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Application of Stochastic Production Frontier in the Estimation of Technical Efficiency of Cassava Farmers in Oluyole and Akinyele Local Government Areas of Oyo State

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Abstract: This research work broadly examined the technical efficiency of the female cassava production in Oluyole and Akinyele Local Government Areas of Oyo State, Nigeria. The study employed the use of cross-sectional data from farm survey conducted on a sample of 245 cassava farmers from eight villages in the study areas. The data were collected with the aid of structured questionnaire and were later analyzed. The Econometric analytical models were employed in order to analyze the data collected from the field. Among the cassava farmers, the variables that were significant included pesticide quantity used (at 1%) and hired labour employed (at 1%). By implication, the above findings revealed that the major productive inputs that greatly impact on the cassava output of the cassava enterprise were the quantity of pesticide used on their farms as well as the amount of mandays of hired labour employed. The quantity of pesticide used existed as the most important input that impact on cassava output of the farmers. The estimated sigma square (σ^2) for the cassava farmers is 0.1819. The estimated gamma (γ) parameter of cassava farms revealed that 99% of the variations in the cassava output among the cassava farmers in the study area are due to the differences in their technical efficiencies. The study also revealed the existence of inefficiency effects among the cassava farmers in the study area as the farmers whether male or female were not fully technically efficient. The RTS for the cassava farmers is 1.03 in the study areas.

Key words: Stochastic, production, frontier, efficiency, Nigeria

INTRODUCTION

Nigeria is predominantly an agrarian country with over 70.0% of its population engaged in farming. Agriculture provides the bulk of employment, income and food for the populace. Also, it provides raw materials for the agro-allied as well as market for industrial goods. Nigeria has substantial economic potential in its agricultural sector. However, despite the importance of agriculture in terms of employment creation, its potential for contributing to economic growth is far from being fully exploited. The sector's importance has fluctuated with the rise and fall in oil revenue. Data from the Federal Office of Statistics (FOS, 1999) indicated that poverty levels in the country have been on the increase since 1986. Detailed analysis of the poverty situation in Nigeria revealed that most of the poor people work in the agricultural sector and most of them reside in the rural areas.

Studies in Nigeria (D'Situ and Bysmouth, 1994) and elsewhere (World Bank, 2000) have traced an evident linkage between poverty and agricultural sector performance. Therefore, improvements in performance of the agricultural sector can have far-reaching and beneficial implications for food security, income generation, as well as poverty.

Nigeria has continued to be the largest producer of cassava since the beginning of the 1990s with an estimated contribution of 40 million metric tonnes per annum with an average yield of 10.2 t ha^{-1}. In recent years, the demand for Nigeria cassava has increased appreciably due to increased awareness on cassava utilization. The presidential initiative move by the Federal Government of Nigeria in 2002 was geared towards raising the production level of cassava to 150 million metric tonnes by the end of year 2010 and realized an income of US $5.0 billion per annum from the export of 37.6 million tonnes of dry cassava products (Nigerian National Report, 2006).

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Cassava is Africa's second most important food staple, after maize in terms of calories consumed. In the early 1960s, Africa accounted for 42% of world cassava production. Thirty years later, in the early 1990s, Africa produced half of world cassava output; primarily because Nigeria and Ghana increased their production four fold. In the process, Nigeria replaced Brazil as the world's leading cassava producer (Nweke, 2004).

In Nigeria, traditionally, cassava is produced on small-scale family farms. As noted by Nweke (2004) the roots are processed and prepared as a subsistence crop for home consumption and for sale in village markets and transported to urban centers. In Congo, Madagascar, Sierra Leone, Tanzania and Zambia, Cassava leaves are consumed as vegetable (Fresco, 1986; Dostie *et al*., 1999; Haggblade and Zulu, 2003). In Nigeria, cassava is primarily a food crop. In the year 2000, 90% of total production in Nigeria was used as food and the balance as livestock feed (Nweke, 2004). In Nigeria, traditionally, cassava is produced on small-scale family farms. As noted by Nweke (2004) the roots are processed and prepared as a subsistence crop for home consumption and for sale in village markets and transported to urban centers.

The term efficiency of a firm can be defined as its ability to provide the largest possible amount of output from a given set of inputs. The modern theory of efficiency dates back to the pioneering work of Farrell (1957) who proposed that the efficiency of a firm consist of technical and allocative components and the combination of these two components provide a measure of total economic efficiency (overall efficiency). As noted by Farrell (1957) technical efficiency, which is the main focus of this study, is the ability to produce a given level of output with a minimum quantity of inputs and can be measured either as input conserving oriented technical efficiency or output-expanding oriented technical efficiency. Output-expanding oriented technical efficiency is the ratio of observed to maximum feasible output, conditional on technical and observed input usage (Jondrow *et al*., 1982; Ali, 1996). This study aims at using output-expanding orientation to measure technical efficiency effects.

The term frontier involves the concept of maximality in which the function sets a limit to the range of possible observations (Forsund *et al*., 1980). It is therefore, possible to observe points below the production frontier for firms producing below the maximum possible output, but there cannot be any point above the production frontier, given the available technology. Deviations from the frontier are attributed to inefficiency. The need to measure inefficiency effects is the major motivation for the study of frontiers.

Frontier studies are classified according to the method of estimation. Kalaitzandonakes *et al.* (1992) grouped these methods into two broad categories-parametric and non-parametric methods. For the parametric methods, it can be deterministic, programming and stochastic depending on how the frontier model is specified. Many researchers, including have argued that efficiency measures from deterministic models are affected by statistical noise. This however, led to the alternative methodology involving the use of the stochastic production frontier models. Aigner *et al.* (1977) and Meeusen and Vander Broek (1977) independently proposed the idea of stochastic measurement.

The major feature of the stochastic production frontier is that the disturbance term is a composite error consisting of two components, one symmetric and the other one-sided. The symmetric component, V,, captures the random effects due to measurement error, statistical noise and other influences outside the control of the firm and it is assumed to be normally distributed. The one-sided component Ui, captures randomness under the control of the firm. It gives the derivation from the frontier attributed to inefficiency. It is assumed to be half-normally distributed or exponential. The major weakness of the stochastic frontier model is its failure to provide an explicit distribution assumption for the inefficiency term (Sharma *et al*., 1999).

By definition, stochastic frontier production function is Eq. (1) Where Y; is the output of the ith farm; X, is the corresponding (MX2) vector of conventional physical inputs; P is a vector of unknown parameter to be estimated; F (.) denotes an appropriate functional form, V, is the symmetric error component that accounts for random effects and exogenous shock; while, U,<0 is a one sided error component that measures technical inefficiency.

In recent times, econometric modeling of stochastic frontier methodology associated with efficiency estimation has been important aspect of economics research. Both time varying and cross-sectional data have been used in studies based mostly on Cobb-Douglas function and transcendental logarithmic functions that are specified either as production function or cost function to estimate individual firm efficiency (Bagi and Hunag, 1983; Bagi, 1984; Ali, 1996; Apeziteguia and Garate, 1997; Yao and Liu, 1998; Udoh and Akintola, 2001a, b; Udoh, 2005; Etim *et al*., 2005; Udoh and Etim, 2006). However, this study uses a Cobb-Douglas production function to estimate technical efficiency effect at farm levels by assuming a stochastic nature of production.

MATERIALS AND METHODS

The study area, sampling and data collection procedure: This study was carried out in Oluyole and Akinyele local government areas of Oyo state. The study area represents two out of the eleven local government areas under Ibadan/Ibarapa zone of Oyo State Agricultural Development Programme (OYSADEP). The study area is situated within the tropical rainforest region and agriculture is the predominant occupation in the study area. The climate in the study area is of tropical type with two distinct rainfall patterns. The rainy season, which marks the agricultural production season is normally between the months of April and October. The heaviest rainfall is recorded between the months of June and August while driest months are November to March. The average total annual rainfall ranges between 1000 mm and 1500 mm with high daily temperature ranging between 28 and 30°C. Agriculture is the main occupation of the people and the major food crops grown in the study area include maize, rice, yam cassava and cocoyam while the major cash crops grown are: cocoa, kola nut and oil palm.

The data collected include socio-economic characteristics of farmers such as age, gender, years of formal education or educational level, marital status, household size, years of experience in farming, income level, off-farm activities, income sources and amount of farm credit and loans, expenditure and problems encountered in agricultural production. Input-output data were also collected. Output data included quantity and values of cassava output, market prices while input data include quantity and cost of inputs such as farm size, hired labour, family labour, fertilizers, seeds, chemical and amount on farm implements. The data obtained pertained to 2006 season and were obtained between the months of September and November, 2006.

The study used a multi-stage stratified random sampling technique. The first stage involved purposive selection of Oluyole and Akinyele local government areas noted for cassava production in Oyo State. The second stage involved random selection of major villages from the list of cassava-growing villages obtained from the information units of each LGA. A total of eight villages were sampled, that is, four villages from each of the LGAs. In Oluyole local government, the villages sampled include: Onidajo, Alata, Olosa and Onipe while the villages sampled in Akinyele local government included Elekuru, Agbedo, Alore and Oreku. The last stage involved a stratified random sampling selection of cassava farmers from each of the four villages in each of the two LGAs (Oluyole and Akinyele) in Oyo State. A total of 120 female cassava farmers out of the 128 female cassava farmers interviewed with the aid of a structured questionnaire had complete information necessary for data analysis as 8 of the respondents had their questionnaire not proper filled.

The empirical model: In congruent with the works of several scholars like the one of where the Cobb-Douglas stochastic frontiers was used in estimating the technical efficiency and productivity of maize farmers within and outside the Sasakawa-Global 2000 project in Ethiopia. Therefore, for the sake of this study, the stochastic frontier production functions in which Cobb-Douglas as proposed by Battese and Coelli (1995) represents the best functional form of the production frontier and also as confirmed by Yao and Liu (1998) was applied in the data analysis in order to better estimate the efficiency of the female cassava farmers.

The model of the stochastic frontier production for the estimation of the TE is specified as:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + \beta_6 \ln X_{6i} + \beta_7 \ln X_{7i} + V_i - U_i \quad (1)$$

Where, subscript i refers to the observation of the ith farmer and

Y = Output of cassava tubers (Kg).
X_1 = Stem Cuttings (bundles).
X_2 = Farm Size (ha).
X_3 = Fertilizer Quantity (litre).
X_4 = Herbicide Quantity (litre).
X_5 = Pesticide Quantity (litre).
X_6 = Hired Labour (Manday).
X_7 = Family Labour (Manday).
β_i's = The parameters to be estimated.
ln's = Natural logarithms.
V_i = The two-sided, normally distributed random error.
U_i = The one-sided inefficiency component with a half-normal distribution.

The inefficiency model: For this study, it is assumed that the technical inefficiency measured by the mode of the truncated normal distribution (i.e. U_i) is a function of socio-economic factors (Yao and Liu, 1998). Thus, the technical efficiency was simultaneously estimated with the determinant of technical efficiency defined by:

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

Where:

U_i = Technical inefficiency of the ith farmer.
Z_1 = Age of farmer (years).
Z_2 = Household size.
Z_3 = Year of farming experience.
Z_4 = Educational level.
Z_5 = Extension contribution.

The above equation was used to examine the influence of some of the female farmers' socio-economic variables on their technical efficiency. Therefore, the socio-economic variables in equation above were included in the model to indicate their possible influence on the technical efficiencies of the female cassava farmers. In the presentation of estimates for the parameters of the above frontier production, two basic models were considered. Model 1 is the traditional response function in which the inefficiency effects (U_i) are not present. It is a special case of the stochastic frontier production function model in which the parameter $\gamma = 0$. Model 2 is the general frontier model where there is no restriction in which γ, σ^2s are present. The estimates of the stochastic frontier production function were appraised using the generalized likelihood ratio test and the t-ratio for significant econometric relevance.

RESULTS AND DISCUSSION

Among the cassava farmers, the variables that were significant included pesticide quantity used (at 1%) and hired labour employed (at 1%). By implication, the above findings revealed that the major productive inputs that greatly impact on the cassava output of the male cassava enterprise were the quantity of pesticide used on their farms as well as the amount of mandays of hired labour employed. The quantity of pesticide used existed as the most important input that impact on cassava output of the male farmers.

The estimated sigma square (σ^2) of the cassava farmers is 0.1819 (significant at 10%). 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 of the cassava farmers is 0.99 and is highly significant at 5% level of significance. This means that 99% of the variations in the cassava output among the cassava farmers in the study area are due to the differences in their technical efficiencies. This result is consistent with the findings of Yao and Liu (1998). The RTS for the cassava farmers is 1.03 in the study areas.

Table 1: Maximum likelihood estimates for the parameters of the stochastic frontier production function for Cassava farmers in the study area

Variable	Parameter	Model 2	T-value
General model (Production function)			
Constant	β_0	0.1014	31.099
Stem cutting	β_1	0.4086	0.8444
Farm size	β_2	-0.3845	-0.7598
Fertilizer quantity	β_3	0.9099	1.069
Herbicide quantity	β_4	-0.4931	-0.3735
Pesticide quantity	β_5	0.3050	3.100*
Hired labour	β_6	-0.2327	-3.074*
Family labour	β_7	0.5026	1.093
Inefficiency model			
Constant	δ_0	-0.2099	-0.2200
Age of farmer	δ_1	0.4673	0.1820
Household size	δ_2	0.1531	0.8588
Year of farming experience	δ_3	-0.1045	-1.157
Educational level	δ_4	0.6583	0.6254
Extension contributions	δ_5	0.4110	2.403**
Variance parameters			
Sigma squared	σ^2	0.1819	6.282*
Gamma	γ	0.9999	0.2912
Log likelihood function		-16.27	
X_c^2		21.23	
$X^2_{(0.05,7)}$		14.07	

Notes: * =1% level; ** = 5%; *** = 10% (Figures in parentheses are t- values), Source: Computed from Field Survey Data, 2006

Inefficiency model: Among the cassava farmers, the coefficients of age, household size, education level and extension contributions were positive while the years of farming experience was negative. The findings above revealed that the age, household size, educational level and extension contribution tend to increase the level of technical inefficiency of the cassava farmers while the years of farming experience tend to reduce the level of technical inefficiency of the farmers. The above findings were not conformed to *a priori* expectation and were incongruent to the findings of Ajibefun and Daramola, (1999), Ojo (2003), Obwona (2000) and Kalirajan, 1981. The reasons for age, household size, educational level and extension contributions contributing to the inefficiency level of the farmers may include inefficient and inadequate family labour input, lack of proper supervision of their farms due to other profitable off-farm activities as well as trivialization of proven extension information on personal grounds.

Elasticities of production (εP): Among the cassava farmers, the estimated elasticities of the explanatory variables of the preferred model (Model 2) show that farm size, herbicide quantity and hired labour were negative (decreasing) functions to the factors and this showed that the use of an extra unit of these inputs will bring about a decrease in the cassava output of the cassava farmers (i.e., this indicates over-use of such variables). Stem cutting, fertilizer quantity, pesticide quantity and family labour were positive (increasing)

Table 2: Elasticities (εP) and Returns-to-Scale (RTS) of the Cassava farmers in oluyole and akinyele local government areas of Oyo State

EP	Cassava farmers
Stem Cutting	0.4086
Farm Size	-0.3845
Fertilizer Quantity	0.9099
Herbicide Quantity	-0.4931
Pesticide Quantity	0.3050
Hired Labour	-0.2327
Family Labour	0.5026
RTS	1.03

Source: Computed from field survey data

Table 3: Decile range of frequency distribution of technical efficiencies of the cassava farmers in oluyole and akinyele local government areas of Oyo State

	Technical efficiency	
Decile range (%)	No	%
> 90	17	13.70
81-90	20	16.13
71-80	19	15.32
61-70	18	14.52
51-60	20	16.13
41-50	17	13.70
31-40	9	7.25
21-30	4	16.13
Mean %	65.98%	
Minimum %	24.88%	
Maximum %	98.68%	

Source: Computed from field survey data, 2006

Table 4: Summary of cost savings according to efficiency indicator by cassava farmers in oluyole and akinyele local government areas of Oyo State

Efficiency indicator		Value of savings (%)
	Most technically efficient	34.02
TE	Most technically inefficient	74.77

Source: Computed from field survey data, 2006

Table 5: Test of hypotheses on technical efficiency

H_{02}: Cassava farmers are fully technically efficient ($\gamma = 0$)						
L.G.A	L (H_0)	L (H_a)	$X^2_{Computed}$	d.f	$X^2_{7,0.05}$	Decision
Cassava	26.88	16.27	21.23	7	14.07	Reject H0

Source: Computed from field survey data, 2006

functions to the factors which indicate that the use and allocation of these variables was profitable and as such a unit increase in these inputs will eventually result in an increase in the cassava output of the farmers.

The elasticity of cassava output with respect to fertilizer quantity has the highest value among the male cassava farmers and hired labour prevailed among the female cassava farmers. These findings indicated that fertilizer was the most important variable factor of production among the male cassava farmers in the study area and should be readily available and among the female farmers, hired labour existed as the most important factor of production; hence, there should be wage control scheme in order to enable female farmers maximize its usage on their farms considering their restricted access to credit facilities for farm activities.

Returns To Scale (RTS): The analysis of results in Table 2 shows that the RTS for the cassava farmers is 1.03 in the study areas, respectively. Among the cassava farmers, there existed increasing returns to scale and they were operating in the irrational zone of production (stage 1) with the implication that the resources are not efficiently allocated and used on their farms.

Technical efficiency analysis of the female cassava farmers in the study area: The predicted cassava farm specific Technical Efficiency (TE) for the cassava farmers' indices ranged from a minimum of 24.88% to a maximum of 98.60% for the farms, with a mean of 65.98% (Table 3). Thus, in the short run, an average cassava farmer has the scope of increasing his/her cassava production by about 34.02% by adopting the technology and techniques used by the best practiced (most efficient) cassava farmers. Such cassava farmers could also realize 33.08% cost savings (i.e.1-[65.98/ 98.60]) in order to achieve the TE level of his most efficient counterpart (Bravo-Ureta and Evenson, 1994; Bravo-Ureta and Pinheiro, 1997). The above findings unfolds the capacity of an average cassava farmers to increase his/her technical efficiency level to a tune of 34% and in turn attain a cost-saving status of about 33% that the most technically efficient cassava farmer had enjoyed in his/her cassava production enterprise using the available production techniques and technology in the study area (Table 4).

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. The hypothesis is defined thus: H_{02}: $\gamma = 0$. The generalized likelihood ratio test was conducted and the Chi-square (X^2) statistics was computed. Table 5 shows the results of the generalized likelihood ratio test for the absence of technical inefficiency effects. The null hypothesis, $\gamma = 0$, was rejected among the female cassava farmers in the study area. This revealed that the technical inefficiency effects existed among the female cassava farmers in the study area and that the variations in their production processes may be due to certain inefficiency factors in the study area.

Test of the significance of coefficients of the socio-economic variables of the inefficiency model: The null hypothesis states that each of the estimated coefficients of the explanatory variables of the inefficiency model of the stochastic frontier production function is not statistically significant (i.e. socio-economic variables do not have any significant relationship with TE of the cassava farmers).

Table 6: T-ratio test for the significance of coefficients of the socio-economic variables of the inefficiency models of the cassava farmers

H_{03}: Socio-Economic variables have no significant relationship on the farmers' TE ($\delta_I = 0$)

	Cassava farmers			
Variables	Parameter	Coefficient	T-ratio	T-critical
Age of farmer	δ_1	0.4673	0.1820	1.645
Household size	δ_2	0.1531	0.8588	1.645
Years of farming expexperience	δ_3	-0.1045	-1.157	1.645
Educational Level	δ_4	0.6583	0.6254	1.645
Extension	δ_5	0.4111	2.403	1.645

Source: Computed from field survey data, 2006

The hypothesis is defined thus: H_{03}: $\delta_i = 0$, where δ_i is the individual explanatory coefficient. The test used was the t-ratio test and was conducted at $\alpha = 0.05$ given a degree of freedom 119 for the female cassava farmers, respectively. Table 6 showed the results of t-ratio tests for the coefficients of the inefficiency model of the stochastic frontier production function for the cassava farmers, respectively. It has been seen that among the cassava farmers, none of the inefficiency variable was significantly different from zero, hence; the null hypothesis was accepted for each of these variables. Therefore, it can be concluded that the only the production function variables determine TE among the cassava farmers in the study area.

CONCLUSION

This study has empirically examined technical efficiency of cassava farmers in Oluyole and Akinyele Local Government area of Oyo State. The following conclusions were drawn based on the major findings of this study:

The cassava farmers were not fully technically efficient in the use of production resources. In the short run, an average cassava farmer have the scope of increasing their cassava production by about 34.02% by adopting the technology and techniques used by the best practiced (most efficient) cassava farmers. Such cassava farmers could also realize 33.08% cost savings in order to achieve the TE level of his most efficient counterpart (Bravo-Ureta and Evenson, 1994; Bravo-Ureta and Pinheiro, 1997). The most technically inefficient cassava farmer revealed cost saving of about 74.77%. About 45.15% of the cassava farmers had TE of over 70% and about 30.65% had TE ranging between 51 and 70%.

The analysis of the influence of socio-economic variables on technical efficiencies of the male and female cassava farmers showed that none of the socio-economic variables had significant influence on their TE in the study area. For the cassava farmers, the variables that significantly affected their technical efficiencies include stem cutting, farm size, pesticide quantity used and family labour employed. Stem cuttings, Farm size, Fertilizer quantity and Pesticide quantity carried positive signs while Herbicide quantity, Hired labour and Family labour carried negative sign.

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