

Where:
Edu = Educational level of farmer (Years of schooling)
Exp = farmers experience (Years)
Age = Age of farmer (Years)
HHS = Household size (Number of household members)
Ext = Extension agents contact (Dummy; 1 = yes, 0 = no)
Ln = Natural logarithm
β, and δ, = parameters to be estimated

Wj is as defined earlier

Equation (7) and (8) are estimated by Maximum Likelihood Estimation (MLE) with the use of "Frontier Version 4.1" developed by Coelli (1996).

Returns to Scale
In order to determine the returns to scale, the sum of output elasticities with respect to each resource was computed. According to Olayide and Headly (1982), when

SEPi = 1, we have constant returns to scale
SEPi < 1, we have decreasing returns to scale
SEPi > 1, we have increasing returns to scale

Results and Discussion
The result in table 1 indicates that fertilizer, farm size, labour and planting materials contributed significantly to the technical efficiency of the farmers. Farm size and labour were significant at 1% level of significance while fertilizer and planting materials were significant at 5% and 10% significant levels respectively. All the variables had positive signs which are the expected signs. This implies that, the explanatory variables have positive relationship with the output. Therefore, a one unit increase in any of these variables will lead to a corresponding increase in output by the coefficient of the variable.

The result of the inefficiency effects model showed that none of the included variables had significant effects on the technical efficiency of the farmers. This conforms to the result obtained by Ogundele and Okorowa (2006). Therefore, the technical inefficiency of the farmers might have been accounted for by other natural and environmental factors that were not captured in the model, which could include land quality, weather, labour quality, pest and disease infestation. Three of the variables: education, household size and extension contact were correctly signed. Age and farming experience had positive signs. This could be that the older and more experienced farmers are more conservative and are not willing to adopt new technologies.

The frequency distribution of technical efficiency presented in table 2, shows that about 79.44% of the respondents had technical efficiency of ≤0.60 while 12.78% operates at technical efficiency of between 0.61 and 0.80, whereas, only 7.78% exceed technical efficiency of 0.80. This shows that the farmers’ technical efficiency is very low, hence, there is need to increase their resource use in ginger production.

The value of gamma (γ) statistics was 0.71 indicates that 71% of the changes in ginger output were attributable to the inefficient factors. It also confirms the presence of the one-sided error component in the model; this renders the use of the Ordinary Least Square (OLS) estimation techniques inadequate in representing the data. The sigma square on the other hand was 0.58 and significant at 1% level of significant, indicating the correctness of the specified assumption of the distribution of the composite error term. The mean technical efficiency of 0.620 implies that the farmers can still increase their productive efficiency by proper utilization of resources. The mean technical efficiency of 62% signifies that there exists 38% potential for farmers to increase their production vis-a-vis their income at the existing level of technology. The foregoing also means that by being efficient, farmers in the study area can increase their production by 38% at the current level of technology and resources.

The sum of elasticities, Ep, presented in table 1 is 1.045 which implies increasing returns to scale such that when all inputs specified in the model for the production of ginger are increased by 10 percent, output will in turn increase by 10.45 units. The non-negative and greater than one value of the sum of elasticities imply that producers are operating in stage one of the production process, which is usually considered as the irrational stage of production. Hence, they are inefficient in the utilization of their resources for ginger production.

Conclusion and Recommendation
The estimation of the Cobb-Douglas stochastic production function demonstrated that all the independent variables (fertilizer, farm size, labour and planting materials) had statistically significant positive impact on ginger output, implying that they are important in increasing ginger production in the study area. Hence, productivity level can be increased by raising their technical efficiency level and this can be achieved through increased input usage. The technical inefficiency variables included in the model were all insignificant. Though, education, household size and extension agents were correctly signed, implying that, other factors are responsible for the inefficiency in the production of
ginger in the area of study. The technical efficiency index computed shows that the sampled ginger farmers are technically inefficient with a mean efficiency of 62.09 percent. This implies that there is a significant potential for the farmers to sustainably increase output using the available inputs and existing technology. Thus, there will be no need to develop new technologies to raise productivity but that technical efficiency can be increased by increasing the usage of inputs already available.

Therefore, efforts should be geared towards the increasing the relevant variables that determine technical efficiency in ginger farming. The returns to scale, RTS, of 1.045 shows that the farmers are operating in stage one of production process, which is the irrational stage; therefore, they are inefficient in the use of their productive resources. Based on the findings of this study, the respondents’ technical efficiency should be increased so as to improve Ginger production in the study area.

Table 1: Maximum likelihood estimate (MLE) of frontier for ginger production

<table>
<thead>
<tr>
<th>Variables</th>
<th>Parameter</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$\beta_0$</td>
<td>0.1491</td>
<td>0.1926</td>
<td>0.774</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>$\beta_1$</td>
<td>0.2517</td>
<td>0.1214</td>
<td>2.073**</td>
</tr>
<tr>
<td>Farm Size</td>
<td>$\beta_2$</td>
<td>0.3534</td>
<td>0.0990</td>
<td>3.569***</td>
</tr>
<tr>
<td>Labour</td>
<td>$\beta_3$</td>
<td>0.2453</td>
<td>0.0490</td>
<td>5.006***</td>
</tr>
<tr>
<td>Planting material</td>
<td>$\beta_4$</td>
<td>0.1946</td>
<td>0.1176</td>
<td>1.655*</td>
</tr>
<tr>
<td>Age</td>
<td>$\delta_1$</td>
<td>0.2145</td>
<td>0.5947</td>
<td>0.361</td>
</tr>
<tr>
<td>Education</td>
<td>$\delta_2$</td>
<td>-0.1376</td>
<td>0.1899</td>
<td>-0.724</td>
</tr>
<tr>
<td>Farming experience</td>
<td>$\delta_3$</td>
<td>0.3471</td>
<td>0.8349</td>
<td>0.416</td>
</tr>
<tr>
<td>Household size</td>
<td>$\delta_4$</td>
<td>-0.1044</td>
<td>0.1880</td>
<td>-0.555</td>
</tr>
<tr>
<td>Extension contact</td>
<td>$\beta_5$</td>
<td>-0.2210</td>
<td>0.3799</td>
<td>-0.582</td>
</tr>
<tr>
<td>Sigma-square</td>
<td>$\sigma^2$</td>
<td>0.5828</td>
<td>0.1000</td>
<td>5.828***</td>
</tr>
<tr>
<td>Gamma</td>
<td>$\gamma$</td>
<td>0.7108</td>
<td>0.1096</td>
<td>6.485***</td>
</tr>
<tr>
<td>Log likelihood function</td>
<td></td>
<td>-0.4584</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean technical efficiency</td>
<td></td>
<td>0.6209</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: computed from computer printout. *Sig. at 10% level, ** sig. at 5% level, *** sig. at 1% level.

Table 2: Distribution of technical efficiency of ginger production in Kaduna State

<table>
<thead>
<tr>
<th>Class</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.2</td>
<td>69</td>
<td>38.33</td>
</tr>
<tr>
<td>0.21 – 0.40</td>
<td>31</td>
<td>17.22</td>
</tr>
<tr>
<td>0.41 – 0.60</td>
<td>43</td>
<td>23.89</td>
</tr>
<tr>
<td>0.61 – 0.80</td>
<td>23</td>
<td>12.78</td>
</tr>
<tr>
<td>0.81 – 1.0</td>
<td>14</td>
<td>7.78</td>
</tr>
</tbody>
</table>

*Source: computed from computer printout
References


