AN EXAMINATION OF TECHNICAL, ECONOMIC AND ALLOCATIVE EFFICIENCY OF SMALL FARMS: THE CASE STUDY OF CASSAVA FARMERS IN OSUN STATE OF NIGERIA

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ABSTRACT

This study examined empirically production efficiency of cassava farms in Osun state of Nigeria using farm level data. The stochastic frontier production and cost function model was used to predict the farm level technical and economic efficiencies respectively. The predicted technical efficiency and economic efficiency are the basis for estimating allocative efficiency of the farms. Estimated results however, show that cassava farms in the study area exhibit decreasing positive return-to-scale giving the value of return to scale (RTS) of 0.840 obtained from the analysis, meaning that cassava farmers were efficient in allocating their resources. Additionally, the analysis reveal that predicted efficiency measure disaggregated into technical (TE), economic (EE) and allocative efficiency (AE) with a view of examining not only TE but EE and AE when measuring productivity shows that mean TE, EE and AE of 0.903,0.89 and 0.807 were obtained from the analysis respectively meaning that TE appears to be more significant than AE as a source of gain in EE. The policy implication of these findings point to the fact that cassava farms in the study area were efficient in allocating their resources considering their scope of operation and the limited resources.

Key words: Cassava, Smallholder farms, Technical, Economic, Allocative Efficiencies

JEL CLASSIFICATION: Q12

INTRODUCTION

Food has been persistently used as a weapon during wars, national and international politics. Whosoever therefore controls the key to the store house controls the conscience of a hungry man or nation. In view of this, cassava not only serves as food crop, it is a major source of income and employment for rural households in Nigeria. As a food crop, cassava has some inherent characteristics which make it attractive especially to the small holder farmers in Nigeria. Firstly, it is rich in carbohydrates, especially starch, and consequently has multiplicity of end uses. Secondly, it is available all the year round, making it preferable to other more seasonal crops such as grains, peas, beans and other crops for food security, and lastly it is tolerant of low soil fertility and more resistant to drought.Currently, Nigeria is the largest producer of cassava in Africa with an annual production of about 35 million metric tones of tuberous roots [4].

Cassava tubers are mostly processed into cassava flour (lafun), gari and fufu (lafun is dried powered form of cassava, gari is fried granulated form of cassava while fufu is fermented pounded form of cassava) in Nigeria. It can also be cooked or eaten, pounded and consumed in its raw form, most especially the sweet variety. By implication, cassava has become a regular item in household diets in Nigeria. Presently, the crop had achieved an ‘export status’ because of the increasing demand for cassava as industrial raw material abroad. To meet the export demand and domestic demand, Nigeria needs about 150 metric tones of cassava which prompted the Federal government of Nigeria to come out with a policy for cassava production with a view of setting policies that will stimulate domestic production.

Hence, in view of this development, the role of increased efficiency and productivity of cassava farms is no longer debatable but a great necessity in order to reverse the low technical, economic and allocative efficiency of small holder farms in Nigeria, since cassava has the potential for bridging the food gap, as it has been discovered from research that famine rarely occurs where cassava is widely grown [12].

This study is aimed at opening a new dimension to farmers and policy makers on how to increase cassava production by determining the extent to which it is possible to raise efficiency of cassava farms with the existing resource base and available technology in order to address food the production problem in Nigeria. To be useful for policy intervention, the efficiency measurements in this study were disaggregated into technical, allocative and economic efficiencies using stochastic efficiency decomposition frontier analysis.

This paper is organized as follows: section 1 is an introduction and describes the study objectives while study area and data used are presented in section 2. Section 3 describes the conceptual framework to measure both technical, economic and allocative efficiency using the production and cost function framework plus model specification, while section 4 describes results and discussion. In section 5 conclusions and policy implications from the result are drawn.

THE STUDY AREA AND THE DATA

Study area:

Osun state is located in the south western part of the country with a land area of 8,802 square kilometers and a population of 2.2million people [8]. The state is agrarian and well suited for the production of permanent crops such as cocoa and oil palm and arable crops such as maize, yam and cassava because of favorable climatic conditions. The annual rainfall is between 1000 mm and 1500mm with high daily temperatures of about 30^0C. The people are predominantly peasant farmers with a relatively small holding ranging between 0.6-1.1 hectares.

Data collection and sampling technique:

The data used in this study were generated by a cross-sectional survey collected from 200 cassava farmers selected from four Local Government Area (LGAs) of the state which include; Ilubu, Ife-central, Ilesa and Ede using multistage sampling technique. The first stage involved a purposive sampling of four LGAs based on the prevalence of cassava farmers in these areas. The second stage involved a simple random selection of 50 respondents from each LGAs based on the list provided by the extension agents of the state’s agricultural development project (ADP).Data were collected with the aid of a structured questionnaire designed to collect information on output, input and prices of input which serve as basis for computing cost of materials used in course of production. The information colleted include: total output measure in kilogram(kg), labour used in man days, planting materials [kg], farm size in hectares [ha], age of farmer(yrs), average wage rate per man days of labour (naira), average price per kg of planting materials(naira) ,average price of 10kg of agro-chemicals used and price of farm tools in naira (Nigerian currency).

CONCEPTUAL FRAMEWORK \ MODEL SPECIFICATION

Efficiency and Frontier Production Functions:

Farrell [7] provided the impetus for developing the literature on empirical estimation of technical, allocative and economic efficiency. His work led to a better understanding of the concept of the efficiency. He proposed that the efficiency of a firm consisted of these components: technical, allocative and economic efficiencies. Technical efficiency is defined as the ability to produce a given level of output with a minimum quantity of inputs under certain technology. Allocative efficiency refers to the ability to choose optimum input levels for given factor prices. Economic or total efficiency is the product of technical and allocative efficiencies. An economically efficient input-output combination would be on both the frontier function and the expansion path.

Early studies focused primarily on technical efficiency using a deterministic production function with parameters computed using mathematical programming techniques. However, with inadequate characteristics of the assumed error term, this approach has an inherent limitation on the statistical inference on the parameters and resulting efficiency estimates. Aigner, [1] and Meeusen, and Van den Broeck [11] independently developed the stochastic frontier production function to overcome this deficiency.

Model Specification:

The stochastic frontier production function model for estimating farm level technical efficiency is specified as:

$$Y_i = f(X_i; \beta) + \varepsilon_i \quad i = 1,2,\ldots\ldots..n \qquad (1)$$

Here Y_i is output, X_i denotes the actual input vector, β is vector of production function and ε is the error term that is composed of two elements, that is:

$$\varepsilon = V_i - U_i \qquad (2)$$

Where Vi is the symmetric disturbances assumed to be identically, independently and normally distributed as N $(0,\sigma^2_v)$ given the stochastic structure of the frontier. The second component U_i is a one-sided error term that is independent of V_i and is normally distributed as $(0,\sigma^2_u)$, allowing the actual production to fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

Following Jondrow [9], the technical efficiency estimation is given by the mean of the conditional distribution of inefficiency term U_i given ε; and thus defined by:

$$E(U_i|\varepsilon_i) = \frac{\sigma_u \cdot \sigma_v}{\sigma} \cdot \left[\frac{f(\varepsilon_j \lambda \mid \sigma)}{1-F(\varepsilon_i \lambda|\sigma)} - \frac{\varepsilon_i \lambda}{\sigma} \right] \qquad (3)$$

here $\lambda = \sigma_u/\sigma_v$, $\sigma^2 = \sigma^2_u + \sigma^2_v$ while *f* and F represents the standard normal density and cumulative distribution function respectively evaluated at $\varepsilon_j\lambda/\sigma$

The farm –specific technical efficiency is defined in terms of observed output (Y_i) to the corresponding frontier output (Y_i^*) using the available technology derived from the result of the last equation (3) above as:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{E(Y_i|u_i, X_i)}{E(Y_i|u_i=0, X_i)} = E[\exp(-U_i)/\varepsilon_i] \qquad (4)$$

TE takes values within the interval (0,1), where 1 indicates a fully efficient farm.

The stochastic frontier cost functions model for estimating farm level overall economic efficiency is specified as:

$$C_i = g(Y_i, P_i; \alpha) + \varepsilon_i \qquad i = 1, 2, \ldots n. \qquad (5)$$

Where C_i represents total production cost, Y_i represents output produced, P_i represent cost of input, α, represents the parameters of the cost function and ε_i represents the error term that is composed of two elements, that is:

$$\varepsilon_i = V_i + U_i, \qquad (6)$$

Here V_i and U_i are as defined earlier. However because inefficiencies are assumed to always increase costs, error components have positive signs [5].

The farm specific economic efficiency (EE) is defined as the ratio of minimum observed total production cost (C*) to actual total production cost (C) using the result of equation 3 above. That is:

$$EE = \frac{C^*}{C} = \frac{E(C_i|u_i=0, Y_i, P_i)}{E(C_i|u_i, Y_i, P_i)} = E[\exp.(U_i)/\varepsilon] \qquad (7)$$

Here EE takes values between 0and 1.

Hence a measure of farm specific allocation efficiency (AE) is thus obtained from technical and economic efficiencies estimated as:

$$AE = EE/TE. \ [10] \qquad (8)$$

This means that $0 \leq AE \leq 1$.

A Cobb-Douglas functional form is employed to model cassava production technology in this study, because of the following reasons: (I) the functional form has been used in many empirical studies, particularly, those relating

Table 1: Summary Statistics of Variables for Stochastic Production and Cost Function Analysis

Variable	Mean	St.Dev.	Min.	Max.
Cassava produced (kg)	963.41	1,433.86	270.62	1,731.97
Farm size (ha)	0.89	0.72	0.25	1.60
Labour (man days)	281.42	443.15	105.60	368.76
Planting materials (kg)	28.55	17.30	6.50	42.80
Age of farmers(yrs)	59.82	67.53	27	.63
Average wage rate per man days (₦)	56.13	89.82	40	1000
Price per kg of planting materials(₦)	931.69	1,731.41	590	2,450
Aveg. price per 10kg Agro-che.(₦)	430.789	643.41	300	1,600
Price of farm tools(₦)	308.15	431.89	250	600
Total production cost (₦)	23,424.05	36.641.47	8,300	46,900

1US$ =₦145

Table 2: Estimates of Stochastic Frontier Models

Production Function Estimates			Cost Function Estimates		
Variable	**Parameters**	**Coefficients**	**Variable**	**Parameters**	**Coefficients**
Constant	β_0	5.641*(6.94)	**Constant**	α_0	3.565*(9.66)
Farm size	β_1	0.708*(6.94)	Price of labour	α_1	0.134*(5.531)
Labour	β_2	0.385*(2.551)	Price of plant mate.	α_2	0.237*(4.64)
Planting materials	β_3	0.514 (1.647)	Price of Agro-che.	α_3	0.152*(3.293)
Age of farmers	β_4	-0.767(0.699)	Price of farm tools	α_4	1.438*(2.681)
			Cassava produced	α_5	0.803*(2.257)
Variance Parameter			**Variance Parameter**		
Sigma –square	$\sigma^2 = \sigma^2 v + \sigma^2 u$	1.131*(8.705)	Sigma –square	$\sigma^2 = \sigma^2 v + \sigma^2 u$	0.742*(5.48)
Gamma	$\gamma = \sigma^2 u/ \sigma^2$	0.815*(12.76)	Gamma	$\gamma = \sigma^2 u/ \sigma^2$	0.927*(3.93)

Figures in parameters are t-ratio
**Estimates are significant at 5% level of significance.*

Table 3: Elasticities and Return to Scale of the parameters of SFP Function

Variables	Elasticities
Farm size	0.708
Labour	0.385
Planting materials	0.514
Age of farmers	-0.767
RTS	**0.840**

to developing country agriculture[2,3] ;(II) the functional form also meets the requirement of being self-dual that is allowing an examination of economic efficiency.

The Cobb-Douglas functional form for the cassava farm in the study area is specified as follows for the production functions:

$$Y_i = \beta_o + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + V_i - U_i \quad (9)$$

Here Y_i is total output of cassava measured in kg, X_1 is farm size (ha), X_2 is labour (labour days) X_3 is planting materials (kg) and X_4 is age of farmers (yrs).

Also, a Cobb-Douglas cost frontier function for cassava farms in the study area is specified as:

$$C_i = \alpha_0 + \alpha_1 P_{1i} + \alpha_2 P_{2i} + \alpha_3 P_{3i} + \alpha_4 P_{4i} + \alpha_5 P_{5i} + V_i + U_i \quad (10)$$

Here C is total production cost per year; P_1 is the average wage rate per man days of labour, P_2 is the price per kg of planting materials, P_3 is the average price of 10kg of agro-chemicals, P_4 is the average price of farm tools and Y_i is as earlier defined above. The Bs, αs, σs are parameters to be estimated. The frontier functions (production and cost) are estimated through maximum likelihood methods. For this study, the computer programme FRONTIER version 4.1c [6] was used.

However, it should be noted that this computer programme estimates the cost efficiency (CE), which is computed originally as the inverse of equation 7. Hence, farm –level economic efficiency (EE) was obtained using the relationship:

$$EE = 1/\text{ Cost efficiency (CE)} \quad [5] \quad (11)$$

That is EE is the inverse of CE.

RESULTS AND DISCUSSIONS

Production Analysis:

The summary statistics of the variables used for the stochastic production and cost function analyses is presented in Table 1. The average output per farmer per annum was 963.41kg while the analysis of the inputs revealed an average farm size of 0.89ha per farmer an indication that the study covered small-scale, family managed farm units. The average labour used of 281.42 man days shows that cassava farmers depend heavily on human labour to do most of the farming operations as this is also reflected in the percentages shown for labour costs represent 71.9 percent of total production cost. All these findings point to the characteristics nature of subsistence farming that dominate agricultural production in Nigeria.

The analysis of other variables shows that the percentage share of cost of planting materials, cost of agro-chemicals and farm tools accounted for 8.24 percent, 9.35 percent and 10.51 percent of the total production cost respectively.

Productivity Analysis:

Presented in Table 2 are the estimated parameters for the production and cost functions of equation 9 and 10 respectively. However, estimates of the parameters of the stochastic frontier production model revealed that all the estimated coefficients of the variables of the production function were positive except the age of the farmers. The positive coefficients of farm size, labour and planting materials implies that as each of these variables are increased, cassava output increased. While the negative coefficient of age shows that as farmers become aging, cassava output decreases, reflecting the mean age of about 60 years obtained from the analysis. This implies that the farmers are relatively old; hence, they were with no vigor to accomplish the tasks associated with cassava production that depend heavily on human labour as most operation under cassava production in the country are done manually. Farm size and labour are significantly different from zero at 5 percent level of significance.

The return to scale (RTS) analysis which serves as a measure of total resource productivity is given in Table 3. The RTS parameter (0.840) is obtained from the summation of the coefficients of the estimated inputs (elasticites) which indicates that cassava production in the study area was in the stage II of the production surface. Stage II is the stage of decreasing positive return-to-scale, where resources and production were believe to be efficient .Hence, it is advisable that the production units should maintain the level of input utilization at this stage as this will ensure maximum output from a given level of input ceteris paribus.

The estimates of the stochastic frontier cost function are presented in Table 2. The result revealed that all the independent variables conform with the a prior, expectation as all the estimated coefficients (average wage rate per man days of labour, price per kg of planting materials, average price of 10kg of agro-chemicals, average price of farm tools and cassava yield in kg) gave positive coefficients, meaning as these factors increased, total production cost increased ceteris paribus. The result of t – ratio test shows that all the variables are statistically different from zero at 5 percent level of significance.

Table 4: Deciles Range of Frequency distribution of Technical, Allocative and Economic Efficiency Of the farmers

Efficiency level	Technical Efficiency		Economic Efficiency		Allocative Efficiency	
	Frequency	percentage	Frequency	percentage	Frequency	percentage
0.30-0.39	-	-	1	0.5	-	-
0.40-0.49	-	-	1	0.5	2	1
0.50-0.59	-	-	7	3.5	1	0.5
0.60-0.69	1	0.5	25	12.5	12	6
0.70-0.79	9	4.5	38	19	14	7
0.80-0.89	62	32	89	44.5	48	24
0.90-0.99	128	64	39	19.5	123	61.5
Total	200	100	200	100	200	100
Mean	0.903		0.807		0.89	
Std.Deviation	0.049		0.021		0.029	
Minimum	0.686		0.325		0.411	
Maximum	0.981		0.952		0.979	

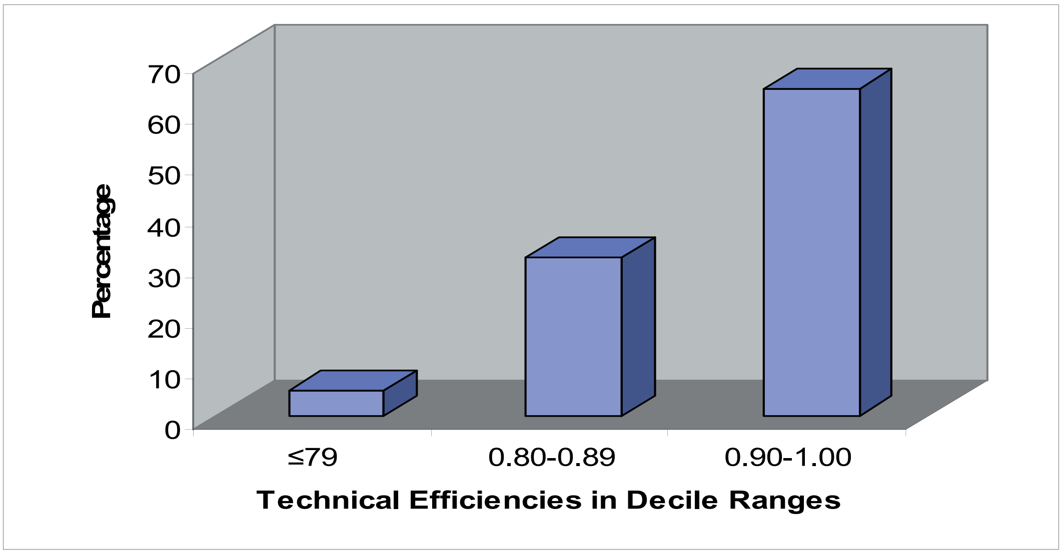

Fig 1: Frequency Distribution of Technical Efficiency

Hence, these variables are important determinant of cassava production in the study area.

Analysis of Production Efficiency:

Technical Efficiency Analysis:

The technical efficiency analysis of cassava production revealed that technical inefficiency effects existed in cassava production in the study area as confirmed by the gamma value of 0.815 that was significant at 5 percent level (Table 2). The gamma (γ) ratio indicates the relative magnitude of the variance σ^2, associated with technical inefficiency effects. Hence, 0.815 implies that about 82 percent variation in the output of cassava farmers was due to differences in their technical efficiencies.

The predicted technical efficiencies (TE) range between 0.686 and 0.981 with the mean TE of 0.903 as presented in Table 4. This means if the average farmer in the sample was to achieve the TE level of its most efficient counterpart, then the average farmer could realize a 7.95 percent cost saving [i.e., 1-(90.3/98.1) x100]. A similar calculation for the most technically inefficient farmer reveals cost saving of 30 percent [i.e., 1-(68.6/98.1)x 100].

In order to give a better indication of the distribution of the technical efficiencies, a frequency distribution of the predicted technical efficiencies is presented in Figure 1. The frequencies of occurrences of the predicted

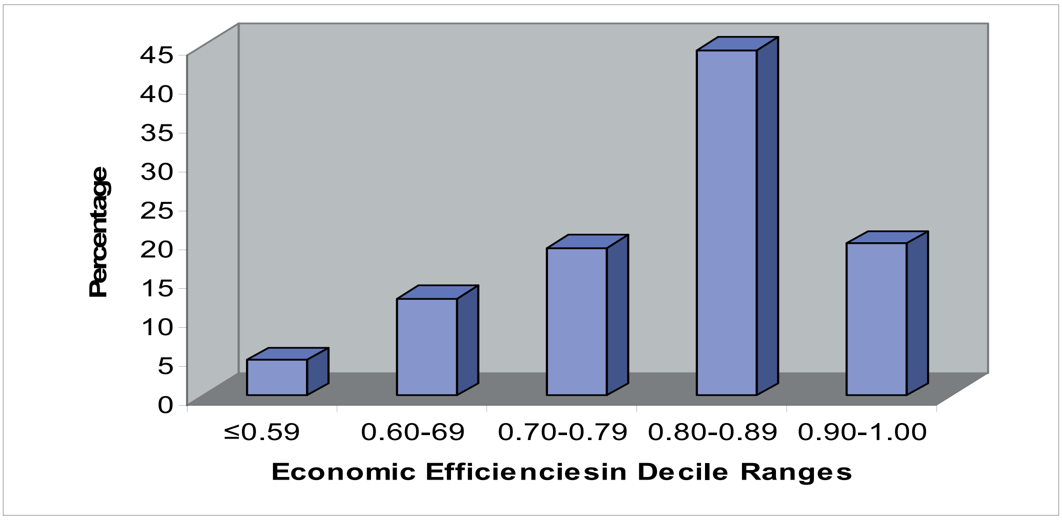

Fig 2: Frequency Distribution of Economic Efficiency

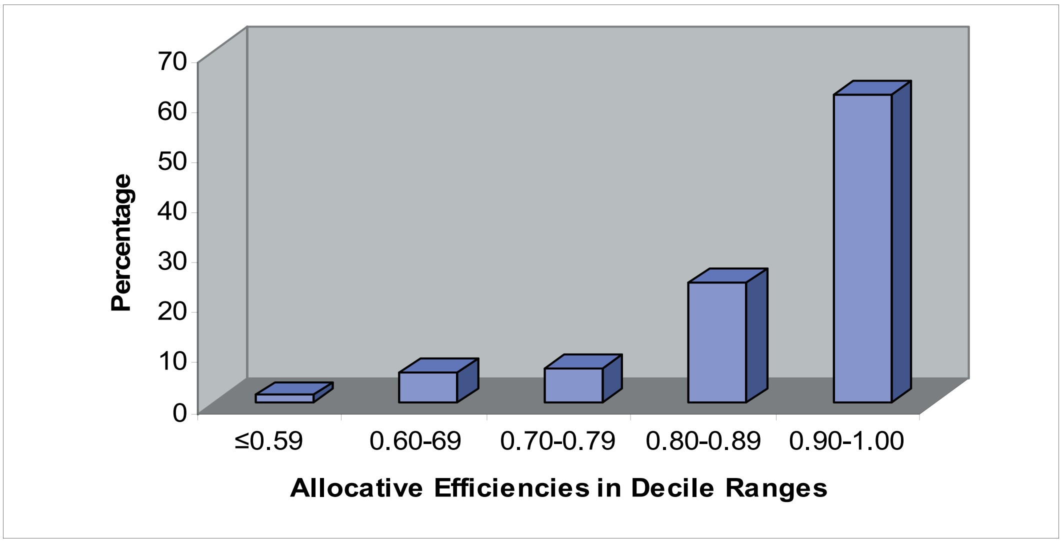

Fig 3: Frequency Distribution of allocative Efficiency

technical efficiencies in decile ranges indicate that the highest number of farmers have technical efficiencies between 0.90 – 0.99. The sample frequency distribution indicates a clustering of technical efficiencies in the region 0.90 – 0.99 efficiency ranges, representing 64 percent of the respondents. This implies that the farmers are fairly efficient. That is, the farmers are efficient in deriving maximum output from input, given the available resources.

Economic Efficiency Analysis:

The economic efficiency analysis of cassava farmers revealed that there was presence of cost inefficiency effects in cassava production as confirmed by the significance gamma value of 0.927 at 5 percent level (Table 4). This implies that about 93 percent variation in the total production cost is due to differences in their cost efficiencies.

The predicted economic efficiencies (EE) estimated as inverse of cost of efficiencies differs substantially among the farmers, ranging between 0.325 and 0.952 with a mean EE of 0.807 as presented in Table 4. This means that if the average farmer in the sample area were to reach the EE level of its most efficient counterpart, then the average farmer could experience a cost saving of 15 percent [i.e. 1-(80.7/95.2) x100].The same computation for the most economically inefficient farmer suggests a gain in economic efficiency of 66 percent [i.e. 1-(32.5/95.20 x100].

And to give a better indication of the distribution of the economic efficiencies, a frequency distribution of the predicted economic efficiencies is presented in Figure 2. The frequencies of occurrence of the predicted economic efficiencies in decile range indicate that the highest number of farmers have economic efficiencies between 0.80 – 0.89, representing about 45 percent of the respondents while 82 percent of the respondents have EE of 0.70 and above which is an indication that farmers are fairly efficient. That is, the farmers are fairly efficient in producing a pre – determined quantity of cassava at a minimum cost for a given level of technology.

Allocative Efficiency Analysis:

The predicted allocative efficiencies differ substantially among the farmers ranging between value 0.411 and 0.979 with the mean AE of 0.893. This implies that if the average farmer in the sample was to achieve AE level of its most efficient counterpart, then the average farmer could realize 9 percent cost saving [i.e. 1-(89.3/97.9) x100]. A similar calculation for the most allocative inefficient farmer reveals cost saving of 58 percent [i.e. 1-(41.1/97.9) x100].

And to give a better indication of the distribution of the allocative efficiencies, a frequency distribution of the predicted allocative efficiencies is presented in Figure 3. The figure reveals that the frequency of occurrence of the predicted allocative efficiencies in decile ranges indicate that a clustering of allocative efficiencies in the region of 0.90 – 0.99 efficiencies range. This implies that the farmers are fairly efficient. That is, the farmers are fairly efficient in producing cassava at a given level of output using the cost minimizing input ratio as about 93 percent of the respondents have AE of 0.70 and above.

SUMMARY AND CONCLUSIONS

This paper used a stochastic efficiency decomposition frontier analysis to estimate and analyse the technical, economic and allocative efficiencies of small holder cassava farmers in Osun State of Nigeria. The analysis reveals an average level of technical, allocative and economic efficiency equal to 90 percent, 89 percent and 81 percent respectively. The results of this study are consistent with "Shultz poor – but – efficient hypothesis" that peasant farmers in traditional agricultural setting are efficient in their resources allocation behaviour giving their operating circumstances [13] when considering the relative size of TE, AE and EE obtained from the analysis, which is a clear indication that average farms in the sample area are technically, allocatively and economically efficient.

The results also point to the importance of examining not only TE, but also AE and EE when measuring productivity at farm level. The implication of these findings (TE, EE and AE) point to the fact that given the production resources at the disposal of the farmers, who are mainly small – scale poor farmers with limited resources, are fairly efficient in the use of their resources giving the result of the frequencies of the predicted efficiencies presented in Table 4 and Figure 1, 2 and 3..

However, an important conclusion stemming from the analysis is that overall economic efficiency (EE) of cassava farms could be improved substantially and that allocative efficiency constitutes a more serious problem than technical inefficiency as TE appears to be more significant than AE as a source of gains in EE. Hence, it is of this view worth pointing out that despite the role higher efficiency levels can have on output, productivity gains stemming from technological innovations remain of critical importance in the agricultural sector of the Nigerian economy. Therefore, efforts directed to generation of new technology should not be neglected.

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