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RESEARCH ARTICLE

# RELATIONSHIP BETWEEN PLOT SIZE AND TECHNICAL EFFICIENCY OF CASSAVA FARMS IN OYO STATE OF NIGERIA: A STOCHASTIC FRONTIER ANALYSIS

*Oladeebo, J. O. and Oyetunde, O. T.

Department of Agricultural Economics, Ladoke Akintola University of Technology, P.M.B 4000, Ogbomoso, Nigeria

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**ABSTRACT**

The general objective of the study was to examine the relationship between plot size and technical efficiency in cassava production in Oyo State of Nigeria. Specifically, the study estimated technical efficiency of cassava farmers; determined the most productive resource in cassava production as well as determined the nature of return to cassava production. Data obtained from 120 representative cassava farmers were analyzed by the use of Stochastic Frontier Production Function technique. Results obtained showed that labour was the most significant productive resource in cassava production. Results further showed that plot size had negative relationship with technical efficiency. Level of education and amount of credit obtained were the significant factors of cassava farmers' technical efficiencies. The value of 0.8024 obtained for returns to scale showed that cassava farmers were operating in the rational zone of production surface. The study suggested that cassava farmers should reduce their cassava plot size to a manageable size; more credit should be made available to cassava farmers while most of the educated farmers should pay more attention to the operations on their farms in order to reduce their level of technical inefficiency.



## INTRODUCTION

Nigeria has continued to be the largest producer of cassava since the beginning of the 1990s with an estimated contribution of 40 million metric tons per annum with an average yield of 10.2 tons per hectare. In recent years, the demand for Nigeria cassava has increased appreciably due to increased awareness on cassava utilization. According to Akinsanmi (1980), balanced diet is necessary for the building up of a healthy reservoir of which human resources are needed for increased productivity in both agricultural and industrial sector of the economy. Food is very important item in any country, no matter how industrial or progressive it may be. The production of food crops in Nigeria has been growing at a slower rate than the rate of domestic population and domestic demand has to be balanced by importing foods to provide the need of the populace (Adun, 1991). The current food and nutrition crisis in Africa is as a result of inability of most countries in this region to produce, purchase or stock enough food to satisfy the rising demand especially in the urban center when the food supplies cannot meet the demand which then results in nutritional deficiency (Adeyinka, 1990). Cassava is one of the most important crops in Nigeria. It is widely cultivated in the southern part of Nigeria compared with all other crops, in terms of area devoted to it and the number of farmers growing it. In all places, cassava has become very popular as a food and cash crops and it is fast replacing yam and other traditional staples of the area (FACU, 1993). As a food crop, cassava fits well into the farming systems of the smallholder farmers in Nigeria, because it is available all year round, thus providing household food security. Cassava is important not just as a food crop, but even more as a major source of cash income for the largest number of households, in comparison with other staples, contributing positively to poverty alleviation (FACU, 1993). Cassava food products are the most important staples of rural and urban households in Southern Nigeria. Current estimate shows that the dietary calorie equivalent of per capita consumption of cassava in the country amounts to about 235 kcal. This is derived from the consumption of *garri* (roasted granules), chips/flour, fermented paste and/or fresh roots, the principal cassava food forms (Cock, 1985). Cassava flour has been tested as a substitute for wheat flour in bread making in order to reduce the cost of wheat flour; the most suitable varieties can only replace 20% of the wheat flour (Carter, 1995). Cassava farming and processing provides employment opportunities for many farmers. Both rich and poor farmers sell a higher proportion of cassava than other cropsand derive more cash income from cassava (Berry, 1993). Technical efficiency implies the ability of a firm to obtain maximum output from the given inputs. It is the ratio of output to input and the greater the ratio, the more the magnitude of technical efficiency (Oluwatusin, 2011).

***Corresponding author: Oladeebo, J. O.** *Department of Agricultural Economics, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.*

### The Problem

In Nigeria, more than 70% of the rural population depended wholly on smallholder agriculture for food and income. Labour force which comes from the household consists of men, women, and children; and as a result of this rural agriculture remained the major power for rural growth and livelihood improvement. The rural population provides about 90.0% of the food produced in Nigeria while the remaining 10% is assumed to be obtained through importation which means Nigeria is yet to be self-sufficient in food production. In Nigeria, the problems with smallholder agriculture dwell on the use of traditional technology which is associated with low productivity, the extension services which are not properly funded, and lack of farmers' access to agricultural inputs due to lack of credit facilities. There is dearth of studies on the use of farm plot size, agrochemicals, machinery, labour, cassava stem cuttings (which are the inputs involved in cassava production) as well as technical efficiency of cassava farms in Oyo State of Nigeria. Hence, the study was undertaken to address the following research questions.

1.How efficient are resources being used in cassava production?
2.What factors affect cassava productivity in the study area?
3.Which of the factors are mostly productive in cassava production?
4.Are cassava farmers producing efficient region of production surface?

**Objective of the Study**

The general objective of the study was to investigate the effects of plot size (farm land) on technical efficiency of cassava farmers in Oyo State of Nigeria. The specific objectives of the study were:
1.To estimate resource use efficiency (technical efficiency) in cassava production
2.To examine factor determining technical efficiency.
3.To determine the most productive resources in cassava production.
4.To determine the nature of return to scale in cassava.

**Hypothesis of the Study**

There is absence of inefficiency effects in cassava production in the study area.

**CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW**

**Concepts of Land**

The term *land* is often used in the physical or geographical sense to refer to a variety of natural resources found in a profile from the atmosphere to some meters beneath the soil surface, (Fabiyi, 1990). Land is the most fundamental productive resources in the rural economy. The use of land varies not only according to ecological or physical factors which may limit what can be grown. Land exists as the single most important natural resources which affect every aspect of peoples' live. (Fabiyi, 1990). Nigeria has a land of some 98 million hectares of which nearly three quarters is cultivable (Olayide, 1980).

**Farm Size and Efficiency Studies**

Berry and Cline (1970) found that the value added per unit of invested capital for the second smallest farm size group (10 to 50 ha) in the Muda river region of Malaysia exceeded of the largest farm group (200 to 500 ha) by 65 percent. Bagi (1982) estimated stochastic frontier production functions for both small and large farms in West Tennessee farms. He found that both small and large crop farms had almost equal technical efficiency, but large mixed farms were technically more efficient than small mixed farms. A World Bank (1983) study of the efficiency of small versus large farms in Kenya, using 1973/1974 data, found that output per hectare was 19 times higher andemployment per hectare was 30 times higher on holdings under 0.5 hectares than on holdings over 8 hectares. Coelli and Battese (1996) estimated stochastic frontier production functions using panel data from three villages with diverse agro-climatic characteristics in the semi- arid tropics of India.The technical inefficiency effects in the stochastic frontier were modeled in terms of farm size, age, education of the farmers and the years of education.The results indicated a significant inverse relationship between farm size and the level of technical inefficiency effects in two of the three villages. From the brief review above, there were different conclusions on the relationship of farm/plot size and technical efficiency in agricultural production. This study also contributes to literature on plot size and technical efficiency in crop production.

## METHODOLOGY

**The Study Area**

The study was carried out in Ogbomoso South Local Government Area (LGA) of Oyo State. Ogbomoso South LGA lies between latitude 60 N and longitude 40 E of Greenwich meridian. Important villages in the study area include, Igbo-Ile, Agbala, Ibapon, Owolaake, Jagun, Temidire, and Ile-Titun. The main occupation of the inhabitants is farming; crops like cassava, yam, groundnut, maize, beans (cowpea), pepper and vegetable were being grown in the study area.

**Sampling Procedure**

The study used a multi-stage random sampling technique. The first stage involved purposive selection of the Ogbomoso South LGA of Oyo State due to the preponderance of cassava farmers in the LGA. The second stage involved simple random selection of six major villages from the list of cassava-growing villages in the LGA. The LGA consists of ten wards out of which six villages were purposively selected due to high concentration of cassava farmers. Thus, Owolaake, Ile-Titun, Ibapon, Jagun, Temidire, and Igbo-Ile were selected. 20 respondents from each village were simple randomly selected making a total sample size of 120 respondents. However, only 110 copies of correctly filled research instrument were processed for data analysis.

**Types of Data and Method of Data collection**

Primary data were used for this study and they were collected by the use of structured questionnaire and supplemented with oral discussion.

**Data Analysis**

The Stochastic Frontier Production Function (SFPF) technique was used to analyze the technical efficiencies of cassava farmers. According to Oluwatusin (2011), production efficiency is concerned with the relative performance of the method applied in the conversion of inputs into output. Following the works of Jondrow *et al* (1982) which was adopted by Battese and Coelli (1995), production function was viewed as a locus of maximum output levels from a given inputs set such that the output of each firm is bounded above a frontier. This according to the authors quoted above, believed that the frontier is stochastic such that it captures exogenous shocks which are beyond the control of firms. Since all firms are not able to produce the frontier output, an additional error (second error term) is introduced to represent technical inefficiency, something which is in the control of the firms (Oluwatusin, 2011). Thus, stochastic frontier production model is a special form of regression model which considered output variability based on second part error term (Oluwatusin, 2011). The first error term (measurement error) takes into consideration the statistical noise or data noise while the second error term is associated with technical inefficiency as against Ordinary Least Square (OLS) which according to Oluwatusin (2011), assumes variability in output by first part error term (measurement error). The stochastic frontier model of parametric approach measures firm level of technical efficiency using corrected form of OLS known as Maximum Likelihood Estimate (MLE). The original specification involved a production function which had an error term which had two components: one to account for random effects and another to account for technical inefficiency. This model is expressed in the following equation form as given by Coelli (1995).

$$Yi = Xi\,\beta + (Vi - Ui) \quad (i = 1, \ldots .N) \qquad (1)$$

Where:

Yi = The production of i-th firm
Xi = Vector of input quantities of the i-th firm
β = Vector of unknown parameters
Vi's = Random variables which are assumed to be identically, independently and normally
distributed with mean zero and constant variance
[iid $N(0,\ \delta^2{}_V)$] and represents those shocks that are not directly controlled by the farmers and independent of the U;'s.
Ui's = Non-negative random variables which are assumed to account for technical inefficiency in
productionand are often assumed to be iid $|N(0,\delta^2{}_U)$.

**Model Specification**

This study adopted the model of Battese and Coelli (1995) where the stochastic production frontier for cassava farmers is assumed to be of the cob-Douglas. The explicit form of the model is specified as follow:

$$\ln Yi = \beta_0 + \beta_1 \ln X_{ii} + \beta_2 \ln X_2; + \beta_3 \ln X_3; + \beta_4 \ln X_4; + \beta_5 \ln X_{5i} + V_i - U_i \quad (2)$$

Where ln represents the natural logarithm:
$Y_i$ = Amount of cassava produced (kg)
$X_i$ = Farm size (hectare)
$X_2$ = Amount spent on agrochemicals (₦)
$X_3$ = Labour used (man-days)
$X_4$ = Amount spent on machinery (₦)
$X_5$ = Amount of cassava stem cutting used (kg)
βs = Unknown scalar parameters to be estimated
The inefficiency model ($U_i$) is specified as follow:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} \quad (3)$$

Where:
$\delta_s$=Unknown scalar parameters to be estimated
$Z_i$=Years of education
$Z_2$= Farming experience (years)
$Z_3$= Household size (number)
$Z_4$= Amount of credit obtained (₦)
$Z_5$ =Extension contact (number)

According to Oluwatusin (2011), the socio-economic variables in equation (3) are included in the model to show their possible effects on the technical efficiency of the cassava farmers. Therefore, since the endogenous variable of inefficiency model depicts the mode of inefficiency, a positive sign of an estimated parameter implies that the associated variable has negative effect on efficiency but positive effect on inefficiency and vice versa. Following the study by Battese and Coelli (1995) and considering the stochastic frontier production function defined by equation (2), the technical efficiency of the i-th farmer (TEi) is defined in terms of the ratio of the observed output (Yi) to the corresponding output (Yi*) given the available technology such that

$$TEi = \frac{\ }{\ ^*} = EXP\ (-Ui) \quad (4)$$

TE has value between 0 and 1 where 1 implies a fully efficient farm and 0 a fully inefficient farm. Thus, TEi indicator is interpreted as a measure of managerial efficiency, that is, an expression of the farmer's ability to achieve results comparable to those shown on the production frontier. The parameters of the stochastic frontier production function and the inefficiency model were estimated using the computer program Frontier 4.1 (Coelli, 1996). Two models were estimated for this study. The first model which is the traditional response function of Ordinary Least Square (OLS) assumes that the inefficiency effects are absent. It is a special form of the Stochastic Frontier Production Function (SFPF) model where the total output variation due to technical inefficiency is zero that is, $\gamma = 0$ (Jondrow *et al.*, 1982). The second model is the general frontier model where there is no restriction here $\gamma \neq 0$. Using the generalized likelihood ratio test, the two models were compared for the presence of technical inefficiency effects which is defined by the test statistic, chi-square, $\chi^2$ (Greene, 1980).

$$\chi^2 = -2\ [\ln (L\ (Ho)] - \ln [L\ (H_1)] \quad (5)$$

$\chi^2$ has a mixed Chi-square distribution with the degree of freedom equal to the number of parameters imposed under the null hypothesis. $H_0$ is the null hypothesis that $\gamma = 0$ (first model). This is given as the value of likelihood function for the frontier model while $H_1$ is the alternative hypothesis that $\gamma \neq 0$ (second model) for the general frontier model. In testing the hypothesis, when the estimated $\chi^2$ is lower than the corresponding critical value of $\chi^2$ for a stated level of significance, the null hypothesis is accepted and vice versa. To determine the return to scale the sum of output elasticities (E) with respect to each resource was computed. In the case of linearized Cobb-Douglas production function adopted for this study, the coefficients of the explanatory variables are the direct partial elasticities (E). When the sum of partial elasticities is equal to one ($\Sigma$ E= 1) it implies constant return to scale, when$\Sigma$ E<I or $\Sigma$ E>1, it indicates decreasing or increasing return to scale respectively.

## RESULTS AND DISCUSSION

### The Stochastic Frontier Production Function Analysis

The Ordinary Least Square (OLS) (Model 1) and the Maximum Likelihood Parameter Estimates (MLE) (Model 2) of the stochastic production frontier models with the assumption of half-normal and production technology assumed to be specified as Cobb-Douglas frontier production function for cassava farmers are presented in Table 1.The coefficients of the variables are very important in discussing the results of the analysis of data. These coefficients represent percentage change in the dependent variables as a result of percentage change in the independent variables. Results of Model 2 for thecassava farms show that the significant variables at 5% level of significance include: labour, amount spent on agrochemicals and amount spent on machinery. Labour has the highest coefficient with value of 0.6642 (Table 1) in the model. Amount spent on agrochemicals, labour and amount spent on machinery had positive signs while farm size and amount of cassava stem cuttings both carried negative signs in the model. The variables with positive coefficient imply that any increase in such variables would lead to an increase in cassava output and vice versa.

### Goodness of Fit

The estimated sigma square ($\sigma^2$) for the cassava farms was 0.7165. The value is large and significantly different from zero (Table 1). This indicates a good fit of the model and the correctness of the specified distributional assumptions.

### The estimated Gamma (γ) Parameter

The estimated gamma ($\gamma$) parameter of cassava farms is 0.75 and highly significant at 5% level of significance. This means that 75% of the variations in the cassava output among cassava farmers in the study area are due to the differences in their technical efficiencies.

### Inefficiency Model

The estimated parameters of the inefficiency model in the stochastic frontier models for the cassava farmers are presented in the lower portion of Table 1. The analysis of the inefficiency model showed that the signs and significance of the estimated coefficients in the inefficiency model have important policy implications on the technical efficiency (TE) of the cassava farmers. The coefficients of all the variables in the inefficiency model except amount of credit obtained were positive and education was significant at 5% level of significant. Amount of credit obtained was a negative and significant (at 5% level) coefficient of technical inefficiency implying that if more credits are available to cassava farmers their level of technical inefficiency would reduce.

### Efficiency Analysis

### Technical Efficiency Analysis of Cassava Farms in the Study Area

The decile range of the predicted technical efficiency estimates obtained using the estimated stochastic frontier models for the individual cassava farms in the study area are presented in Table 2. The predicted cassava farm specific technical efficiency (TE) for the cassava farmers ranged from a minimum of 61.70% to a maximum of

**Table 1. Maximum Likehood Estimates for the Parameters of the Stochastic Frontier Production Function for Cassava Farmers**

| Variable | Parameter | Model 1 | Model 2 |
|---|---|---|---|
| General Model (production function) | | | |
| Constant | $\beta_0$ | 0.2285 (0.1573) | 0.2761 (0.1543) |
| Plot size ($X_1$) | $\beta_1$ | - 0.1978 (-0.5692) | - 0.1992 (-0.1330) |
| Amount spent on agrochemicals ($X_2$) | $\beta_2$ | 0.34572** (3.976) | 0.3292** (3.849) |
| Labour ($X_3$) | $\beta_3$ | 0.5672** (3.904) | 0.6642** (2.105) |
| Amount spent on machinery ($X_4$) | $\beta_4$ | 0.2150 (0.1496) | 0.2504** (2.010) |
| Amount of cassava stem cuttings ($X_5$) | $\beta_5$ | - 0.0106 (-0.9544) | - 0.2422 (- 0.2963) |
| Inefficiency model | | | |
| Constant | $\delta_0$ | 0 | 0.2999 (0.1262) |
| Education ($Z_1$) | $\delta_1$ | 0 | 0.8202** (1.969) |
| Farming experience ($Z_2$) | $\delta_2$ | 0 | 0.1984 (0.5740) |
| Household size ($Z_3$) | $\delta_3$ | 0 | 0.1790 (0.9893) |
| Amount of credit ($Z_4$) | $\delta_4$ | 0 | - 0.3282** (-6.559) |
| Extension contact ($Z_5$) | $\delta_5$ | 0 | 0. 3011 (0.1049) |
| Sigma squared | $\sigma^2$ | 0.733 | 0.7166 (0.7166) |
| Gamma | | 0.500 | 0.754 (0.1187) |
| Log like hood function | | - 0.1275 | - 0.1274 |
| $X_c^2$ | | 0 | 0.2762 |
| $X_{(0.05,7)}^2$ | | 0 | 14.07 |

Notes: **= 5% level. (Figures in parentheses are t-values). Source: Field Survey Data Analysis

99.97% with a mean of 83.52%. Thus, in the short run, an average cassava farmer has the scope of increasing his/her cassava production by about 16.5 % by adopting the technology and techniques used by the best practiced (most efficient) cassava farmers. Such cassava farmers could also realize 16.45% cost savings (i.e.1-[83.52/99.97] in order to achieve the TE level of his most efficient counterpart (Bravo-Ureta and Pinheiro, 1997). A similar calculation for the most technically inefficient cassava farmer reveals cost saving of about 38.28% (i.e. 1- [61.70/96.06]as shown in Table 3. The decile range of the frequency distribution of the TE indicates that about 57.02% of the cassava fanners had TE of over 70 % and about 26.5% had TE ranging between 51 % and 70 % respectively.

**Table 2. Decile Range of Frequency Distribution of Technical Efficiencies of Cassava Farmers**

| Decile Range | Frequency | % |
|---|---|---|
| >90 | 33 | 30.0 |
| 81-90 | 30 | 27.27 |
| 1-80 | 34 | 30.91 |
| 61 – 70 | 13 | 11.82 |
| Total | 110 | 100.0 |
| Mean% | 83.52% | |
| Minimum % | 61.70% | |
| Maximum % | 99.97 % | |

Source: Field Survey Data Analysis

**Table 3. Summary of Cost Savings According to Efficiency Indicator**

| Efficiency Indicator | Value of Savings (%) |
|---|---|
| Most Technically Efficient | 16.48 |
| TE Most Technically Inefficient | 38.28 |

Source: Field Survey Data Analysis

## Returns to Scale

Table 4 shows that plot size and amount of cassava stem cuttings planted were negative decreasing functions to the factors, indicating over use of those factors and they are in stage III of the production function. However factors of cassava production like amount spent on chemicals, labour and amount spent on machinery were positive decreasing functions to the factors which indicated that their use and allocation were in stage II of the production function.

**Table 4. Elasticities and Return to Scale**

| Factor of Production | Elasticity |
|---|---|
| Plot size | -0.1992 |
| Amount Spent on chemicals | 0.3292 |
| Labour | 0.6642 |
| Amount spent on Machinery | 0.2504 |
| Amount of cassava stem cuttings | -0.2422 |
| Returns to scale | 0.8024 |

Source: Field Survey Data Analysis

The implications of the findings in Table 4 are that plot size as well as amount of cassava stem cutting should be reduced in their use while other factors should be increased in their use. The return to scale of 0.8024 obtained in Table 4 showed that generally, cassava farmers were operating in the rational zone of production (Stage 11).

## Test of Hypothesis for the Absence of Inefficiency Effects

The null hypothesis specifies that the cassava farmers were technically efficient in their production and that the variation in their output was only due to random effects, which are beyond the control of the decision maker and as such the average response function (OLS)was adequate to estimate the production function parameters. The hypothesis is defined thus;

$H_0$: = 0

The generalized likelihood ratio test was conducted and the Chi-square ($\chi^2$) distributionwas computed. Table 15 shows the results of the generalized likelihood ratio test for theabsence of technical inefficiency effects. The results showed that the null hypothesis, $\gamma = 0$, was accepted for the cassava farmers in the study area. This indicates that the technical inefficiency effects were not strong in the production of cassava by the farmers in the study area and that variation in their production processes was only due to random effects.

**Table 5. Test of Hypotheses on Technical Efficiency**

| $H_o$:Cassava farmers are fully technical efficient | | | | ($\gamma$= 0) | |
|---|---|---|---|---|---|
| L($H_0$) | L(Ha) | $X_{computed}^2$ | d.f | $X_{7, 0.05}$ | Decision |
| -0.1275 | -0.1274 | 0.2762 | 7 | 14.07 | Accept Ho |

Source; Field Survey Data Analysis

## Conclusion

The general objective of the study was to examine the relationship between plot size and technical efficiencies in Oyo State of Nigeria. The study went ahead to estimate technical efficiency in cassava production; examined factors affecting cassava farmers technical efficiencies; determined the most productive resource in cassava production as well as determined the nature of return to scale in cassava production. Data were obtained from one hundred and twenty representative cassava farmers in the study area.Results of data analysis showed that the most significant productive resource in cassava production was labour because ithas the highest coefficient with value of 0.6642 (Table 1). Amount spent on machinery was also a significant explanatory variable of cassava production. Plot size had negative relationship with technical efficiency but not significant. Education and amount of credit obtained were significant factors of technical efficiency while other variables in inefficiency model were not significant.Results also show that cassava farms were operating in the rational zone of production. In order for cassava farmers to operate at economic optimum, it is suggested that farmers should reduce their plot size to a manageable size as well as reducing their use of cassava stem cuttings, more credits should be made available to cassava farmers while more educated farmers should pay more attention to their farms in order to reduce their level of inefficiency.

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