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A stochastic frontier approach to determine technical efficiency of cassava farmers in Ondo state, Nigeria

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ABSTRACT

The stochastic frontier production model showed an improvement over the traditional average function and the deterministic functions, which use mathematical programming to construct production frontiers. The study was conducted to analyze the technical efficiency of sole cassava farmers in Ondo State using a stochastic frontier model. Primary data were obtained with the aid of a structured questionnaire, and a multistage sampling technique was used to sample 160 respondents. The result revealed that the variance of parameters (gamma and sigma squared) of the frontier production function was both significant at 1% levels. The mean technical efficiency was 0.732. Farm size and fertilizer were significant and had positive effect on output, whereas labour was significant and inversely related to the farmers' technical efficiency. The determinants of technical inefficiency of cassava farmers in Ondo State indicated that sex (0.094), family sisze (0.209), level of education (-0.011), farming experience (-0.614), co-operative membership (-0.10), extension visit (-0.061) and access to credit (-0.100) are the significant variables that influenced technical inefficiency of cassava production among the respondents. It was therefore recommended that the government should encourage and fund research in fertilizer production, there should be farming education on cassava production, farmers should belong to farmers' co-operative society, more extension officers should be employed, and banks should grant loans to farmers at low interest rates.

Keywords: Cassava; producers; technical efficiency; stochastic frontier.

INTRODUCTION

Nigeria is one of the Sub-Sahara Africa countries that is facing poverty and food insecurity challenge since her independence in 1960, which is typical of most African countries. Asogwa *et al*. (2017) opined that Africa is faced with dire food security challenge. Nigeria government have taken various policies and measures to mitigate these challenges, one of such measures is to identify crops that gain popular acceptability and wider ecological adaptability, cassava is one of those crops.

Cassava (*Manihot* spp) is a staple food of an average household, particularly for a poor rural family in Nigeria. Cassava or its derivatives form part of daily diet both for poor and non-poor households in Nigeria. Therefore, this makes it an essential staple capable of

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mitigating food insecurity, alleviating poverty and aid employment generation, among others (Angba and Iton, 2020).

The world production of cassava amounted to 278 million metric tons in 2018, out of which Africa's share was about 61% (FAOSTAT, 2020). According to the Food and Agriculture Organization (FAO) projections, by 2025, about 62% of global cassava production will come from sub-Saharan Africa (FAOSTAT, 2020). Nigeria ranks first among the world producers of cassava, with a share of 20.4% of the global output, based on a total production value of 59 million metric tonnes (FAO, 2019; IITA, 2020). However, The Democratic Republic of Congo is the largest consumer of cassava in SSA, followed by Nigeria and it is estimated that 37% of dietary energy in Nigeria comes from cassava. (IITA, 2020).

Sanusi *et al.* (2020) opined that cassava is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root. It is a major source of carbohydrates, when dried and grinded to powdery form called cassava flour which serves as a major diet in different parts of the country. It is one of the most drought tolerant crops capable of growing on soils with limited nutrients.

Cassava has wide ecological adaptability which makes it perform relatively well where other crops may not be able to produce reasonable yield (Otekunrin and Sawicka, 2019). This attribute confers on cassava a reliable food security for farming households in the tropics (Ikuemonisan *et al.*, 2020). In addition, it also provides dietary energy for close to a billion people and livelihood for millions of farmers/processors traders worldwide (FAO, 2018).

In Nigeria about 69-80% of the diet is made of starchy food, and cassava alone makes up of about 54-58% which provides an average of 347 calories daily for each individual (FAO, 2000). Cassava provides a basic daily source of dietary energy for those that are vulnerable to food insecurity in society. It is a staple in rural and urban households in southern Nigeria (Oladejo *et al.*, 2014). FAOSTAT (2012) reported that cassava bye products have a wide array of uses and it is used as starch and applicable in many types of products such as foods, confectionery, sweeteners, glues, plywood, textiles, paper, biodegradable products, monosodium glutamate, animal feed alcohol production and production of drugs. Its production is next to yam among the root and tuber food crops. It is an important root crop consumed as a staple food, boiled, baked or often fermented into other foods and beverages all over the world (Simonyan, 2015).

Despite its various uses and government intervention in its production, the yield in Nigeria is far below those of other major cassava producers. For instance, in Thailand, where farmers are also smallholders, yields are 21.8 tonnes/hectare compared to Nigeria that have average yield of 13.9 tonnes/hectare. This may be due to inefficient use of resources, also, these farmers hardly use modern technology and inputs, resulting in low cassava productivity (Mustefa *et al.*, 2017; Tadesse *et al.*, 2021)

FAO (2018) asserted that under optimal conditions, cassava can yield about 80 tons per hectare. Studies from scholars such as Elahi *et al.* (2018); Zhang *et al.* 2022 have shown that improving agricultural productivity and efficiency of production is crucial to ensuring the safe supply of food and reducing poverty in rural areas. However, Ezedinma (2006) and Isitor (2017) noted that the government of Nigeria have embark on various programmes and policies over the years to raise farmers' efficiency and productivity in cassava production, yet the farmers have not attained the desired efficiency levels. Therefore, there is need for investigation into technical efficiency of cassava producers in Ondo State as it is one of the major cassava producing states in Nigeria.

Although, several studies have been carried out on Stochastic Frontier Analysis (SFA) to determine technical efficiency of cassava farmers (Abass *et al.,* 2019 studied drivers of technical efficiency of cassava processing in Nigeria implication for a commercializing food sector; Akerele *et al.,* 2019 cassava production efficiency in Ogun State Nigeria; Tafesse *et al.* 2021 determined cassava production efficiency in southern Ethopia). Therefore, there is need to carry out similar study on the use of a stochastic frontier model to determine technical efficiency of cassava farmers in Ondo State. SFA is considered appropriate for this study since it accounts for measurement error in the model specification and estimation of production function, because many farmers are small scale, family owned and farm records are seldom kept, even the available data on production are likely to contain measurement error (Nelson, 2015). Therefore, the objectives of this study were to describe the socioeconomic characteristics of the farmers, determine the technical efficiency level of the farmers and investigate factors influencing technical inefficiency of the farmers.

METHODOLOGY

Area of Study

This study was carried out in Ondo State. Ondo borders Ekiti State to the north, Kogi State to the northeast for 45 km, Edo State to the east, Delta State to the southeast for 36 km, Ogun State to the southwest for 179 km, Osun State to the northwest for 77 km, and the Atlantic Ocean to the south. The temperature throughout the year ranges between 21^0C and 29^0C with high relative humidity. The state enjoys luxuriant vegetation with high forest zone. It lies between latitudes $5^0 45'$and $8^0 15'$North and longitudes $4^0 45'$ and 6^0 East of the Greenwich meridian, it has a land area of 15,500 km^2 (6,000 sq miles) and the population projection of Ondo State in 2022 is 5,316,600 (City Population, 2022). It has 18 Local Government Areas divided into four Agricultural Development Zones which are Ondo, Ikare, Owo and Okitipupa. Some of the prominent cultivated in the state are arable crops such as yam, maize, melon, cocoyam, cassava, plantain, with tree crops such as cocoa, oil palm, and kola.

Sample Size and Sampling Procedure

Primary data were collected from 160 cassava farmers with the aid of structured questionnaire. A multistage sampling technique was employed to arrive at the number of respondents required. The first stage entailed a purposive selection of one Local Government Area (LGA) from each of the four agricultural zones that are predominant in cassava production. In the second stage, the lists of ten villages that were prominent in cassava cultivation were collected from each LGA and at the third stage, five villages were randomly selected from the list of the villages in each LGA. At the last stage eight cassava farming households were randomly selected from villages noted for cassava production.

Analytical Technique

The Cobb–Douglas form of the stochastic frontier production model was used to analyse the technical efficiency level of cassava farmers, in line with the studies of Mango *et al. (*2015), Memon *et al*. (2016) and Henri-Ukoha *et al*. (2020).

Cobb-Douglas function in stochastic frontier form is expressed as follows:
$\ln Yi = \ln\beta_0 X_i + Vi\text{-}U_i$

The explicit Cobb-Douglas production frontier function that specifies technical efficiency of cassava producers is expressed as follows:

$\ln Yi = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + V_i - U_i$ .... (1)

Where:
Y = Cassava output (Kg)
X_1 = Farm size (Ha)
X_2 = Labour use (Man days)
X_3 = Quantity of cassava (Bundle)
X_4 = quantity of fertilizer use (Kg)
X_5 = Weeding rate (Number, 1, 2, 3…n)
β_0 is the intercept, $ß_1$, β_2, β_3, β_4, β_5 are the parameters to be estimated, and V-U is the error term that accounted for causes of inefficiency.

V is assumed to be independently and identically distributed random error, having N (0, σ^2) distribution; it accounts for factors beyond the control of the farmers, such as luck, flood, draught, climatic change e t c, and the U is non-negative one-sided random variable, U_i captures the technical inefficiency of the farmers. In other words, U measures the shortfall in output. It is assumed that the inefficiency effects are independently distributed with a half normal distribution (U~ / N (0, σ^2_{u}/).

The model for the technical inefficiency effects in the stochastic frontier of equation (1) is defined by

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + N_i \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where:
Z_1 = Age (Yrs),
Z_2 = Sex (Male 1, Female = 2),
Z_3 = Family size (Number)
Z_4 = Education level (Yrs),
Z_5 = Farmers farming experience (Yrs),
Z_6 = Co-operative membership (Member = 1, non-member = 0)
Z_7 = Extension visits (Number),
Z_8 = Access to credit (Access = 1, Otherwise = 0).
Z_9 = Land preparation (Heap or ridges = 1, Otherwise = 0).
δ_0 is the intercept and $\delta_1 - \delta_9$ are the inefficiency parameters

The β and δ coefficients are unknown parameters to be estimated, together with the variance parameters which are expressed in terms of:

$$\delta^2 = \delta^2_u + \delta^2_v$$

and

$$\gamma = \delta^2_{u/}\, \delta^2$$

Where the γ parameter has value between zero and one. The parameters of the stochastic frontier production function model were estimated by the maximum likelihood method, using computer program-FRONTIER Version 4.1.

RESULTS AND DISCUSSION

The results of maximum likelihood estimate (MLE) of the parameters of the stochastic frontier model of cassava farmers is shown in Table 1. The variance parameters of the frontier production are represented by sigma squared (δ) and gamma (γ). The sigma squared in Table 1 is 0.781 which is significantly different from zero at 1%. This indicates a good fit and correctness of the distribution form assumed for the composite error term. Gamma indicates that the systematic influence of the unexplained variables by the production function is the dominant sources of random error. The gamma estimate, which was 0.881, shows the amount of variation in output resulting from the technical inefficiencies of the farmers. This means that 81.4% of the variation in farmers' output was due to technical efficiency. Hence, the specification of a stochastic frontier production function is therefore justified. Typical of the Cobb –Douglas production function, the estimated coefficients for the specified function can be explained as the elasticity of the explanatory variables. The mean technical efficiency (TE) of cassava farmers was 0.814 (81.4%), implying that the farmers were not fully efficient as the observed output was 18.6% less than the maximum output.

The estimate of the parameters of the stochastic production frontier indicated that the elasticity of output with respect to farm size was positive (0.722) and it significant at 1%. This implies that farm size is a positive and significant factor that influences the output of cassava farmers. The implication is that a 1% increase in the area of land cultivated will result in an increase in output by 0.729% and consequently increase the technical efficiency of the farmers. This result is in line with the findings of Taru *et al.* (2011) who reported a significant and direct relationship between area of land cultivated and TE of cowpea in Adamawa State.

Table 1: Maximum likelihood estimates of parameters of Cobb-Douglas stochastic frontier production function for cassava famers in Ondo State

Variables	Parameters	Coefficient	Std. Error	t-Value
Constant	β_0	2.710***	0.189	14.331
Farm size	β_1	0.722***	0.229	3.150
Labour used	β_2	-1.022***	0.268	3.811
Quantity of cassava	β_3	1.123	0.655	1.715
Quantity of fertilizer	β_4	0.809**	0.385	2.103
Weeding rate	β_5	1.243	2.068	0.601
Inefficient effects				
Constant	δ_0	19.222***	0.835	23.012
Age	δ_1	0.041	0.136	0.301
Sex	δ_2	0.094**	0.046	2.005
Family size	δ_3	0.209**	0.073	2.863
Education level	δ_4	-0.011***	0.0.02	-5. 500
Farming experience	δ_5	-0.614*	0.211	-2.910
Cooperative membership	δ_6	-0.107***	0.008	-13.375
Extension visits	δ_7	-0.061***	0.009	-.258
Access to credit	δ_8	-0.100**	0.045	-2.212
Land preparation	δ_9	-0.772	0.636	-1.214
Variance parameters				
Sigma squared (δ^2)		0.781	0.055	14.143
Gamma (γ)		0.881	0.008	110. 125
Mean TE = 0.814				
Log likelihood function =	-2.538			

Source: Field survey, 2023.

***, Significant at 1%; **significant at 5% and *significant at 10%.

The production elasticity of labour is negative (-1.022) and significant at 1%. This implies that an increase in labour by 1% will result in a decrease in output by 1.022%. This obeys the law of diminishing returns of labour with respect to cassava production. Meaning overutilization of labour, this may be explained by the fact that there is a very high amount of labour use in cassava production, this could result from excessive use of family labour. This result is in line with Abass *et al*. (2019) who find negative relationship between technical efficiency and cassava processing in Nigeria.

The use of fertilizer is positive (0.809) and significant at 1% to technical efficiency. This shows that an increase in use of fertilizer holding other factors constant will result in higher output of cassava in Ondo State. This may arise from the fact that the application of fertilizer in the farm can replenish depleted soil nutrients or provide the required nutrients to the soil. This finding is in line with Wongnaa and Awunyo-Victor (2018) who find significant positive relationship between fertilizer use and technical efficiency in maize farm in Ghana.

The determinants of technical inefficiency of cassava farmers in Ondo State indicated that sex (0.094), family size (-0.209), level of education (-0.01), farming experience (-0.614), and co-operative membership (-0.107), extension visit (-0.061) and access to credit (-0.100) are the significant variables that influenced technical inefficiency of cassava production in Ondo State. The negative sign showed that they have an inverse relationship with technical inefficiency therefore increasing technical efficiency.

The positive sign of sex may translate to technical inefficiency of female farmers. The negative effect of sex on technical inefficiency can be attributed to the laborious works perform by men in farming activities which positively affect their technical efficiency. Such as clearing of the farm, planting and weeding. This is in contrast to Abdulai *et al.* (2013) who found negative relationships between gender and technical inefficiency.

An increase in household size decreases technical efficiency of the farmers, this may be that since farmers in the area are mostly operating in small scale, they may divert profit realized in their farm to cater for the family instead of purchasing improved varieties or embarking on modern technology in cassava production.

The negative sign of the level of education means that the higher the level of education of cassava farmers in the study area the higher their technical efficiency. The level of education attain can increase farmers' ability to optimize existing technologies and attain higher efficiency levels. This may be explained by the fact that the level of education enables the farmers to adjust and adopt new research innovations cassava production. Wongnaa and Awunyo-Victor (2018) opined that farmers who have received formal education are able to access information from extension agents, which affect effective use of their production technologies. These results also conform to Henri-Ukoha, Onyenma and Aroyehun (2020) who find positive relationship between education and technical efficiency in value addition to cassava among small scale *garri* processors in Abia State, Nigeria and Erhabor and Emokaro (2007) who find negative relationship between relative technical efficiency of cassava farmers in the three agro-ecological zones of Edo State, Nigeria.

Farming experience has negative coefficients with technical inefficiency and is statistically significant at 10% levels. This shows that the more years spent in cassava production the more they are technically efficient.

The coefficient of co-operative membership is negative and significant at 1% level. This is in consonance with the a priori expectation since being a member of a co-operative is advantageous to the processors in terms of having access to credit and other processing inputs which could cause an upsurge in their technical efficiency. This, however, agrees with the findings of Chukwuji, Inoni and Ike (2007) who in their study on the determinant of technical efficiency in *garri* processing in Delta State found a negative coefficient for co-operative membership.

The coefficient of access to credit was negative and significant, suggesting that agricultural households that have access to credit facilities reduce technical inefficiency. This may stem from the fact that farmers that have prompt access to credit will be able to buy farm input at the right time, leading to an increase in output per unit area of land. This result is consistent with Abdulai and Abdulai (2016) and Ng'ombe and Kalinda (2015) who reported that access to credit has a negative relationship with technical inefficiency among maize farmers in Zambia also Usman and Olagunju (2019) found negative relationship between food security and technical inefficiency among agricultural households in Nigeria.

Table 2: Distribution of technical efficiency of cassava farmers in Ondo State

Technical efficiency ranges	Number of farmers	Percent
0.50 – 0.60	02	1.250
0.61 – 0.70	13	8.125
0.71 - 0.80	55	34.38
0.81 - 0.90	86	53.750
>0.90	04	2.025
Total	160	100.00
Mean: = 0.814, Minimum: = 0. 56, Maximum: = 0. 95		

Table 2 gives the distribution of technical efficiency scores among cassava in Ondo State. The table shows that the highest frequency of maize farmers in the sample (53.75%) have technical efficiencies ranging from 81 to 90%. The implication is that most cassava farmers in Ondo State have at least 18.6% of their potential output lost to inefficiency.

The mean technical efficiency of the cassava farmers was estimated to be 81.4%, indicating that the farmers are inefficient with 18.6%. This indicates that the outputs of cassava farmers in the study area can be increased by 18.6% if they are able to use the resources available to them more efficiently.

CONCLUSION

Cassava is one of the crops that provide staple in Nigeria therefore, there is need to investigate the technical efficiency of farmers in order to ascertain area which need adjustment for improved productivity. This study examines technical efficiency and its determinants of cassava farmers in Ondo State in Nigeria. The study reveals that the mean technical efficiency estimates for cassava farmers 81.4%, this means that cassava farmers in the study area require 18.6% to reach the frontier. Fertilizer also enriches the fertility of the soil, and most improved seeds are high yielding. The study also revealed that technical inefficiency of cassava farmers in Ondo State indicated that sex, increase in level of education, farming experience and co-operative membership, extension visit and access to credit increases technical efficiency of cassava farmers in Ondo State. Male farmers are more technically efficient than female farmers, the higher educational level increase technical efficiency of cassava farmers. Experience of the farmers in cassava production impact positively on the productivity of cassava in the study area. The activities of extension officers aid adoption of improved technologies in cassava production. This can be attributed to the crucial roles' women perform in the domestic and economic life of society which negatively affect their technical efficiency. Furthermore, membership of a farmer in cooperative society will increase the technical efficiency of cassava farmers since it is the easiest means for farmers to acquire credit. While technical efficiency decreases with an increase in family size.

Based on the outcome of this study, it is therefore recommended that the government encourage and fund research fertilizer production. There should be farming education on cassava production, farmers should belong to farmers' co-operative society, more extension officers should be employed, and banks should grant loans to farmers with low interest rate.

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