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Resource-Use and Technical Efficiency of Small Holder Cocoa Producers in Ondo State, Nigeria: A Stochastic Frontier Analysis

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Abstract: This study examined resources-use and technical efficiency of small holder cocoa farmers in Ondo state in the context of stochastic frontier approach. The data used for this study were obtained from a cross-sectional survey of 240 farmers in four Local Governments Area of the state. Estimated results shows that age of cocoa trees and farming experiences have negative elasticities while production exhibits increasing return to scale with RTS value of 1.238. The empirical results shows that technical efficiencies of the farms varied between 0.594-0.887 with mean TE of 0.732, implying average technical efficiency as 65.2% of the differentials between observed and best practiced output among the sampled farms was explained by technical inefficiencies. This is further confirmed by the significance generalized likelihood ratio test of the presence of technical inefficiency and gamma of 0.731.

Key words: Small holder, cocoa, technical efficiency, stochastic frontier

INTRODUCTION

The decline in agriculture in Nigeria in recent time is severely felt in the tree crops sub- sector especially cocoa which accounted for a significant proportion of the agricultural export trade judged by the fact that with respect to total export, agriculture of which cocoa is a major contributor in 60's and 70's contribute nosedived from 71% in 1962-64, 36.1% in 1968-70,4.4% in 1986 to a mere 1.5% in 1995-1996 CBN[1].

Cocoa is a valuable tree crop in Nigeria .The high value is due largely to its significant contribution to Nigeria's economic development. The contribution of cocoa to the national economy as a foreign exchange earner, employment of labour, raw materials, government revenue and component of Gross Domestic product (GPD) have been well documented in literature[2,3]. The main product (cocoa bean) is used as cocoa butter, cocoa cake and powder (which is used in making chocolate and beverages) while the by-products such as cocoa pod husk is used for manufacturing livestock feed, fertilizer, alkali source and native soap, the discarded cocoa bean is used as livestock feed, the coca sweetens used as wine, alcohol products and soft drinks, the cocoa bean shell is used as livestock feeds, putting medicine for nursing seedlings[4].

Cocoa output in Nigeria which peaked at 305,000 tonnes in 1970 dropped to 155,000 tonnes in 1988/89 and 110,000 tonnes by 1990.91. However, by 1996/97 the production level rose to 135,000 and 160,000 in 2000 which is an indication that the outputs have been consistent over the years[5].

In related development, cocoa production has been growing by at least 3% per annum which is still below the 5.5% set in the national rolling plan for 2000-2002. And one the major reasons for the decline in production of cocoa in Nigeria has been attributed to low adoption of modern agronomic practices, relatively low level of productivity of resources-use and technical efficiency in of cocoa farms in the country.

The general objective of this study is to examine the resource-use and technical efficiency of the cocoa farms in the light of efficiency measurement which is important for the following reasons: Firstly, it is a success indicator and performance measure by which production units are evaluated. Secondly, it is only by measuring efficiency and separating its effects from the effects of production environment that one can explore hypothesis concerning the source of efficiency differentials. Thirdly, the ability to quantity efficiency provides the decision maker with a control mechanism with which to maintain the performance of the product system. Increased production and productivity are a direct consequence of efficiency of production resulting from efficiency of input combination given the available technology as this will open a new

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dimension to policy makers on how best to improve upon the present state of cocoa production in Nigeria.

MATERIALS AND METHODS

The study area: The study was carried out in Ondo State. This State lies between longitudes 4° 30¹ and 6° 00¹, East of the green wish meridian and latitude 5° 45¹ and 8° 15¹ North of the equator. The state has a tropical climate with high temperature all the year round. It has heavy rainfall during the rainy season (April to October) and dry wind during the dry season (November to March).This favorable climate account for the reason why about 75% of the inhabitants are farmers. They grow both cash and food crops. The main cash crops are cocoa, kola nut, rubber e.t.c. They also grow food crops like cocoa yam, rice, yam, plantain, maize and tomatoes e.t.c.According to Osamard[6], Ondo state alone produced between 45-65% of the total Nigeria cocoa product in any coca season.

Sampling technique: A multistage sampling technique was used to select 240 cocoa farmers in four Local Government Area (LGAs) of Ondo state. The LGAs purposively selected include Akure North, Idanre, Ile-Oluji and Akoko North-West. The choice of these LGAs is because of the prevalence of cocoa farmers in the areas. The second stage involved a random selection of 60 farmers from each of the LGAs.

The data: Data were collected with the aid of a structured questionnaire. Information was collected on cocoa output per annum measured in kg. Other information collected include; farm size in hectare (ha), labour (Man days), cost of chemicals in naira, age of cocoa farm and farming experience in years.

Theoretical framework/model specification

Theoretical framework: Aigner[7], Meeusen and Van de Broeck[8] and Battese and Corra[9] independently developed the stochastic frontier production function to provide basis for estimating productive efficiency of firms. Their model can be summarized as: y = f(x;) exp V-U. Where y is scalar output, x is a vector of inputs and is a vector of technology parameters.

Measurement of firms' productive efficiency is decomposed in their technical and allocative efficiencies depending either production or cost functional form is specified or both for the firm. Technical efficiency is defined as minimizing input for a given output level or maximizing output with fixed input use while allocative efficiency reflect the ability of a firm to use the inputs in optimal proportions, given their respective price (that is operating at cost-minimizing input ratio).

Model specification: In this study, Battese and Coelli[10] model was used to specify a stochastic frontier production function. This model is specified as follows;

$$Y_i = f(X_a; \beta) + V_i - Ui \qquad (1)$$

Where Y_i is output, X_a donates the actual input vector, β is the vector of production function parameters, V_i and U_i are error terms defined below. The frontier production function is represented by f (X_a, β) and is a measure of maximum potential output for any particular input vector X_a. Both V_i and U_i cause actual production to deviate from this frontier. The random variability in production that cannot be influenced by producers is represented by V_i, it is identically and independently distributed as N (0, σ^2v). The non-negative error term U_i represents deviation from maximum potential output attributable to technical inefficiency which is independent of V_i.It is also assumed to be identically and independently truncated in i instead of zero(half-normal distribution when $\mu = 0$) as N (μ, σ^2u).

Following Jondrow[11] the technical inefficiency estimation of a farm is given by the mean of the conditional distribution of U_i given ε_i as defined by:

$$E(U_i/\varepsilon_i) = \frac{\sigma u \sigma v}{\sigma}\left[\frac{f(\varepsilon_i\lambda/\sigma)}{1-F(\varepsilon_i\lambda/\sigma} - \frac{\varepsilon_i\lambda}{\sigma}\right] \qquad (2)$$

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 Eq. 2 above as:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{E(Y_i \mid u_i, X_i)}{E(Y_i \mid u_i = 0, X_i)} = E[\exp(-U_i)/\varepsilon_i] \qquad (3)$$

The measure of technical efficiency is thus based on the conditional expectation of Eq. 3, given the value of (V_i-U_i) evaluated at the maximum likelihood estimates of the parameters in the model, where the expected maximum value of Y_i is conditioned on U_i = 0 Battese and Coelli[10].TE takes values on the interval (0,1) where 1 indicates a fully efficient farm and the Eq. [exp (-U_i).] says the larger is U_i, the less technical efficient is the farmers.

However, following the adoption of Battese and framework for this study[11], the Cobb Douglas functional form was used to represent the production technology of the cocoa farms in the study area because it is use in many empirical studies particularly those relating to developing countries agriculture, commonly used for its

simplicity e.g. the coefficients serve as parameters of productivity analysis such as elasticity of production and flexibility coupled with the empirical support it has recorded from various industries and countries[12] and as such is specified as follows:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{5} \beta_j X_{ji} + V_i - U_i \quad (4)$$

Where Y_i represents total output per farm per annum in kg; X_1 represents farm size (ha); X_2 represents labour used (man days); X_3 represents cost of agro-chemicals (N); X_4 represents Age of cocoa farm in yrs); X_5 represents farming experience (yrs). The σ^2s, βs, σ^2, σ^2_v, σ^2_u and Meu (μ) are scalar parameters to be estimated. The variances of the random errors, σ^2_v and that of technical inefficiency effects, σ^2_U and overall variance of the model σ^2_S are related as $\sigma^2 s = \sigma^2_v + \sigma^2_u$ and the ratio $\gamma = \sigma^2_u / \sigma^2 s$ represents the share of inefficiency in the overall residual variance with values in the interval (0, 1). A value 1 suggests the existence of a deterministic frontier whereas a value of 0 can be seen as evidence in favour of a Ordinary Least Square (OLS) estimation. In the latter study, no structural inefficiency existence.

The frontier functions were estimated through Maximum Likelihood methods and for this study computer programme frontier version 4.1c[13] was used to estimate the farm specific technical efficiency as defined above and error component which is the basis for estimating Meu (μ).

The null hypothesis test of presence of technical inefficiency effects among the cocoa farms (.H_0: $\gamma = 0$) and presence of half-normal distribution of technical inefficiency estimated for the error component ($H_0 : \mu = 0$) were tested using the generalized Likelihood Ratio (LR) test which is defined by:

$$LR = -2\,[\log(\text{likelihood}(H_0)) - \log(\text{likelihood}(H_1))] \quad (5)$$

Where LR has an approximated chi-square distribution with the degree of freedom equal to the number of parameters excluded in the unrestricted model. H_0 is the null hypotheses that $\gamma = 0$ and $\mu = 0$ given the value of the likelihood function for the frontier model and H_1 is the alternative hypotheses that $\gamma > 0$ and $\mu > 0$, respectively.

RESULTS AND DISCUSSION

Production analysis: The summary statistics of variable of interest, in the analysis is presented in Table 1. They include the sample mean value, standard deviation, minimum and maximum values of the variables. The average cocoa output per farm per annum was 1,700.84 kg. Farm size ranged between 0.845 and 4.18 ha with an average of 1.217 ha and a standard deviation of 2.997. The variability in the farm size is an indication that cocoa farms in the study area in small and medium scales. The mean total family and hired labour used was 499.15 with a standard deviation of 334.45 man days. This is because cocoa farmers depend heavily on human labour to do most of the farming operation as operations in cocoa production have not been mechanized. The average cost of agro-chemicals used was N12, 297.71 while average age of cocoa farm and farming experience were 26.85yrs and 33.93 yrs, respectively.

Table 1: Summary of statistics of variables of stochastic frontier production variables for cocoa farms per annum

Variables	Mean	St.Deviation	Minimum	Maximum
Cocoa output (kg)	1,7004.84	2004.19	322.00	16,200.00
Farm size(ha)	1.217	2.997	0.845	4.18
Labour (man days)	499.15	334.45	161.00	305.00
Cost of agrochemicals(N)	12,297.71	10,735.74	6,700	38,000.00
Age of cocoa farm(yrs)	26.85	18.56	9.00	32.00
Farming Experience(yrs)	32.93	12.09	6.00	38.00

Resources-use efficiency analysis: Based on the model discussed in the previous section, Table 2 presents Ordinary Least Square (OLS) and Maximum Likelihood (ML) estimates of the production function parameters. The OLS function provides estimates of the "average "production function while the ML model yields estimates of the stochastic production frontier. The results revealed that estimated coefficients (model 2) of farm size, labour and cost of agro-chemicals were positive meaning that cocoa output in the sampled area increased as each of these variables increased while the negative coefficient of age of cocoa farm and farming experience implies that output of cocoa produced per annum decreased as each of this variables increased. However, the negative coefficient of farming experience is against the a priori expectation that farmers with more experience tend to be less inefficient while reduction in the level of inefficiency translate to more output. The over use of farming experience can be attributed to the fact that there is large positive correlation with the age of the farmers. The more experience the farmer the older in age and the less productive which can also be attributed to the failure to take risk associated in replacing aged cocoa trees via modern techniques introduced to them by extension agents.

The estimated coefficients are also the elasticity of production of the variables. The elasticities of the independent variables of model 2 presented is Table 3. The elasticity of farm size, labour and cost of agro-chemicals were between zero and unity. This indicates that the allocation and use of each of these variables was in the rational or efficient stage (stage II) of the production region and thus efficiently allocated. The elasticity of age of cocoa farm and farming experience showed decrease negatively returns of the factors. This

Table 2: Estimates of the stochastic frontier production function

Variables	Parameters	Model 1 average-OLS	Model 2 frontier-ML	Model 3 frontier+Error component
Constant	β_0	3.352*(4.562)	3.368*(4.224)	3.373*(3.567)
Farm size (X_1)	β_1	0.448*(11.566)	0.752*(10.829)	0.649*(11.544)
Labour used (X_2)	β_2	0.489*(3.701)	0.499*(3.389)	0.482*(3.783)
Cost of agroche.(X_3)	β_3	0.188*(3.569)	0.240*(3.449)	0.187*(3.551)
Age of cocoa farm (X_4)	β_4	-0.142*(2.509)	-0.239*(2.510)	-0.142*(2.523)
Farming Expe.(X_5)	β_5	-0.086(1.264)	-0.014(1.116)	-0.286(1.221)
Variance parameters				
Sigma square	σ^2s	0.318	0.312*(13.886)	0.312*(4.941)
Gamma	$\gamma = \sigma^2_u/\sigma^2$s	0	0.652*(9.11)	0.731*(2.775)
Meu	μ	0	0	0.087(0.111)
Log likelihood function	Llf	-15.247	-39.451	-19.365

implies that factor were being over used in the production process and thus reducing cocoa output from the farms. To ensure increased production of cocoa from these factors, their usage must be reduced so that it can come back to stage II (stage of efficient factor usage).

Also a t-ratio test of significance at 5% showed that all the variable except farming experienced were significantly different from zero and thus were important determinant in cocoa production in the study area. The Return To Scale (RTS) of 1.238 presented in the lower part of Table 2 implies that cocoa production was in stage I (inefficient stage of the production region). In view of this cocoa production should be expanded by using more of the variable factors most especially farm size, labour and agro-chemicals until RTS would be in stage II product region.

Technical efficiency analysis: The technical efficiency analysis of cocoa farms revealed that there was presence of technical inefficiency effects in the production of cocoa in the study area as confirmed by the significant gamma value obtained from the analysis and generalized likelihood ratio test of hypotheses for the parameters of the stochastic frontier produced function. The gamma value of 0.652 of model 2 in the lower part of Table 2 was significance at 5% level. This implies that the inefficiency effects are highly significant in the analysis of the value of output of the farmers.

The results of testing on various hypotheses of interest are presented in Table 4. The first null hypothesis H_0: $\gamma = 0$, which specifies that the technical inefficiency effects are absent from the model is strongly rejected, indicating that the traditional response function (OLS) is not an adequate representation of the data. The second null hypothesis considered in Table 4, $H_0 : \mu = 0$ specifies that technical inefficiency effects are non-negative at zero or half normal distribution with zero mean and constant variance is strongly accepted for model 2. All these hypotheses point to the fact that cocoa production in study area is not without a significant level of inefficiency.

Table 3: Elasticity of production and return to scale

Variable	X_1	X_2	X_3	X_4	X_5	RTS
Elasticities	0.752	0.499	0.240	-0.239	-0.014	1.238

Table 4: Generalized likelihood ratio tests of hypotheses for the parameters of the stochastic frontier production function

Null hypotheses	Log likelihood	LR	χ^2-tabulated	Decision
H_0: $\gamma = 0$	-39.451	48.41	12.60	Rejected
$H_0 : \mu = 0$	-19.365	8.236	11.91	Accepted

Table 5: Summary statistics of technical efficiency of the farms

Statistics	Mean	St.Deviation	Minimum	Maximum
TE	0.732	0.024	0.594	0.887

The predicted Technical Efficiencies (TE) ranges between 0.594 and 0.887 with mean TE of 0.732 as presented in Table 5. 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 17.5% cost saving [i.e., 1-(73.2/88.7)x100]. A similar calculation for the most technically inefficient farmer reveals cost saving of 39.8% [i.e., 1-(59.4/98.7)]x100]. The implication of the findings above is that given the production resources at the disposal of the farmers, who are mainly small-scale and resource-poor farmers and considering the average farm size obtained from the analysis one could conclude that the farmers are relatively efficient in the use of their resources .However, the result is in line with the findings of Schultz[14] which states that small scale farmers are efficient in the use of their production inputs.

CONCLUSION

This empirical study is on resource-use and technical efficiency of small holder cocoa producers using stochastic frontier production model. The study observed that cocoa production should be expended from, its present level (stage I of production surface) by using more variables factor until RTS gets to stage II. The result further revealed that there was presence of technical inefficiency effects among the farms as confirmed by the generalized likelihood ratio tests performed on the variance parameters with mean TE of 0.732 also recorded meaning that cocoa farms are fairly efficient in allocating their resources.

In conclusion the relative size of TE obtained is an indication that cocoa trees are aging as conformed by the average age of cocoa farm of 26.85 yrs obtained .Hence, in an attempt to improve the present level of technical efficiency of the farms, government through her agency should make it a matter of priority via pubic enlightenment programme by encouraging farmers to adopt the techniques of best practiced in course of production with emphasis on replacing the aged cocoa tress (although gradual replacement) with new one as this in particular will go along way in boosting their future output in no distant time since most farmers are not ready to take the risk of replacing the aged trees considering that fact that their livelihood is attached to the tree year in year out.

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