Bulgarian Journal of Agricultural Science, 13 (2007), 185-195
National Centre for Agrarian Sciences

An Examination of Technical, Economic and Allocative Efficiency of Small Farms: The Case Study of Cassava Farmers in Osun State of Nigeria

K. OGUNDARI and S. O. OJO
Dept of Agricultural Economics and Extension, Federal University of Technology, Akure, Nigeria

Abstract

OGUNDARI, K. and S. O. OJO, 2007. An examination of technical, economic and allocative efficiency of small farms: the case study of cassava farmers in Osun state of Nigeria. *Bulg. J. Agric. Sci.*, 13: 185-195

This study examined empirically productive efficiency of cassava farms in Osun state of Nigeria. Using farm level data, the study estimates a stochastic frontier production and cost functions model, which was used to predict the farm level technical and economic efficiencies. The predicted technical efficiency and economic efficiency are the basis for estimating allocative efficiency of the farms. Estimated results shows that cassava farms exhibits decrease positive return to scale judged by 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 ,economic and allocative efficiency with a view of examining not only TE but EE and AE when measuring productivity.However,the results of the predicted efficiency shows that mean TE,EE and AE of 0.903,0.89 and 0.807 were obtained respectively. Meaning that TE appears to be more significant than AE as a source of gain in EE. The policy implication of these findings is 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, Nigeria

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 storehouse 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

e-mail: kogundari@yahoo.com

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 (CBN 2003).

Cassava tubers are mostly processed into cassava flour (lafun), gari and fufu in Nigeria. It can also be cooked or eaten, pounded and consumed in its raw form, most especially the sweet variety. By implication therefore, cassava has become a regular item in household diets in Nigeria. Presently, the crop had achieved an 'export statuses because of the increasing demand for cassava as industrial raw materials abroad. To meet the export demand and domestic demand, Nigeria needs about 150 metric tones of cassava, hence the Federal government of Nigeria has come out with a policy for cassava production with a view of setting policies that will stimulate domestic production. 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 (Nweke et al., 2002).

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 production problem in Nigeria. To be useful for policy intervention, the efficiency measurement in this study were disaggregated into technical, allocative and economic efficiencies.

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

Study Area and the Data

Study area

The state is located in the south western part of the country with a land area of 8.802 squared kilometers and a population of 2.2million people [FOS, 1996]. 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 1000mmand 1500mm with high daily temperature of about 30°C. The people are predominantly pleasant farmers with a relatively smallholding ranging between 0.6-1.1 hectares.

Data collection and sampling technique

The data used in this study were cross-sectional survey collected from 200 cassava farmers selected from four Local

Government Area (LGAs) of Osun state of Nigeria 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.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 compacting cost of materials used in course of production. Information was colleted on total output measure in kilogram(kg), labour used in man days, planting materials [kg], farm size in hectares [ha], age of farmer(yrs), cost of labour (naira), cost of planting materials(naira) and cost of farm tools in naira (Nigerian currency).

Conceptual Framework\Model Specification

Efficiency and Frontier Production Functions

Farrell (1957) 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 which 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 characteristic of the properties of the assumed error term, this approach has an inherent limitation on the statistical inference on the parameters and resulting efficiency estimates. Aigner et al. (1977) and Meeusen and Van den Broeck (1977) 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:

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

Where Y_i is output, X_i is 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 V_i 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 one-sided error term that is independent of V_i and is normally distributed as $(0, \sigma_u)$, allowing actual production to fall below the frontier but without attributing all short fall in output from the frontier as inefficiency.

Following Jondrow et al. (1982), technical efficiency estimation is given by the mean of the conditional distribution of inefficiency term U_i given ε; and thus defined by:

$$E(U_i/\varepsilon_i) = \frac{\sigma u \sigma v}{\sigma}\left[\frac{f(\varepsilon_j \lambda / \sigma)}{1-F(\varepsilon_i \lambda/\sigma)} - \frac{\varepsilon_i \lambda}{\sigma}\right] \qquad (3)$$

Where $\lambda = \sigma_u/\sigma_v$, $\sigma^2 = \sigma^2_u + \sigma^2_v$ 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 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 value on 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:

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

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

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

Where V_i and U_i as defined earlier. However because inefficiencies are assumed to always increase costs, error components are preceded by positive signs (Coelli et al., 1998).

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:

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

EE takes the value between 0 and 1.

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

AE=EE/TE.

(Martin and Taylor, 2003) (8)

That is 0 < AE <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 to developing country agriculture. (Brave-ureta and pinheiro (1997), Ajibefin et al. (2002) e.t.c; (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:

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

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

$$\text{In } C_i = \alpha_o + \alpha_1 \text{InP}_{1i} + \alpha_2 \text{InP}_{2i} + \alpha_3 \text{InP}_{3i} + \alpha_4 \text{InP}_{4i} + \alpha_5 \text{InP}_{5i} + V_i + U_i \qquad (10)$$

Where C; is total production cost per annum; P_1 is cost of labour, P_2 is cost of planting materials, P_3 is the cost of agrochemicals, P_4 is cost of farm tools and $Y_{i;}$

as earlier defined above. The Bs, αs, αs are parameters to be estimated. The frontier functions (production and cost) are estimated through maximum likelihood methods. In addition, for this study, the computer programme FRONTIER version 4.1c was used.

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

$$EE = \frac{1}{\text{Cost efficiency (CE)}} \quad \text{(Coelli et al., 1998)} \qquad (11)$$

That is EE as inverse of CE.

Results and Discussion

Production Analysis

The summary of statistics variable used for the stochastic production and cost function analyses is presented in Table 1. The average output per farmer per annum was 963.41 kg with large variability of 1.433.861 kg. This implies there are large inequalities in output of cassava among the sampled farmers.

Farm size ranged between 0.25ha and 1.60ha with average size of 0.89ha. The average labour used shows that cassava farms used relatively small amount of labour. The mean person-day of 281.42 man days. This is so because farmers in the study area depend heavily on human labour to do most of the farming operations as this is also reflected in the percentage show of labour cost of 71.9 percent out of total production cost.

The analysis of the variable 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

Table 2 presents estimates for the production and cost functions parameters of equation 9 and 10 respectively. However,

Table 1

Summary statistics of variables for stochastic production and cost function analysis

Variable	Mean	St. Dev.	Min.	Max.	% of TC
Cassava produced, kg	963.41	1433.86	270.62	1731.97	-
Farm size, ha	0.89	0.72	0.25	1.60	-
Labour, man days	281.42	443.15	105.60	368.76	-
Planting material, kg	28.55	17.30	6.50	42.80	-
Age of farmers, yrs	59.82	67.53	27	0.63	-
Cost of labour	16841.21	29820.11	4700	31200	71.90
Cost of planting materials	1931.69	3731.41	590	4450	8.24
Cost of Agro-chemical	2189.35	3643.41	1200	5600	9.35
Cost of farm tools	2461.80	4.231.89	1850	4100	10.51
Total production cost (TC)	23424.05	36641.47	8300	46900	

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)	Cost of labour	α_1	0.134*(5.531)
Labour	β_2	0.385*(2.551)	Cost of plant mate.	α_2	0.237*(4.64)
Planting materials	β_3	0.514 (1.647)	Cost of Agro-che.	α_3	0.152*(3.293)
Age of farmers	β_4	-0.767(0.699)	Cost of farm tools	α_4	1.438*(2.681)
			Cassava produced	α_5	0.803*(2.257)
Variance Parameter			Variance Parameter		
Sigma –square	$\sigma^2 = \sigma^2 v +$	1.131*(8.705)	Sigma –square	$\sigma^2 = \sigma^2 v +$	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 .*

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 that of 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 the farmers become aged, cassava output decreases. This finding is in conformity with the mean age of about 60 years recorded in the area which implies that the farmers are relatively old; hence, they were with no vigor to accomplish the task associated with cassava production. Farm size and labour are significantly different from zero at 5 percent level of significance.

The elasticities of production (farm size, labour and planting materials) were positive decreasing function to the factors indicating the variables allocation were in stage II of the production region, meaning that these variables were efficiently utilized in course of cassava production. The return to scale (RTS) analysis is given in Table 3. The RTS of 0.84 implies that cassava production in the study area was in the stage II of the production region, hence, resources and production were efficient at this stage.

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 (cost of labour, cost of planting materials, cost of agro-chemicals, cost of farm tools and cassava yield) 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

Table 3

Elasticities and return to scale of the parameters of SFP function

Variable	Elasticities
Farm size	0.708
Labour	0.385
Planting materials	0.514
Age of farmers	-0.767
RTS	0.84

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

Analysis of Productive Efficiency

Technical Efficiency Analysis

The technical efficiency analysis of cassava production revealed that there was presence of technical inefficiency effects in cassava production in the study area as confirmed by the gamma value of 0.815 that was significance at 5 percent level (Table 2). The gamma (γ) value of 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) ranges 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)x100].

In another development to give a better indication of the distribution of the technical efficiencies, a frequency distribution

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 Minimum	0.049		0.021		0.029	
Maximum	0.686		0.325		0.411	
	0.981		0.952		0.979	

of the predicted technical efficiencies is presented in Figure 1. The frequencies of occurrences of the predicted technical efficiencies in decile range 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

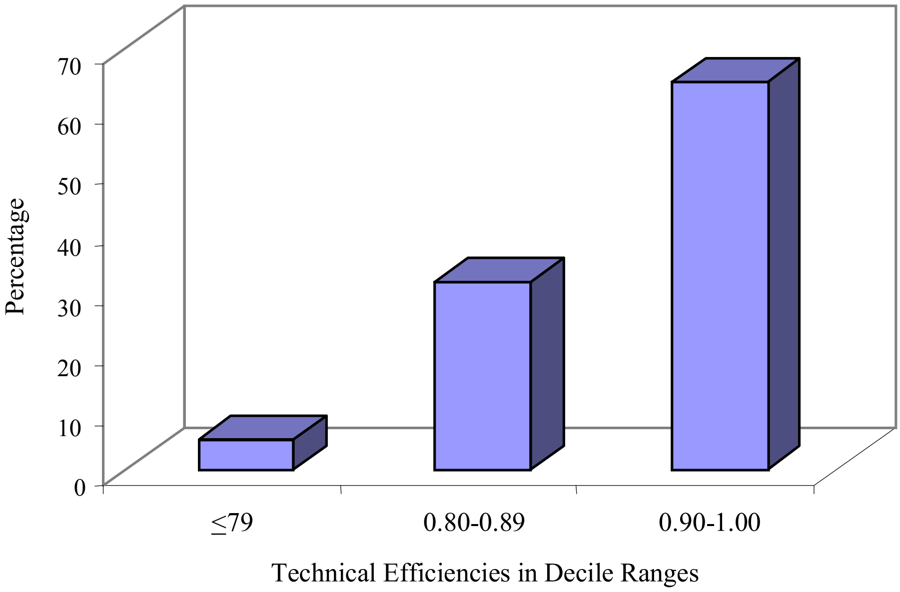

Fig. 1. Frequency distribution of technical efficiency

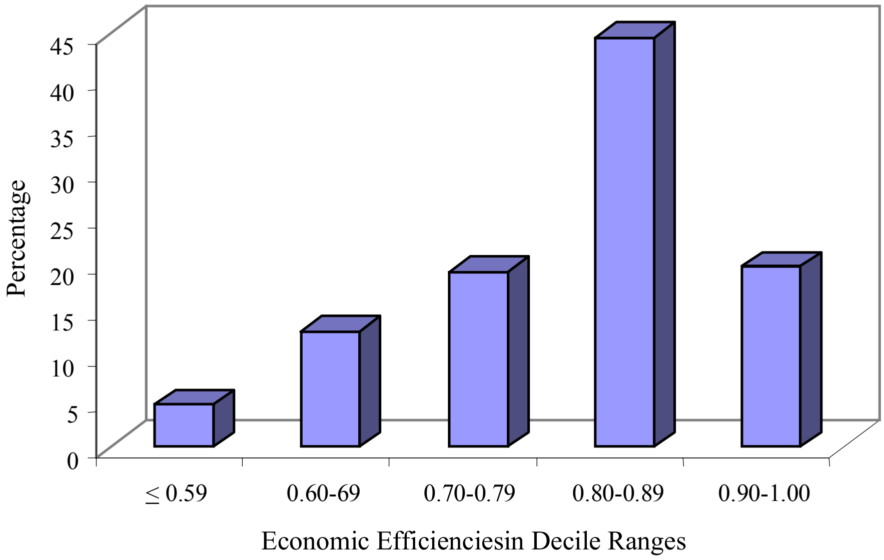

Fig. 2. Frequency distribution of economic efficiency

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.

The implication of these findings (TE, EE and AE) is that given the production resources at the disposal of the farmers, who are mainly small - scale resource poor farmers are fairly efficient in the use of

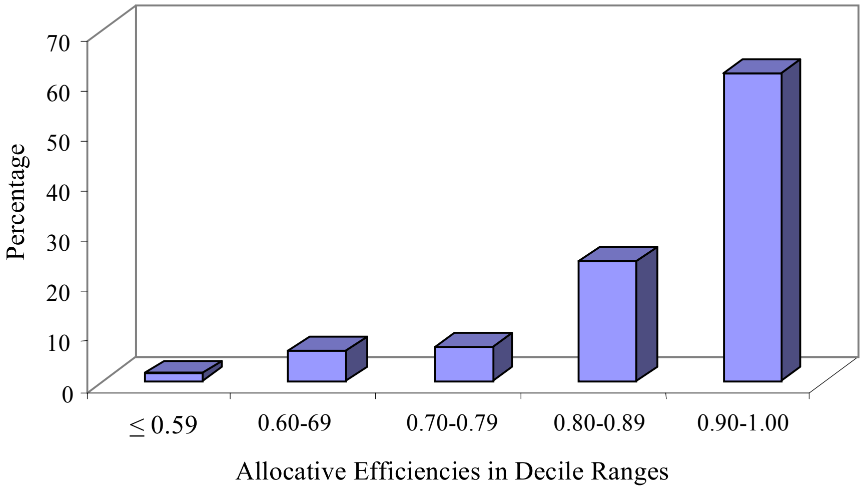

Fig. 3. Frequency distribution of allocative efficiency

their resources. And judged by the result of the frequency of occurrence of the predicted efficiencies presented in Table 4 and Figure 1 2 and 3, it is evident that variation in economics efficiency largely come from difference in allocative efficiency.

Conclusion

This paper used a stochastic production and cost frontier models 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 (Shultz, 1964) 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. 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 that one would like to point out that despite the role higher efficiency level can have on output, productivity gains stemming from technological innovations remain critical importance in agriculture sector of Nigerian economy. Therefore, efforts directed to generation of new technology should not be neglected.

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Received November, 12, 2006; accepted February, 12, 2007.