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A Stochastic Frontier Production Function Approach to Technical Efficiency among Cassava Farmers in Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

In this study the stochastic frontier production function approach was employed in the empirical analysis of technical efficiency among smallholder cassava farmers in Rivers State, Nigeria. Multistage random sampling technique was used in the data generation exercise. A total of 94 cassava farmers were randomly selected from ten out of the fifteen Upland Local Government Areas of Rivers State, Nigeria, for interview using structured questionnaire. The results showed that there was a significant positive and elastic

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relationship between output of cassava and farm sizes, family labour, cassava stem cuttings, and depreciated values of implements among cassava farmers in Rivers State. Production elasticity estimates showed that the farmers were experiencing increasing returns to scale (1.27). The significant determinants of technical inefficiency among these farmers include Age, household size and farming experience. The mean technical efficiency of the farms was 70%. This shows that there is still room for the farmers to increase their technical efficiency as they grow older in age. Furthermore, incentives on cassava farming such as subsidized inputs from the governments should be skewed in favor of the older and more experienced farmers.

Keywords: Stochastic; frontier; technical; efficiency; cassava.

1. INTRODUCTION

Cassava is already incredibly important for Nigeria and possesses the potential of playing even bigger role in the future, not only in foreign exchange earning but also in the nation's economic development generally. This derives from the fact that Nigeria is the world's highest producer of cassava. The industry, still in its burgeoning state, has not yet translated into a buoyant economic value-chain due to its abysmally low value addition occasioned probably by inefficiency or inadequacy of research in unraveling the critical variables responsible for such poor performance or the lack of political will on the part of policy makers in implementing research recommendations. That may explain why despite Nigeria's dominance in cassava production, Thailand is the world's largest exporting country of dried cassava with a total of 77% world export in 2005, followed closely by Vietnam (13.6%), Indonesia (5.8%), and Costa Rica (2.1%) [1]. From the foregoing, it is apparent that Nigeria is not yet visible in the world market in the exportation of dried cassava despite her dominance in its production.

Nigeria is the first African country to massively invest in the potential of cassava to meet the rapidly growing global demand for industrial starches, which are used in everything from food products to textiles, plywood and paper. Nigeria hopes to mimic the success of countries in Southeast Asia, where a cassava-driven starch industry now generates $5 billion per year and employs millions of smallholder farmers and numerous small-scale processors. Interest in cassava production has intensified across Africa as rising temperatures and shifting rainfall patterns caused by climate change threaten the future viability of food staples such as maize and wheat [2].

Cassava is the most important tropical root crop. Its roots are a major source of dietary energy for more than 500 million people. The demand for cassava is increasing at a faster rate daily. This may be due to the fact that it is known to be the highest producer of carbohydrates among staple crops. According to the United Nations Food and Agriculture Organization (FAO), cassava ranks fourth as a food crop in the developing countries, after rice, maize and wheat. Every part of cassava plant has economic value: the roots or tubers, stems, peels, and leaves can all be used to produce a large variety of food and non-food products. For instance the leaves are relatively rich in protein and can be consumed. Cassava tubers can be stored in the ground for several seasons, thereby serving as a major reserve food when other crops fail. In the livestock industry cassava is also increasingly used as animal feed and in the manufacture of different industrial products. It is also used in industrial processes [3].

But the challenge that is facing Nigerian agriculture is low productivity. The farming systems in the Niger Delta are principally traditional subsistence crop farming [4].They are characterized by small sized farm holdings of less than one hectare per household. Cassava remains the largest grown crop produced followed by yam and Maize. Fertilizers, agro chemicals and improved seeds are not readily available and have not been widely adopted. A number of other factors have been implicated for the low productivity especially in Rivers State, Nigeria. These include increased levels of biotic and abiotic farm level, as well as socio-demographic constraints. In recent times prices of farm inputs have tripled [4]. These factors combine synergistically to reduce efficiency in cassava production in the State. The extent of their culpability in reducing efficiency need to be isolated for proper scrutiny or diagnosis so that the requisite prescriptions could be built on evidence-based research that can transmit the current position or mean technical efficiency (MTE) in cassava production to relevant policy makers or stake holders from the private sector who are ready to develop this important sub-sector of the economy.

In Nigeria, cassava is more widely grown in the humid zone where it occupies more than 60% of staple crop field area than in the sub-humid zone where it occupies less than 20% [5]. Rivers State falls under the humid agro-ecological zone of Nigeria and about 15 out of the 23 Local Government Areas are major producers of cassava [6,4]. It has been observed that the loamy and alluvial soils which are very fertile accounted for why Rivers State is one of the major producers of root crops like yam, cocoyam, and cassava [7]. Land, in relation to the population, is relatively scarce in the Niger Delta Region and as population increases, the pressure on land for all purposes including agriculture increases accordingly. The highest pressure on land is in the coastal vegetation zone with a population density of 0.46 ha/person followed by the derived savannah zone with 0.49 ha/person [4]. In addition, fertile lands are under severe pressure caused by conflicts from competing land uses such as intensification of agricultural activities by farmers, industrial uses, oil exploration, etc. Under this scenario, if cassava production must transcend this stage into a full blown commercial production involving middle to large scale enterprises, and the federal government policy on inclusion of 20 per cent cassava flour in bread achieved [2], while still maintaining the increased demand for cassava-based products and sustaining the ban on importation of cassava products; then resource inputs used in cassava production must be efficiently utilized. The extent of their efficient utilization should also be determined not by a comparative analysis of farmer groups as in [8-13] or such similar studies but by the use of appropriate research model that possesses the capacity of delineating farm –specific level of technical efficiency and sources of inefficiency at a prevailing level of technological development. This gap in knowledge is what the current study intends to fill using the stochastic frontier production function approach developed by [14,15].

More so, improved farm productivity and efficiency was one of the strategies recommended for the successful implementation of the Seven Point Agenda of the Federal Government under Yar' adua [16].

1.1 Analytical Framework

Technical efficiency is the ability of the firm to maximize output for a given set of resources while allocative efficiency shows the ability of the firm to use the inputs in optimal proportions given their respective prices and the production technology. Recent developments in cost and production frontiers are attempts to measure productive efficiency as proposed by [17]. This frontier defines the limit to a range of possible observed production levels and identifies the extent to which the firm lies above or below the frontier.

Literature suggests two alternative approaches to measuring productive efficiency-parametric frontiers and non-parametric frontiers. The parametric frontiers impose a functional form on the production function and make assumptions about the data. The most commonly used functional forms include the Cobb-Douglas, constant elasticity of substitution and translog production functions. In the non-parametric frontiers, functional forms are not imposed on the production frontiers and do not make assumptions about the error term. Linear programming approaches and the more recent Data Envelopment Analysis (DEA) are among the most popular nonparametric approaches used.

Another distinction is between deterministic and stochastic frontiers. While the deterministic frontiers assume that all the deviations from the frontier are a result of firms' inefficiency the stochastic frontiers assumes that part of the deviations from the frontier are due to random events such as measurement errors and statistical noise and part is due to firm specific inefficiency [18].

The stochastic frontier approach, unlike the other parametric frontier measures, makes allowance for stochastic errors due to statistical noise or measurement errors. The stochastic frontier model decomposes the error term into a two-sided random error that captures the random effects outside the control of the firm (the decision making unit) and the one-sided efficiency component. The model was first proposed by [19,20]. The stochastic frontier production function model has the advantage of allowing simultaneous estimation of individual technical efficiency of respondent farmers as well as determinants of technical efficiency [21].

2. METHODOLOGY

The study was conducted in Rivers State. The State lies between longitude 6º50' E and Latitude 4º45' N bounded on the South by the Atlantic Ocean to the North by Imo and Abia States to the East by Akwa Ibom State and to the West by Bayelsa and Delta states. The state is made up of 23 Local Government Areas (LGAs). Total annual rainfall decreases from about 4,700 mm on the coast to about 1,700 mm in extreme north of the State. Rainfall is adequate for all year round crop production in the State. The mean monthly temperature is in the range of 25 to 28ºC. The main root crops are yam, cassava and cocoyam; while the grains are maize, lowland rice and beans. Other crops grown for food include vegetables, melon, pineapples and plantain. The major cash crops are oil palm products, rubber, coconut, raffia palm and jute.

Multistage sampling technique was used in the data generation exercise. There are 23 Local Government Areas (LGA) in Rivers State. Fifteen of these were purposively selected for the study, because they constitute the upland (Abua/Odual, Ahoada East, Ahoada West, Emohua, Eleme, Etche, Omuma, Gokana, Ikwerre, Khana, Obio/Akpor, Ogba/Egbema/Ndoni, Oyigbo, Port Harcourt and Tai) while 8 are Riverine. The predominance of land or rivers/creeks guided this division [4]. From these 15 L.G.As, ten (Emohua, Ahoada East, Ahoada West, Ikwerre, Khana, Obio/Akpor, Eleme, Oyigbo, Omuma and Gokana) were randomly selected. From the lists of communities in these L.G.As, one community was randomly selected. This gave a total of ten communities. From the lists of cassava farmers collected through the assistance of the extension agents, 10 cassava farmers were randomly selected. This gave a total sample size of 100 cassava farmers in the 2012 farming season. Well structured questionnaire and interview schedule were used to elicit relevant data from the respondents. Six copies of the questionnaire were discarded because they were not properly filled. Thus 94 copies of the questionnaire were available for analysis.

2.1 Data Analysis

Scholars such as [22-25,15] applied stochastic frontier model to estimate technical efficiency. The empirical model estimated takes the following general form:

$$Y = f(x_i, \beta)e^{v_i - u_i}$$

Where *Y* is the dependent variable, *f(x)* is the functional form, β is the technical coefficient, *vi* is the random component which assumed to be identically and independently distributed with mean zero, and *ui* is the inefficiency effect of the firm. The estimated Cobb-Douglas stochastic frontier Production function is assumed to specify the technology of the farmers and is specified in the form:

$$\ln Yij = \beta 0 + \beta_1 \ln X_{1ij} + \beta_2 \ln X_{2ij} + \beta_3 \ln X_{3ij} + \beta_4 \ln X_{4ij} + \beta_5 \ln X_{5ij} + Vij - Uij \quad (1)$$

Where 'ln' represents logarithm to base e; subscripts ij refers to the jth observation of the farmer.

Y = value of total output of the farmers (Naira).
X_1 = farm size (hectares).
X_2 = family labour (in man days);
X_3 = hired labour (in man days);
X_4 = value of cassava stems expenditure (N);
X_5 = Capital inputs- depreciated value of implements (Naira);
Vij = a symmetric error component that accounts for random effects and exogenous shocks.
Uij ≤ 0 = a one sided error component that measures technical inefficiency. It is assumed that the technical inefficiency effects are independently distributed and Uij arises by truncation (at zero) of the normal distribution with mean μij and variance, δ^2, where uij is defined as.

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

Where Uij represents the technical inefficiency of the farmer;

Z_1 = Age of the farmer (Years)
Z_2 = household size (number)
Z_3 = Years of formal education;
Z_4 = Farming experience (Years)

The maximum–likelihood estimates of the β and δ coefficients in equations (1) and (2) respectively was estimated simultaneously using the computer programmed Frontier 4.1 [26]. The above model was used for determining the efficiencies of cassava production in the study area. The 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 [27].

3. RESULTS AND DISCUSSION

Table 1 presents the summary statistics of variables used in the stochastic frontier production function. The Table shows that the mean gross income and farm sizes of the farmers were N162710.6 and 0.8972 hectares respectively, which indicated that they were smallholder farmers.

Table 1. Summary statistics of variables in the stochastic frontier for cassava farmers in Rivers State

Variables	Mean	Standard deviation	Minimum	Maximum
Gross income (N)	162710.6	1.1475	25300	927497
Farm size (Ha)	0.8972	0.89766	0.03	6.0
Family labour (md)	108.87	71.32	20	189
Hired labour (md)	59.84	41.43	9	180
Stem cuttings (N)	19129.79	23225.40	400	140000
Capital inputs (N)	10612.23	8435.66	1200	37500

Source: Summarized from computer output

3.1 Maximum Likelihood Estimates

Inferences about the stochastic model on the maximum likelihood estimates represented by the elasticity estimates indicates that the elasticity of mean value of cassava output with respect to farm size, family labour, hired labour, expenditure on stem cuttings and depreciated value of implements were 0.57, 0.54, -0.04, 0.10 and 0.10 respectively.

Results in Table 2 shows that farm size (X_1) family labour (X_2), stem cuttings (X_4) and capital inputs (depreciated value of implements) (X_5) had positive signs in line with *a priori* expectation. This implies that as these variable inputs increase, the output of cassava also increases. Hired labour (X_3) on the other hand gave a negative sign which is not statistically significant at 5% level. The coefficient for farm size was 0.57 signifying that a unit increase of farm size added to what was obtainable could lead to a major increase in yield of cassava of up to 0.57%. This factor is significant at 1 percent alpha level. This means that farm size is a significant determinant of output of cassava in Rivers State. This finding is consistent with [11] in Etche L.G.A. of Rivers State, Nigeria.

The coefficient for family labour was 0.54, implying that a unit increase in family labour could lead to an output rise in cassava by as much as 0.54% which is also significant at 1% alpha level. Hired labour on the other hand with a coefficient of -0.04 shows that a unit increase in the type of hired labour used by these farmers could reduce yield or output by -0.04% which is not statistically significant at 5% level. Stem cuttings and depreciated value of implements had coefficients of 0.10 and 0.10 respectively. This implies that a unit.

Increase in the use of improved stem cuttings and farming implements could lead to yield increases of 0.10% in Rivers State. While the coefficient for stem cuttings was significant at 5% level of alpha, the coefficient for capital input was significant at 10% alpha level.

Table 2. Maximum likelihood estimates of the parameters of the stochastic production function

Variable	Parameter	Coefficient	t-ratio
Production factors			
Intercept	β_0	11.50	14.47**
Farm size	β_1	0.57	5.29**
Family labour	β_2	0.54	4.22**
Hired labour	β_3	-0.04	-0.69
Stem cuttings	β_4	0.10	2.15*
Capital inputs	β_5	0.10	1.79*
Inefficiency effects			
Intercept	δ_0	61.42	-1.84
Age	δ_1	-0.10	-2.87**
Household size	δ_2	0.56	2.03**
Level of education	δ_3	0.30	1.28
Farming experience	δ_4	0.16	2.17**
Diagnostic Statistics			
Likelihood ratio		77.366	
Sigma Squared		10.03	2.50**
Gamma		0.99	387.50**

*Significant at 5% level, ** Significant at 1% level, Source: Summarized from computer output*

With respect to the specification of the Cobb-Douglas frontier models, the results reveal that the elasticity of mean value of cassava output was estimated to be an increasing function of farm sizes, family labour, expenditure on stem cuttings and depreciated value of implements and a decreasing function of hired labour. The value of returns to scale was 1.27, indicating increasing returns to scale. The implication of increasing returns to scale in this study means increasing productivity per unit of input. The cassava farmers were not using their resources efficiently. They can still increase their level of output given the same level of resources and production technology. This result is consistent with [23] who found increasing returns to scale of 1.11 for apiculturists in the use of labour, implements, bee hives and other inputs in Imo State, Nigeria and [28] who obtained an increasing return to scale of 1.26 for small scale food crop farmers in the use of land, labour implements, agro-chemicals, and seeds in Nigeria.

3.2 Technical Efficiency Estimates

Results of technical efficiency show a wide variation among the cassava farmers with minimum and maximum values of 0.29 and 0.93 respectively and a mean technical efficiency value of 0.70 (Table 3). The technical efficiency skewed to the right in the 0.60 an 0.79 range, representing 56.4 percent of cassava farmers.

The wide variation in technical efficiency estimates indicates that many of the cassava farmers were inefficient in the use of their resource inputs and there is still favorable time for improving on their current level of technical efficiency.

The results of the inefficiency model in Cobb-Douglas frontier show that the Age of cassava farmers, household size, and farming experience were significant determinants of technical inefficiency at 1% level, implying that these variables significantly affected the level of technical efficiency of cassava farmers in Rivers State (Table 2). Level of education of the cassava farmers did not significantly influence technical inefficiency. Age of the cassava farmers had a negative coefficient, while household size, level of education, and farming experience had positive coefficients respectively.

Table 3. Distribution of cassava farmers by their technical efficiency estimates

Technical efficiency range	Frequency	Percentage
0.20 – 0.39	5	5.3
0.40 – 0.59	10	10.6
0.60 – 0.79	53	56.4
0.80 – 0.99	26	27.7
Total	94	100
Mean	0.70	

The implication of the negative coefficient for age is that an increase in age would lead to a decline in the level of technical inefficiency. This is understandable because as the farmers' age increases, their experience and technical efficiencies would increase ceteris paribus. While the implication of the positive coefficients for household size, level of education and farming experience is that an increase in the value of these variables would lead to an increase in the level of technical inefficiency. This is contrary to a priori expectations. This result with respect to household size could be possible where increase in household size is not directly proportional to increase in available family labour especially where those household members are either in the schools or domiciled outside the farm environment due to out migration or unavailable for farm work. With respect to the wrong signs associated with level of education and farming experience, [29] argued that "wrong signs" can occur because of correlations between included and omitted variables, so that "wrong signs" may occur if the model is not correctly specified. It is probable that some variables that accounted for technical inefficiency among these cassava farmers might have been omitted inadvertently. This therefore necessitates further research among these cassava farmers.

4. CONCLUSION

Results of data analysis showed that there is a positive and significant relationship existing between output of cassava and farm sizes, family labour, cassava stem cuttings, and capital inputs (depreciated values of implements) among cassava farmers in Rivers State. While hired labour was not a significant determinant of output among these cassava farmers.

Age of cassava farmers, their household size and farming experience are important policy variables and determinants of efficiency which policy makers in Rivers State should bear in mind in making agricultural policies aimed at improving the productivity and efficiency of cassava farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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