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Advances in Applied Science Research, 2014, 5(3):230-236

ISSN: 0976-8610
CODEN (USA): AASRFC

Estimation of technical efficiency in the translog stochastic frontier production function model: An application to the oil palm produce mills industry in Nigeria

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ABSTRACT

This study estimated the technical efficiency of the small/semi-mechanized oil palm produce millers in Nigeria using the translog stochastic frontier production function model. A multi-stage sampling method was used to select 30 mills in the study area and cost route approach used in data collection. The estimates for the mills showed firm level technical efficiency mean of 70.62 with range of 37.48% to 93.46%. This wide variation in oil palm produce output of millers from the frontier output was found to have arisen from differences in miller's management practices rather than random variability. This also implies that even under the existing technology, potentials exist for improving productive efficiency with proper utilization of available resources. Education, processing experience, membership of cooperative society, credit, capital, fruits throughput, petroleum energy and water were significant and positive determinants of technical efficiency while age, household size and interest on loans were negatively related to technical efficiency. Policies geared towards the enhancement of productive efficiency of this category of producers should appropriately address such issues as education, cooperativeness, and access to credit/capital, oil palms plantation rehabilitation, sustainable petroleum energy and supply of other necessary facilities.

Keywords: Oil Palm, Industry, Produce, efficiency, technical.

INTRODUCTION

The oil palm produce industry has been of considerable importance in the economy of Nigeria over the years. Nigeria has remained one of the leading producers of palm oil and palm kernel commodities in the world. In terms of global rating, Nigeria hitherto produced and exported the largest tonnage of oil palm produce. However, since the early 1970's, the heavy reliance on the petroleum sector of the economy adversely affected the oil palm produce industry in Nigeria. Currently, the South East Asian producers like Malaysia, Indonesia and Philippines have taken over the leading role in the global oil palm production due to intensive cultivation and processing. ([1], [2], [3], [4]). The Nigerian palm oil among others, before the 50s formed the bulk of the "semi-soft" and "hard" oils of commerce, with Free Fatly Acids (FFA) ranging from 12% to 45% or more. The quality of palm oil exported from Nigeria improved between 1951 to 1957, as a result of drop in FFA to not less than 4.5% ([5]). Furthermore the improvement in palm oil quality was attributed mainly to the introduction of pioneer oil mills and with them, other mechanized milling outfits.

In Nigeria, oil palm produce commodities are produced by any of or combination of traditional, hand press, pioneer, small-scale mechanized and turn-key mechanical milling methods. The traditional methods involve the extraction of oil from the ripped fresh fruits without elaborate mechanical aids. It is indigenous, small-scale; though produce oil of low FFA for domestic consumption are responsible for most of the hard oil of trade. ([5]). The small-scale mechanized milling in most cases involve application of engine propelled locally fabricated machines like digester for maceration of sterilized fruits, curb and/or hydraulic press, kernel-fibre separator among others in palm oil and kernel processing. The curb press has rated extraction efficiency of 55-70% and produces oil of FFA below 5%. ([5], [3], [6],). Ninety percent of Nigeria's palm oil productions are from these small-producers using marginal technologies which at best give about 65% extraction efficiency ([5]). The rated capacity of this category of produce business exceed the traditional small-scale subsistence processing and bridges the gap between this stage of oil winning and that of turn-key commercial milling.

The pioneer oil mills are fairly mechanized with rated extraction efficiency of 72-92% ([3]) with FFA as low as 1.5%. These are now obsolete, face scrapping or outright sales to private operators and have given way to highly mechanize large-scale milling plants like ADAPALM, RISONPALM and so on. This category of milling technology though highly efficient, remain highly capital intensive and thus not affordable to the smallholders in the vast rural locations habouring mixtures of oil palm groves. The existence of all these palm produce processing outfits though have improved oil palm produce production in Nigeria, the level has either fluctuated or stagnated and failed to keep pace with the ever-rising demand resulting in seasonal shortages, soaring prices, importation of vegetable oil and its substitutes. This necessitates an analysis of production efficiency of the major processors – the small-scale mechanized category of processors to help in formulating policy measures to reduce the processing constraints in the Nigerian produce industry particularly in Imo State's oil palm belt.

Previous studies ([7-13]), commonly dealt with the maximization of output per unit of input, and have indicated the low level resource productivity and efficiency in the Nigeria agribusiness economy. However, there exist high levels of information gap especially in the oil palm processing industry in Nigeria.

MATERIALS AND METHODS

The prominent oil palms growing states in Nigeria are Imo, Osun, Akwa Ibom, Cross River, Anambra and Oyo States. These were in 1997 with hectarage capacities of 537,000, 411,000, 331,000, 248,000, 215,000 and 202,000 respectively. Their corresponding tonnage production was 122,000, 23,000, 113,000, 121,000, 84,000 and 58,000. ([14]). Imo State was purposively chosen for this study due to it strategic positions in the oil palm produce agribusiness economy of Nigeria. Imo State consists of three agricultural zones, namely Owerri, Orlu and Okigwe. The selection of respondents was on multi-stage pattern and involved both purposive and random sampling techniques. Owerri and Orlu zones have reasonable concentration of plantations and oil palm produce processing business activities and were thus purposively selected for the study. Furthermore two prominent oil palm producing Local Government Areas (LGAs) from each chosen zone were randomly selected. The sampling frame was composed from records of the commercial business registration units, cooperatives offices and lists compiled with the help of the village extension workers based in the respective LGAs. A maximum of eight oil palm produce processors were randomly selected from each of the four LGAs giving a total of 30 respondents. Two oil palm millers were dropped because they were inconsistent all through the seasons. Data were collected with structured questionnaire, using cost-route approach.

Stochastic frontier production function was specified and adopted in data analysis. Drawing from the studies ([15], [12], [16]), the stochastic frontier model is represented as:

$$Yi = f(X_i; \beta) \exp(V_i - U_i) \quad i = 1,2,\ldots, n. \qquad \ldots\ldots (1)$$

Where

Yi = production output of i^{th} miller;
X_i = Vector of input quantities used by the i^{th} firm,
β = Vector of unknown parameters estimated;
f(.) = an appropriate function (in this case, translog frontier)
V_i = the symmetric component of the error term, associated with random factors not under the control of miller.

U_i = the non-negative random variable under the control of the miller. It represents in -efficiency in production relative to the stochastic frontier quantity defined by $f(X_i, \beta) \exp(V_i)$. The random errors, V_i's are assumed to be independently and identically distributed as $N(O, \delta v^2)$ random variables independent of U_is. Given the density function of U_i and V_i the translog stochastic frontier function is estimated by Maximum Likelihood Methods. Technical efficiency of an individual miller is defined in terms of the ratio of the observed output to the corresponding frontier output subject to given technology.

Technical efficiency (TE) = $\ln Y_i / \ln Y_i^*$.
$= f(X_i; \beta) \exp V_i - U_i / f(X_i; \beta) \exp(V_i)$
$= \exp(-U_i)$ ……………………………….. (2)

Where
Y_i = observed output and
Y_i^* = frontier output,
ln = Natural logarithm.
The variance ratio y, explaining the total variation in output from the frontier level of output attributed to technical efficiencies were computed as $y = \delta^2 u / \delta^2$.

The estimation of the stochastic frontier translog production function made it possible to verify whether the deviation in technical efficiencies from the frontier output is due to firm specific factors or due to external random factors. Technically efficient farmers are those that operate on the production frontier and the level by which a processor lies below its production frontier is taken as a measure of technical inefficiency ([12]),. In this work the production function of the small-scale palm oil processors was theoretically assumed to be expressed by the translog frontier production function specified as follows:

$$\text{In } Yi = ao + \sum_{i=1}^{n} ai \text{ In}Xi + {}^{1}/_{2} \sum_{i=1}^{n} \sum_{j=1}^{n} bij \text{ In}Xi \text{ In}Xj + c\ln C + Vi - Ui \quad \text{………………..(3)}$$

Where,
In = the natural logarithm;
$_i$ = i^{th} respondent miller,
γ_i = Output of miller in kilograms (kg),
X= Variable inputs,
X_j = Fixed inputs,
C = Total cost of production,
ao, ai, bi, bij and c are parameters estimated.
V_is = Assumed to be independently and identically distributed normal, random errors, having zero means and unknown variance (δ^2_v).
U_is = Technical efficiency, which are assumed to be independent of V_is.

The translog production function is alternatively defined as follows:

$$\ln Yi = b_o + b_1 \text{ In } X_1 + b_2 \text{ In } X_2 + b_3 \text{ In } X_3 + b_4 \text{ In } X_4 + b_5 \text{ In}X_5 + \tfrac{1}{2} b_6 \text{In}X_1^{\,2} + \tfrac{1}{2} b_7 \text{ In}X^2{}_2 + \tfrac{1}{2} b_8 \text{ In}X^2{}_3 + \tfrac{1}{2} b_9 \text{In}X^2{}_4 + \tfrac{1}{2} b_{10}\text{In}X^2{}_5 + b_{11}\text{In}X_1\ln X_2 + b_{12}\text{In}X_1\text{In}X_3 + b_{13}\text{In}X_1\text{In}X_4 + b_{14} \text{ In}X_1\text{In}X_5 + b_{15}\text{In}X_2\text{In}X_3 + b_{16}\text{In}X_2\text{In}X_4 + b_{17}\text{In}X_2\text{In}X_5 + b_{18}\text{In}X_3\text{In}X_4 + b_{19}\text{In}X_3\text{In}X_5 + b_{20}\text{In}X_4\text{In}X_5 + e \quad \text{……………………………..…………(4)}$$

Where;

In	=	natural logarithm
Y_i	=	output (kg)
X_i	=	oil palm fruits processed (throughput) quantity (kg)
X_2	=	petroleum energy use (litres)
X_3	=	water quantity used (litres)
X_4	=	Capital employed (₦)
X_5	=	labour involved (man-days)
bs	=	coefficients to be estimated.
e	=	error term ($V_i - U_i$)

The determinants of technical efficiency were modeled in terms of the understated variables. The technical efficiency in equation (2) was simultaneously estimated with the determinants of technical efficiency D specified by;

$$Di = do + di\ Z_1i + d_2\ Z_2i + d_3\ Z_3i + d_4Z_4i + d_5Z_5i + d_6Z_6i + d_7Z_7i + d_8\ Z_8i + d_9Z_9i + d_{10}\ Z_{10}i + d_{11}\ Z_{11}i + d_{12}Z_{12}i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where;

Di = technical efficiency of i^th^ miller

ds = unknown scalar parameters to be estimated.

z_1 = age (years)

z_2 = Level of education (years spent in acquiring formal education)

z_3 = palm oil processing business experience. (years)

z_4 = Capital employed (₦); (measure of capitalization) Borrowed in addition to equity and equity capital only

z_5 = Family size (Number of persons feeding from the same household pot and residing together)

z_6 = Mechanization level (Number of machines)

z_7 = Petroleum energy use (measure of mechanization) (quantity in litres)

z_8 = Mill plant and land ownership. (Binary variable, 1 for Owned and 0 for leased)

z_9 = Cooperative membership (1 for membership, 0 for Non membership)

z_{10} = Ownership of oil palm plantation as major source of FFB (1 for Ownership, 0 for Non-ownership).

z_{11} = Credit (₦)

z_{12} = Interest (₦)

It is expected a priori that the coefficients of z_2, z_3, z_4, z_5, z_6,z_7,z_8,z_9 z_{11}>0; z_1, z_{10} z_{12} <0.

RESULTS AND DISCUSSION

Factors Influencing Oil Palm Produce Mills Output

The maximum likelihood estimates of the stochastic translog production frontier are presented in Table 1. The results show that the variance ratio parameter (γ) is statistically greater than zero and large (0.9614), implying that variation in oil palm produce mill output from maximum output between millers mainly arose from differences in millers' practices rather than random variability. These factors are under the control of the miller and the influence of which can be altered to enhance technical efficiency of the millers.

The result also shows that the coefficients of quantity of fruits processed (throughput) (X_1), petroleum energy use (X_2), water (X_3), Capital (X_4) and labour (X_5) were positive as expected and statistically significant, implying that increase in the magnitude of these inputs increased oil palm produce mills output.

The interaction between fruit throughput and petroleum energy use ($\ln x_1 \ln x_2$) was positive and significant at 1%, implying that the more fruit throughput and petroleum energy used, the higher the oil palm produce mills output. The interaction between fruit throughput and capital ($\ln x_1 \ln x_4$) was positive and significant at 1%, indicating that increases in the use of fruit throughput and capital increased the oil palm produce mills output.

The interaction between fruit throughput and labour ($\ln x_1 \ln x_5$) was positive and significant at 5%, implying that increases in the joint use of fruit throughput and labour leads to increases in oil palm produce mills output.

The coefficient of interaction between petroleum energy and capital ($\ln x_2 \ln x_4$) was positive and significant at 1%, implying that increases in the joint use of petroleum energy and capital leads to increase in oil palm produce mills output.The coefficient of interaction between petroleum energy and labour was positive and significant at 1%, implying that increases in the joint use of petroleum energy and labour leads to increases in oil palm produce mills output. The coefficient of interaction between capital and labour ($\ln x_4 \ln x_5$) was positive and significant at 5%, indicating that increases in the joint use of capital and labour leads to increases in oil palm produce mills output. The translog function produced a chi-square value of 39.27 which was high, indicating that the model had a good fit to the data.

Table 1: Maximum Likelihood Estimates of Stochastic Translog Production Frontier of the oil palm produce millers

Variable	Coefficient	t-ratio
Intercept	29.6527	4.1816**
Lnx_2	0.0739	2.4799*
Lnx_3	0.0993	2.3039*
Lnx_4	0.0715	3.0114**
Lnx_5	0.0857	4.1202**
$½lnx_1^2$	0.0713	3.3791**
$½lnx_2^2$	0.0529	2.6853**
$½lnx_3^2$	0.0213	3.6769**
$½lnx_4^2$	0.0592	2.7156**
$½lnx_5^2$	0.0755	2.9377**
Lnx_1lnx_2	0.0227	2.6706**
Lnx_1lnx_3	0.0183	1.0339
Lnx_1lnx_4	0.0799	2.7647**
Lnx_1lnx_5	0.0164	2.3099*
Lnx_2lnx_3	0.0655	1.1064
Lnx_2lnx_4	0.0198	2.6053**
Lnx_2lnx_5	0.0553	2.6976**
Lnx_3lnx_4	0.0718	1.0301
Lnx_3lnx_5	0.0352	0.9539
Lnx_4lnx_5	0.0427	2.1566*
Log-likelihood function	-106.2715	
Sigma square (δ^2)	0.9123	3.8194**
Lambda (λ)	4.7435	3.5999**
Gamma (γ)	0.9614	3.9847**
δ^2u	0.8529	
δ^2v	0.1412	
Sample size (n)	30	

Source: *computed from survey data, 2005.*
* = *Significant at 5 % level*
** = *Significant at 1 % level*

Technical efficiency of the smallholder palm oil millers

Table 2: Frequency distribution of millers technical efficiency estimates

Technical efficiency range (%)	Frequency	Percentage
31-40	3	10.0
41-50	0	0.0
51-60	4	13.3
61-70	8	26.7
71-80	6	20.0
81-90	8	26.7
91-100	1	3.3
Total	30	100
Mean Technical Efficiency		**70.62**
Minimum Technical Efficiency		**37.48**
Maximum Technical Efficiency		**93.46**

Source: *Survey data, 2005*

The frequency distribution of technical efficiency of oil palm produce millers is presented in Table 2. Individual technical efficiency indices ranged between 37.48% and 93.46% with a mean of 70.62%. Results also show that 26.7%, 26.7% and 20% of the oil palm produce millers had technical efficiency indices ranging between 81-90 percent, 61-70 percent and 71-80 percent respectively. The much variation in the millers technical efficiency from the frontier level as revealed by the analysis imply that the oil palm produce millers are not fully technically efficient in resource use. This result further suggests that there are still opportunities to increase productivity and income through increased efficiency in resources utilization by palm oil millers in Imo State.

Sources of technical efficiency

The estimated determinants of technical efficiency of the oil palm produce millers in Imo State are presented in Table 3. The coefficient of age was negative and significant; indicating that as the miller's age increases, his technical efficiency decreases. The coefficient of education was positive and significant at 5% level, implying that increase in level of education increases technical efficiency of the palm oil miller. The coefficient of processing business experience was positive and significant at 5% level, indicating that, as a miller's processing experience increases, his technical efficiency equally increases. The coefficient of capital employed was positive and significant at 1% level, suggesting that as the level of capitalization of a miller is enhanced, his technical efficiency increases. The coefficient of family size was positive and significant at 1% level, indicating that as the family size of a miller increases, his technical efficiency increases.

Table 3: Estimated determinants of technical efficiency of oil palm produce millers in Imo State

Variable	Parameter Estimates	t-ratio
Constant term	19.2064	6.1525**
Age (Z_1)	-0.7913	-1.3159
Education (Z_2)	0.5024	4.8447**
Processing Experience (Z_3)	0.1791	2.1815*
Capital Employed (Z_4)	0.3942	3.5546**
Net Income (Z_5)	0.2065	3.3687**
Mechanization Level (Z_6)	0.0892	2.8317**
Petroleum Energy (Z_7)	0.0749	3.4516**
Mill Ownership (Z_8)	0.0843	2.4577*
Cooperative Membership (Z_9)	0.0417	3.6579**
Plantation Ownership (Z_{10})	-0.0955	-1.1718
Credit (Z_{11})	0.0573	2.7681**
Interest (Z_{12})	-0.0483	-2.3111*

Source: *Computed from field survey, 2005 * Significant at 5% ** Significant at 1%*

The coefficient of petroleum energy use was positive and significant at 1% level, implying that as the amount of petroleum energy used in processing increases, the technical efficiency also increases. This is indicative of intensity of operations using machines. The more the mill processes using engine powered machines the more diesel energy consumption. The coefficient of mill ownership was positive and significant at 1% level, implying that mills operated by their owners have higher technical efficiency than mills operated by labourers.

These results show that these variables are important factors affecting the technical efficiency of oil palm produce millers in Imo State. The result further shows that the coefficients of gender (X_6), cooperatives membership (X_9) and oil palm plantation ownership were not significant at 5% level, implying that these variables are not important factors affecting the technical efficiency of oil palm produce millers in Imo State

CONCLUSION

The results of this study showed that the small-scale oil palm produce millers under their existing level of technology were not fully technically efficient. They had Mean technical efficiency of 70.65%, and range of efficiency of 37-48% -93.46%. These imply the existence of wide variation of output below their production frontier and indicate the existence of potentials for improving productivity with proper allocation of their existing resources. This variation was also found to be associated with the millers' practices of controlling their productive resources rather than random variability.

Therefore the formulation and judicious enforcement of policies on relevant aspects of education/training, encouragement of formation of cooperatives, injecting capital resources into the industry, encouraging the youths especially those already experienced in the business and liberal provision of social facilities in the rural areas to attract and retain some young category of labour and entrepreneurs for production activities. These variables have been found to influence the technical efficiency of palm produce millers in the study area and their adequate consideration and/or supply by the relevant stakeholders is recommended.

Acknowledgements
We sincerely acknowledge the following institutions and organizations in Nigeria, for the assistance given us during the conduct of this study; Imo State Polytechnic Umuagwo, Michael Okpara University of Agriculture Umudike Abia State Nigeria, Imo State Agricultural Development Programme and Oil Palm Millers Association.

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