



Productivity and technical efficiency of oil palm production in Nigeria

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Abstract

Efficiency is an important factor of productivity in a growing economy like Nigeria where there are dwindling resources for adoption of improved technologies for increased production. The objective of this paper was to investigate the productivity and technical efficiency of oil palm production among oil palm farmers in Nigeria using the stochastic frontier production function analysis. Primary data were collected using a set of validated structured questionnaire from 241 oil palm farmers who were selected through multistage random sampling from six local government areas of Edo and Ondo States, Nigeria. Given the specification of the stochastic frontier production function, the null hypothesis that the oil palm farmers were fully technically efficient is rejected since there were presence of inefficiency effects in the model. Results showed that predicted technical efficiencies varied widely across the farms, ranging between 0.463 and 0.999. The study further showed that oil palm production in the study area was generally in the rational stage of production as portrayed by the returns to scale of (RTS) 0.771.

Key words: Productivity, technical efficiency, stochastic frontier production function.

Introduction

There is always an overwhelming consensus in Nigeria, of the need to increase agricultural production so as to meet the ever growing food and industrial demand of a rapidly expanding population which is at a rate more than 2.83% without a corresponding growth of food production estimated at 2.5%, while food demand is estimated as increasing at a rate more than 3.5%¹¹. Agriculture is an important sector of any economy as it is a sure pathway towards reduction of poverty, improved income distribution, rapid industrialization and diversification of foreign exchange earning capacity. Prior to the early 1970s, Nigeria's economy was mainly sustained through agricultural exports. Indeed, most major industries in the world, especially Europe depended on agricultural raw materials from Nigeria and other commonwealth nations in the tropics and export trade in agricultural commodities accounted for over 60% of Nigerian export earnings. Agricultural sector provided the bulk of the gross domestic products (GDP) and it was the largest source of employment providing income for over 70% of the population. With the discovery of oil in the 1970s, however, the Nigeria's former rulers, especially military, failed to diversify the economy away from over dependence on the capital-intensive oil sector, which provides only 20% of GDP, 95% of foreign exchange and about 65% of budgetary revenues. The largely subsistence agricultural sector has failed to keep up with rapid population growth, and Nigeria once a large net exporter of food, now imports food. In order to reverse this trend and allow agricultural sector to occupy once again its prime of place, the existing generally low levels of production and productivity must be addressed.

The crucial role of efficiency in increasing agricultural output has been widely recognized by researchers and policy makers alike. Indeed, considerable efforts have been devoted to the analysis of farm level efficiency in developing countries. An

underlying premise behind most of the work of efficiency is that if farmers are not making efficient use of existing technologies, then efforts designed to improve efficiency would be more cost-effective than introducing new technologies as a means of increasing agricultural output²¹. Efficiency is a very crucial factor of productivity growth especially in developing agricultural economies, where resources are meagre and opportunities for developing and adopting better technologies have lately stated dwindling. Estimates of the extent of inefficiency can help to decide whether to improve efficiency or to develop new technologies to raise agricultural productivity.

The oil palm is an economic crop and from the very earliest times, its products have played a very important role in the socio-economic and political life of the people of Nigeria. Although West African in origin, its importance and utilization transcends the West African sub-region. The Nigerian oil palm produce, chiefly palm oil and palm kernel, helped to fuel the industrial revolution of Europe²⁰. The contribution of the Nigerian oil palm industry was quite enormous at the early stages of Nigerian economic growth. During the first decade of the twentieth century, for instance, the oil palm industry was the engine of growth contributing over 80 percent of the total domestic export earnings annually. This contribution however declined to 54.5 percent in the period 1914-1918 and to less than 20 percent during 1955-1966, mainly as a result of the appearance of crude petroleum oil in Nigeria's economic scene. The dominance of palm oil and palm kernel in the foreign trade and foreign exchange earnings of Nigeria from 1906 to about 1938 are well documented¹² (various issues of Central Bank of Nigeria, 1973-2003).

The decline in the output of oil palm produce over the years has been attributed to technical inefficiency of the farmers among other variables. There has been the consensus of opinion that oil

palm farmers in Nigeria have not been able to produce maximum output from a given set of inputs. This study is therefore set out to investigate the productivity and technical efficiencies of the oil palm farmers in Nigeria with the view to making policy recommendations that would improve the farmers' productivity and technical efficiencies, which are critical conditions for achieving economic efficiency.

Concept of productivity and efficiency: Olayide and Heady¹⁸ defined agricultural productivity as the ratio of total farm output to total inputs used in farm production. Productive efficiency means the attainment of production goal without waste. Beginning with this idea of 'no waste', economists have built up a variety of theories on efficiency. However, the fundamental idea underlying all efficiency measure is that of the quantity of goods produced and service per unit of input.

Efficiency is often used synonymously with that of productivity, which relates output to input. In agriculture the analysis of efficiency is generally associated with the possibility of farms producing a certain optimal level of output from a given bundle of resources or certain level of output at least-cost.

Technical efficiency (in agricultural production) is defined as the ability to produce maximum output from a given set of inputs, given the available technology²². This definition indicates that difference in technical efficiency exists between farms. In a factor-product relationship, the production function presupposes technical efficiency whereby maximum output is obtained from a given level of input combination. One important assumption that relates to efficiency is that efficient farms operate on the outer bound of the production function, that is, on their frontier, while inefficient farms are those operating below the production frontier. The amount by which a farm lies below its production frontier is regarded as the measure of inefficiency.

The stochastic frontier production function in efficiency studies: The stochastic frontier production function was independently proposed by Aigner *et al.*¹, Battese and Corra⁶ and Meeusen and Van den Broeck¹⁴. The modeling, estimation and application of stochastic frontier production functions to economic analysis assumed prominence in econometric and applied economic analysis during the last four decades. Battese and Corra⁶ applied the technique to the pastoral zone of Eastern Australia, and more recently, different empirical applications of the technique in efficiency analysis have been reported^{2-4, 7, 13, 16}.

The stochastic frontier production function assumed that the error term in the regression model is composed of two additive components – random error (v_i) and error due to technical inefficiency effects (u_i). The frontier function is defined as

$$Y = f(X_i \beta + V_i - U_i) \quad (1)$$

where Y = output, X_i = actual input vector, β = vector of production parameter, V_i = random error term. It is independently, identically and normally distributed and independent of U . The U measures the technical inefficiency relative to the frontier. U is assumed to have a non-negative distribution.

The stochastic frontier production function is a measure of maximum potential output for any particular input vector X . The V and U cause actual production to deviate from this frontier. The

variance of the parameters, systematic V_i and one-sided U_i , are δ_v^2 and δ_u^2 respectively and the overall model variance given as δ^2 are related thus,

$$\delta^2 = \delta_v^2 + \delta_u^2 \quad (2)$$

The measures of total variation of output from the frontier, which can be attributed to technical efficiency, are lambda (λ) and gamma (γ)⁶. These variability measures are derived as

$$\lambda = \delta_v / \delta_u \quad (3)$$

$$\text{and } \gamma = \delta_u^2 / \delta^2 \quad (4)$$

On the assumptions that v_i and u_i are independent and normally distributed, the parameters β , δ^2 , δ_v^2 , δ_u^2 , λ and γ will be estimated by the method of maximum likelihood estimation (MLE) using the computer program FRONTIER version 4.1⁹. This program will also compute estimates of technical efficiency. Following Olowofeso and Ajibefun¹⁹, a three-stepwise procedure in estimating the MLE estimates of the parameters of the stochastic frontier production function will then be used.

Materials and Methods

Study area: The study utilized the data obtained from Edo and Ondo states, two of the major oil palm grower states in the South and South-Western regions of Nigeria respectively. The states lie between longitudes 4°30' and 6°40' East of the Greenwich Meridian and latitudes 50°45' and 8° North of the Equator. They are both located in the forest zone with two distinct seasons. The temperature throughout the year ranges 21-29°C while humidity is relatively high. The annual rainfall varies from 2000 mm in the Southern parts to 1150 mm in the Northern parts. The rainfall decreases in amount and distribution from the coast to the hinterland. The states generally enjoy luxuriant vegetation. The high forest zone (rain forest) is found in the South while the Northern fringe is mostly sub-savannah forest. The soils are deep and very fertile, free from iron concretions and well drained.

Data collection: The data for this study were primary data collected from a cross-sectional survey of smallholder and peasant oil palm farmers in 3 purposively sampled local government areas based on high level of oil palm farming from each of the 2 states. Okitpupa, Ondo West and Ile-Oluji/Okeigho local governments were selected from Ondo state, while Ovia South West, Ovia North East and Esan Central local governments were selected from Edo state. From each of the selected local governments, 5 villages were randomly selected through simple random technique and each of the villages was divided into 4 wards out of which 2 wards were also randomly selected. Five farmers were randomly selected from each of the 2 wards and interviewed. A total sample size of 241 farmers was eventually used for final analysis.

Frontier model for the oil palm farmers: The stochastic frontier production function proposed by Battese and Coelli⁵ and used by Yao and Liu²² was applied in the analysis of data to capture the efficiency of oil palm farmers in this study. The technical efficiency (TE) was also estimated by finding the ratio of the observed output (Y_i) to the corresponding frontier output (Y_i^*) given the available

technology, that is

$$Y_i / Y_i^* \text{ i.e. TE} = (\beta_0 + \Gamma\beta_1 X_j + V - U) / (\beta_0 + \Gamma\beta_1 X_j + V) \quad (5)$$

so that $0 \leq TE \leq 1$.

For this study, a general model specified by a Cobb-Douglas function was assumed and was defined as:

$$\ln Y_{ij} = \beta_0 + \Gamma\beta_1 \ln X_{ij} + V_{ij} - U_{ij} \quad (6)$$

where subscript i refers to the observation of the ith farmer and j refers to oil palm production.

Y = total value of oil palm produce in (Naira)

X₁ = farm size (hectare)

X₂ = age of palms (years)

X₃ = total quantity of labour (man days/ha)

X₄ = cost of fertilizers used (kg/ha)

X₅ = cost of agrochemicals (Naira/ha)

X₆ = cost of harvesting and processing (Naira/ha)

V_{ij} = random errors as previously defined

U_{ij} = technical inefficiency effects as previously defined.

ln = natural logarithm (i.e. to base e).

It is assumed that the technical inefficiency measured by the mode of the truncated normal distribution (i.e. U_{ij}) is a function of socio-economic factors²² as given in equation (7) below.

$$U_{ij} = \delta_0 + \delta_1 Z_{1ij} + \delta_2 Z_{2ij} + \delta_3 Z_{3ij} + \delta_4 Z_{4ij} + \delta_5 Z_{5ij} + \delta_6 D_{ij} \quad (7)$$

where U_{ij} = technical inefficiency of the ith farmer and jth observation of the farmer.

Z₁ = age of the farmer (years)

Z₂ = frequency of extension visits per year

Z₃ = years of formal education

Z₄ = years of farming experience

Z₅ = mode of land acquisitions

D = Dummy variable for mode of land acquisition where one denotes land acquired through outright purchase and zero for land acquired through inheritance.

The β_s and δ_s are scalar parameters to be estimated by the method of maximum likelihood. The variance of the random error and that of the technical inefficiency effects δ_u^2 and the overall variance of the model are related thus: $\delta^2 = \delta_v^2 + \delta_u^2$ and the ratio, $Y = \delta_u^2 / \delta_v^2$ measures the total variation of output from the frontier which can be attributed to technical inefficiency⁶. The estimates for all the parameters of the stochastic frontier production function and the inefficiency model are simultaneously obtained using the program Frontier version 4.1⁹.

Two different models were estimated for this study. Model 1 is the traditional response function in which the inefficiency effects are not present. It is a special case of the frontier production function model in which the total variation of output from the frontier output due to technical inefficiency is zero, that is $Y = 0$. Model 2 is the general model where there is no restriction and thus $Y \neq 0$. The two models were compared for the presence of technical inefficiency effects using the generalized likelihood ratio test which is defined by the test statistic, chi-square, $X^2 = 2 \ln \{H_0 / H_a\}$ where X^2 has mixed chi-square distribution with the degree of freedom equal to the number of parameters excluded in the unrestricted model. H_0 is the null hypothesis that $Y = 0$. It is given

as the value of likelihood function for the frontier model and H_a is the alternative hypothesis then, $Y \neq 0$ for the general frontier model.

Results and Discussion

Summary statistics: The summary statistics of variables for the frontier estimation is presented in Table 1. The mean value of oil palm products produced was ₦72,754 per ha/year which when compared with the mean total cost of ₦52,498 showed that oil palm production was profitable in the study area as this result gave a net returns of ₦20,256 per hectare.

The mean farm size was 3.4 hectares per farmer, which means that oil palm production was mainly on a small-scale level in the area. Oil palm in the study area had a mean age of 19.47 years which shows that majority of the palms were still within their economic ages. Omoti²⁰ found the economic age of oil palm to be between 18 and 28 years post planting. The farmers used an average of 115 man days per hectare for all the production operations. This is very high and it shows the fact that the farmers relied more on labour than machines in their operations. The total cost of procurement and application of fertilizer and agrochemicals was ₦9,481 per hectare per year representing just 18.06% of the total production cost per hectare. Harvesting and processing costs was ₦19,944 per hectare.

Farmers in the study area were reasonably educated as only 30% of them did not have either formal or informal education. The mean oil palm farming experience was 20.52 years. High educational standard and long farming experience of the farmers is expected to positively reflect on the productivity and technical efficiencies of the farmers.

Table 1. Summary statistics of selected variables affecting productivity and technical efficiencies of oil palm farms.

Variable	Mean	Standard deviation
Value of oil products per ha (Naira)	72,754	189.6
Farm size (ha)	3.4	2.49
Age of palms (years)	19.47	9.18
Labour per ha (man-days)	115	34.4
Cost of fertilizers (kg/ha)	5,655	14.88
Cost of agrochemicals (Naira/ha)	3,826	11.07
Cost of harvesting & processing (Naira)	19,944	52.48
Education of farmers (years)	7.44	2.07
Oil palm farming exp. (years)	20.52	11.30

Estimates and tests: The maximum likelihood estimates of the stochastic frontier production function for oil palm production in Nigeria are presented in Table 2. The Y estimate associated with the variance of technical inefficiency effects is high as confirmed by a test of hypothesis for the presence of inefficiency effects using generalized likelihood ratio test. The chi-square computed is 8.329 while the critical value of chi-square at 95% confidence level and 6 degree of freedom $X^2(0.95,6) = 1.742$. The null hypothesis of no inefficiency effects in oil palm production $\gamma = 0$, was strongly rejected. Thus Model 1 was not an adequate representation of the data, hence Model 2 was the preferred model for further econometric and economic analysis. The estimated gamma parameter (γ) of Model 2 of 0.999 indicates that almost 99.9% of the variation in the output of oil palm products among the farmers was due to differences in their technical inefficiencies.

The estimated elasticities of the explanatory variables of the

general model (Table 3) shows that farm size, age of palm, cost of fertilizers and agrochemicals and cost of harvesting and processing were positively decreasing, indicating that the variables' allocation and use were in the stages of economic relevance of the production function (Stage 11). The elasticity of labour was negative decreasing function to the factor indicating over utilization. This could be due to the fact that the farmers were employing too much manual labour in the farming activities, especially slashing where they could have conveniently used rotary slashers or even agro-chemicals. The elasticity of scale was 0.326 as presented in Table 3 indicating that the RTS is between zero and unity and it thus implies that oil palm production was in Stage 11 of the production region and thus efficient. Increasing the farm sizes and employing the use of improved technologies in the production activities could improve the productivity of the factors.

Technical efficiency analysis: The predicted farm specific technical efficiencies (TE) ranged between 0.463 and 0.999, with a mean of 0.778 as shown in Table 3. Thus, in the short run, there is a scope for increasing efficiency of oil palm production by about 22.2% by adopting the production technologies adopted by the best technology-friendly oil palm farmer in the area (Table 4).

Technical inefficiency analysis: The analysis of the inefficiency model (Table 2) shows that the signs and significance of the estimated coefficients in the inefficiency model have crucial implications on the TEs of the farmers. The estimated coefficients of age of farmers, extension visits, years of formal education and

farming experience of farmers were positive, indicating that these factors rather than increase the TEs of the farmers rather decreased their TEs, that is, these variables led to increase in technical inefficiencies. The rational expectation is that TE should increase with increased number of years of formal education, years of farming experience and extension contacts as these would have afforded the farmers opportunities to adopt improved technologies and techniques of production¹⁶. This result might have been due to the fact that the more educated and experienced the farmers are, the more they were noticed to have delegated supervision of their farms to inexperienced labour in order to engage in other vocations such as partisan politics, religious and social activities. This result agrees with the findings of Ojo¹⁷.

The positive contribution of age to technical inefficiency is understandable because older farmers would not only possess lesser vigour for supervision but also very few of them believed in the imperatives of adopting new or improved technologies. The coefficient of mode of land acquisition is, however, negative implying that as land acquisition moved from inheritance to outright purchase, the technical efficiency of the farmers increased considerably. The reason for this being that farmers who got their farm lands free of charge through family arrangement or inheritance could not often see themselves as the absolute or permanent owners of such lands, they are therefore, constraint as to the level of improvement and development they could make on such lands. However, when the land is outright purchased, the farmer-owners possess absolute control of such lands and could plan for high level of improvement. Moreover, a farmer who acquired land through his life-savings or even borrowed at high interest rates

Table 2. Estimates of parameters of stochastic frontier production function model.

Variable	Parameter	Model 1	t ratio	Model 2	t ratio
General model					
Constant	β_0	2.732	22.30	2.888	29.98
Farm size	β_1	0.34	3.36	0.088*	14.34
Age of palm	β_2	0.254	3.77	0.230*	6.290
Labour (man days)	β_3	-0.027	-0.34	0.087	1.71
Cost of fertilizer	β_4	0.081	1.46	0.063*	2.18
Cost of agrochemicals	β_5	0.249	-4.90	0.154*	-4.02
Cost of harvesting/processing	β_6	0.004	0.14	0.012	0.65
Inefficiency model					
Constant	δ_0	0		0.118	1.80
Age of farmers	δ_1	0		0.00002*	3.96
Extension visits	δ_2	0		0.019	0.99
Years of formal education	δ_3	0		0.046	0.88
Years of farming exp.	δ_4	0		0.004	0.08
Mode of land acquisition	δ_5	0		-0.084*	-2.25
Variance parameters					
Sigma squared	δ^2	0.25		0.031	7.18
Gamma	γ	0		0.999	263.56
Log likelihood function	LLF	104.81		141.70	

* Estimate is significant at 5% level of significance.

Table 3. Elasticity of production and returns to scale (RTS).

Variable	Elasticity of production
Farm size	0.088
Age of palm	0.230
Labour	0.087
Farm experience	0.063
Extension visits	-0.154
Education	0.012
RTS	0.326

Table 4. Decile range of frequency distribution of technical efficiencies of farmers.

Decile range of TE	Frequency	Percentage
0.40-0.49	2	0.83
0.50-0.59	10	4.15
0.60-0.69	68	28.22
0.70-0.79	54	22.41
0.80-0.89	56	23.23
0.90-0.99	51	21.16
	241	100

would be more innovative and efficient for him to brake even.

Conclusions

The technical efficiency of oil palm farmers varied widely due to the presence of technical inefficiency effects in oil palm production. While the variables of age of farmers, extension visits, years of formal education and farming experience decreased the farmers' technical efficiencies, land acquisition increased their TEs. The results also showed that there is still the possibility of increasing the efficiency of the farmers in the short run by about 22.2%

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