Technical Efficiency of Small-Holder Cocoyam Farmers in Anambra State, Nigeria, Using a Translog Stochastic Frontier Production Function

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TECHNICAL EFFICIENCY OF SMALL-HOLDER COCOYAM FARMERS IN ANAMBARA STATE, NIGERIA, USING A TRANSLOG STOCHASTIC FRONTER PRODUCTION FUNCTION

BY

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ABSTRACT

This study employed a translog stochastic frontier production function to measure the level of technical efficiency and it's determinants in small-holder cocoyam production in Anambara state, Nigeria. Multi-stage random sampling technique was used to select 120 cocoyam farmers in the state in 2005 from whom input-output data were obtained using the cost-route approach. The parameters of the stochastic frontier production function were estimated using the maxim likelihood method. The results of the analysis shows that individual farm level technical efficiency ranged between 69.01% and 98.42% with a mean of 92.96%. The study found farm size, farming experience, use of fertilizer and membership of farmers association/cooperative societies to be positively related to technical efficiency while no significant relationship was found between technical efficiency and age, education, extension contact, household sizes and credit.

Key words: Translog Stochastic Frontier Production Function and Technical Efficiency.

I INTRODUCTION

Cocoyams (*Colocasia* and *Xanthosoma* spp) are stem tubers that are widely cultivated in both the tropical regions of the world. Nigeria is the largest producer of cocoyam in the world accounting for about 40% of the total world output of cocoyam (Eze and Okorji, 2003). Cocoyam ranks third in importance after cassava and yam among the root and tuber crops cultivated and consumed in Nigeria (Udealor et al, 1996). It is an important staple food crop commonly grown by women in Nigeria.

Nutritionally, cocoyam is superior to cassava and yam in the possession of higher protein, mineral and vitamin contents as well easily digestible starch (Parkinson, 1984, Splitstoesser et al, 1973).It is highly recommended for diabetic patients, the aged, children with allergy and for other persons with intestinal disorders (Plucknet, 1970). Cocoyam can be used as an industrial raw material in the manufacture of alcohol and drugs (Okwuowulu et al 2000). The food energy yield of cocoyam per unit land area is high (Parkinson, 1984).

Some of the advantages of cocoyam cultivation are that it has no vines to stake as in yams, (*Dioscovea* spp), no strong obstructing stems as in cassava (*Manihot* spp) and no entangling vines like in sweet potato (*Ipomea* spp), (Ndom et al, 2003). In addition, cocoyam has good potential for easy mechanization (Enyinnaya, 1972).

Inspite of the many potentials and advantages of cocoyam production, the crop is treated as a minor crop in Nigeria ranking behind cassava and yam as root crops, Research and development have been meagre compared with other tropical root crops while cocoyam is mainly grown by resource poor farmers largely women. Cocoyam production in Nigeria is labour intensive with most operations carried out manually at the traditional level. There is a dearth of information on the economics of cocoyam production in Nigeria.

The objective of this study is to measure the level of technical efficiency and its determinants in cocoyam production in Anambra State, Nigeria using stochastic frontier translog production function. Technical efficiency here refers to the ability to produce the highest level of output with a given bundle of resources (ability to produce on the production frontier).

II MATERIAL AND METHODS

(a) **The Theoretical Model:** A stochastic frontier production function is defined by:

$$Yi = f(Xi;\beta)\exp(Vi-Ui), \quad i = 1,2 \ldots n \qquad (1)$$

Where Yi is output of the i-th farm, Xi is the vector of input quantities used by the i-th farm, β is a vector of unknown parameters to be estimated, f( ) represents an appropriate function (e.g Cobb Douglas, translog etc). The term Vi is a symmetric error, which accounts for random variations is output due to factors beyond the control of the random variations is output due to factors beyond the control of the farmers e.g weather, disease outbreaks, measurements errors etc, while the term Ui is a non negative random variables representing inefficiency in production reolative to the stochastic frontier. The random error Vi is assumed to be independently and identically distributed as $N(o, \sigma_v^2)$ randon variables independent of the Uis which are assumed to be non negative truncation of the $N(o,\sigma_u^2)$ distribution (i.e half-normal distribution) or have exponential distribution.

This stochastic frontier model was independently proposed by Aigner,Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977). The technical efficiency of an individual farmer is defined in terms of the ratio of the observed output to the corresponding frontier output, given the available technology.

Technical efficiency (TE) = Yi/Yi*

$$= f(Xi; \beta) \exp (Vi-Ui) / f(Xi, \beta) \exp (Vi) = \exp (-Ui) \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Where Yi is the observed output and Yi* is the frontier output. The parameters of the stochastic frontier production function are estimated using the maximum likelihood method.

(b) **The Empirical Model :** For this study, the production technology of cocoyam farmers in Anambra State, Nigeria is assumed to be specified by the Translog frontier production function defined as follows

$$\text{In } Q = b_o+b_1\text{In}X_1+b_2\text{In}X_2+B_3\text{In}X_3+b_4\text{In}X_4+b_5\text{In}X_5+b_6\text{In}X_6+1/2b_7(\text{In}X_1)^2+ 1/2b_8(\text{In}X_2)^2 + 1/2b_9(\text{In}X_3)^2 +1/2b_{10}(\text{In}X_4)^2+1/2b_{11}(\text{In}X_5)^2 +1/2b_{12}(\text{In}X_6)^2 + b_{13}\text{In}X_1\text{In}X_2 +b_{14}\text{In}X_1\text{In}X_3 + b_{15}\text{In}X_1\text{In}X_4 + b_{16}\text{In}X_1\text{In}X_5 +b_{17}\text{In}X_1\text{In}X_6 +b_{18}\text{In}X_2\text{In}X_3 +b_{19}\text{In}X_2\text{In}X_4 + b_{20}\text{In}X_2\text{In}X_5 + b_{21}\text{In}X_2\text{In}X_6 +b_{22}\text{In}X_3\text{In}X_4 +b_{23}\text{In}X_3\text{In}X_5 +b_{24}\text{In}X_3\text{In}X_6 + b_{25}\text{In}X_4\text{In}X_5 + b_{26}\text{In}X_4\text{In}X_6 +b_{27}\text{In}X_5\text{In}X_6 + Vi - Ui \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where Q is output of cocoyam in kg., X_1 is farm size in hectares, X_2 is labour input in mandays, X_3 is fertilizer input in kg, X_4 is cocoyam setts planted in kg, X_5 is capital input in naira made up of depreciation charges on farm tools and equipment interest on borrowed capital and rent on land, X_6 is other inputs in naira, b_0, b_1, b_2 ….. b_{27} are regression parameters to be estimated while Vi and Ui are as defined earlier. In addition, Ui is assumed in this study to follow a follow a half normal distribution as is done in most frontier production literature.

(c) Determinants of Technical Efficiency: In order to determine factors contributing to the observed technical efficiency in cocoyam production, the following model was formulated and estimated jointly with the stochastic frontier model in a single stage maximum likelihood estimation procedure using the computer software Frontier Version 4.1 (Coelli, 1996).

$$TEi := ao + a_1Z_1 + a_2Z_2 + a_3Z_3 + a_4Z_4 + a_5Z_5 + a_6Z_6 + a_7Z_7 + a_8Z_8 + a_9Z_9 \;\ldots\ldots \qquad (4)$$

Where TEi, is the technical efficiency of the i-th farmer, Z_1 is farmers age in years, Z_2 is farmers level of education in years, Z_3 is the number of extension contacts made by the farmer in the year, Z_4 is household size, Z_5 is farm size in hectares , Z_6 is farmer's farming experience in years, Z_7 is fertilizer use, a dummy variable which takes the value of unity for fertilizer use and zero otherwise, Z_8 is credit access, a dummy variable which takes the value of unity if the farmer has access to credit and zero otherwise, Z_9 is membership of farmers associations/cooperative societies, a dummy variable which takes the value of unity for members and zero otherwise while $a_0, a_1, a_2 \ldots a_9$ are regression parameters to be estimated. We expect a_2, a_3, a_5, a_6, a_7, a_8 and a_9 to be positive and a_1 and a_4 negative.

(c) The Data: Anambra State in one of the 36 states of Nigeria and is located in the South Eastern zone of the country. It was created in 1991 with a population figure of 2.767 million people (National Population Commission, 1991) and a land mass of 4415.54 square kilometres, 70% of which is rich for agricultural production (Nkematu, 2000). The state is divided into four agricultural zones of Aguata, Anambra, Awka and Onitsha . The zones are further delineated into 24 extension blocks and 120 circles. Farming is the predominant occupation of the people, majority of who are small holders. The major available crops are yam, cassava, rice, maize, cocoyam, cowpea, tomatoes and vegetables, while the livestock produced in the state include poultry, sheep, goats and to some extent pig.

Three out of the four agricultural zones were purposely selected on the basis of the intensity of cocoyam production. The selected zones were Aguata, Awka and Onitsha. Three extension blocks were randomly selected from each agricultural zone and 4 circles from each block. Finally 10 farmers were randomly selected from each circle for detailed study, giving a total sample size of 120 farmers in the state. Data were collected by means of structured questionnaires on the socio-economic characteristics of the farmers, and their production activities in terms of inputs, output, and their prices for the year 2005 using the cost-route approach.

III RESULTS AND DISCUSSION

(a) **Average Statistics of Cocoyam Farmers:** The average statistics of the sampled cocoyam farmers are presented in Table 1. On the average, a typical cocoyam farmer in the state is 50 years old, with 4 years of education, 13 years of farming experience and an average household size of 12 persons. The average cocoyam farmer cultivated 0.27 ha, made an average of 2 extension contacts in the year, used about 21.74kg of fertilizer and 250kg of cocoyam setts, spent about ₦2405 on capital inputs, employed 41.8 mandays of labour and produced an output of 1691kg of cocoyam per annum. Cocoyam production in the state is a female dominated occupation as about 74% of the farmers were females.

(b) **Estimated Production Functions:** The Maximum Likelihood (ML) estimates of the stochastic frontier translog production parameters for cocoyam are presented in Table 2.The coefficients of farm size and cocoyam setts have the desired positive signs and are statistically significant showing direct relationship with output. However the coefficients of labour (X_2), fertilizer (X_3),

Table 1 Average Statistics of Cocoyam Farmers in Anambra State, Nigeria, 2005

S/No	Variable	Mean Value	Maximum Value	Minimum Value
1	Farm size (ha)	0.27	1.50	0.01
2	Labour (mandays)	41.8	141.3	5.76
3	Fertilizer input (kg)	21.74	96.4	0
4	Cocoyam setts (kg)	250.25	2551	50
5	Capital input (₦)	2405.1	11300	176
6	Age (yrs)	50	75	24
7	Education (yrs)	4	10	0
8	Farming Experience (yrs)	13	50	3
9	Household size (No)	12	18	4
10	Output (kg)	1691	10,907	68
11	Extension Contacts (No)	2	8	0
12	Other inputs (₦)	111.86	750	0
13	Female farmers (%)	74	_	_

Source: Field Survey, 2005

capital (X_5) and other inputs (x_6) are negative and statistically significant with the exception of the coefficient of other inputs indicating indirect relationship with output.

Among the second other terms, the coefficients of the square term for farm size ($(^1/_2 \ InX_1)^2$), and those of the interactions of labour and capital (InX_2InX_5), labour and other inputs (InX_2InX_6), and fertilizer and cocoyam sett (InX_3InX_4) are positive and statistically significant showing direct relationship with output. Conversely, the coefficients for the square terms of labour, fertilizer and cocoyam sett as well as the interaction of farm size and fertilizer (InX_1InX_3),

Table 2. Estimated Translog Stochastic Frontier Production Funtion for Cocoyam in Anambra State, Nigeria, 2005.

Variables	Parameters	Estimates	t-ratios
Constant term	b_0	18.259	17.627***
Farm size (InX_1)	b_1	4.518	15.382***
Labour input (InX_2)	b_2	-1.498	-1.688*
Fertilizer (InX_3)	b_3	-0.377	-1.739*
Cocoyam Sett (InX_4)	b_4	1.443	2.174**
Capital Input (InX_5)	b_5	-3.036	-5.604***
Other Inputs (InX_6)	b_6	-0.131	-0.707
½ $(InX_1)^2$	b_7	0.623	11.381***
½ $(InX_2)^2$	b_8	-0.419	-1.506
½ $(InX_3)^2$	b_9	-0.045	-1.702*
½ $(InX_4)^2$	b_{10}	-0.246	-2.207**
½ $(InX_5)^2$	b_{11}	0.045	0.568
½ $(InX_6)^2$	b_{12}	0.007	0.443
InX_1 InX_2	b_{13}	-0.084	-0.818
InX_1 InX_3	b_{14}	-0.110	-4.543***
InX_1 InX_4	b_{15}	0.079	0.968
InX_1 InX_5	b_{16}	-0.528	-7.309***
InX_1 InX_6	b_{17}	0.024	0.944
InX_2 InX_3	b_{18}	-0.017	-0.447
InX_2 InX_4	b_{19}	-0.057	-0.444
InX_2 InX_5	b_{20}	0.563	5.521***
InX_2 InX_6	b_{21}	0.109	3.881***
InX_3 Inx_4	b_{22}	0.073	2.844***
InX_3 InX_5	b_{23}	0.013	0.444
InX_3 InX_6	b_{24}	-0.073	-1.164
InX_4 InX_5	b_{25}	0.033	0.467
InX_4 InX_6	b_{26}	0.002	0.110
InX_5 InX_6	b_{27}	-0.064	-3.341***
Log Likelihood	Function	-35.032	
Sigma squared	σ^2	4.517	6.613***
Gamma	γ	0.397	3.390***
Sample size	n	120	

* = Significant at 10%, ** = Significant at 5% , *** = Significant at 1%

farm size and capital (InX_1InX_5), and capital and other inputs (InX_5InX_6) are negative and significantly different from zero indicating indirect relationship with output. The coefficients of all other second order terms are statistically insignificant indicating no relationship with output.

A statistical text was carried out to confirm that the translog function adequately represents the production rather than the Cobb Douglas. For the production function to be Cobb Douglas, the coefficients of all the second order terms should be zero. The rejection of this hypothesis in the translog function is a confirmation of the fact that the translog function is more suitable for the data and model specification than the Cobb Douglas.

The estimated variance (σ^2) is statistically significant at 1% indicating goodness of fit and the correctness of the specified distribution assumptions of the composite error term. Besides, the variance of the non negative farm effects is a small proportion of the total variance of cocoyam output. Gamma (γ) is estimated at 0.397 and is statistically significant at 1% indicating that only 39.7% of the total variation in cocoyam output is due to technical inefficiency.

The frequency distribution of technical efficiency in cocoyam production is presented in Table 3. Individual technical efficiency indices range between 69.01% and 98.42% with a mean of 92.96%. About 93.3% of the cococyam farmers have technical efficiency indices of above 80%. The high level of technical efficiency obtained in this study are consistent with the low variance of the farm effects.

Table 3. Frequency Distribution of Technical Efficiency in Cocoyam Production in Anambra State Nigeria 2005

Technical Efficiency Range %	Frequency	Relative Frequency
≤60	0	0
61-70	2	1.67
71-80	6	5.00
81-90	11	9.17
91-100	101	84.17
Total	**120**	**100**
Mean technical efficiency	92.96%	
Minimum technical efficiency	69.01%	
Maximum technical efficiency	98.42%	

Source : Field Survey 2005

(c) Sources of Technical Efficiency. The estimated determinants of technical efficiency in cocoyam production are presented in Table 4.The coefficient of farm size is positive and statistically significant at 10% indicating a direct relationship between farm size and technical efficiency. Large farmers are usually more educated, and have more access to credit, land, and other production inputs as well as adopting agricultural innovations more than small farmers. The result obtained in this study is consistent with those of Onyenweaku and Effiong, (2005), Onyenweaku and Nwaru (2005), Onyenweaku, Igwe and Mbanasor (2004), and Flinn and Ali (1986). However, this result contrasts from those of Kalirajan and Flinn (1983), Huang and Bagi (1984), Belbase and Grabowski (1985), Lingard, Castillo and Jayasuriya (1983), Bravo-Ureta and Evenson (1994) and Bravo-Ureta and Pinheiro(1997) who found no significant relationship between farm size and technical efficiency.

The coefficient of farming experience is positive and statistically significant at 10% showing direct relationship between farming experience and technical efficiency. The more experienced a farmer is the more efficient his decision making processes and the more he will be willing to take risks associated with the adoption of innovations. This result agrees with those of Onyenweaku and Effiong, (2005), Onyenweaku and Nwani (2005), Onyenweaku, Igwe and Mbanasor (2004), Kalirajan (1981) in India and Kalirajan and Flinn (1983), in Philippines. However, this result disagrees with that of Onu, Amaza and Okunmadewa (2000), who found a negative relationship between farming experience and technical efficiency in cotton production in Northern Nigeria.

The coefficient of fertilizer use is also positive and statistically significant at 5% showing a direct relationship between fertilizer use and technical efficiency. Fertilizer, an improved technology, shifts the production frontier upwards leading to higher technical efficiency. This result is consistent with that of Hussain (1989) in Pakistan. The coefficient of membership of farmers'

Table 4. Estimated Determinants of Technical Efficiency in Cocoyam Production in Anambra State Nigeria 2005

S/No	Variables	Parameters	Estimates	T-ratios
	Constant term	a_0	-0.167	-0.524
1	Age (Z_1)	a_1	0.002	0.003
2	Education (Z_2)	a_2	-0.003	-0.364
3	Extension contact(Z_3)	a_3	-0.079	-1.520
4	Household size (Z_4)	a_4	0.011	1.073
5	Farm size (Z_5)	a_5	1.037	6.828***
6	Farming experience(Z_6)	a_6	0.023	1.695*
7	Fertilizer use (Z_7)	a_7	0.314	2.492**
8	Credit (Z_8)	a_8	0.116	1.117
9	Membership of Farmers association /cooperative societies (z_9)	a_9	0.234	2.014**

*=Significant at 10%, **=Significant at 5%, ***= Significant at 1%

associations/cooperative societies is positive and statistically significant at 5% showing a direct relationship between membership of farmers' associations/cooperative societies and technical efficiency. Members of farmers' associations or cooperative societies have more access to agricultural information, credit and other production inputs as well as more enhanced ability to adopt innovations than non-members. This result is consistent with those of Onyenweaku and Effiong(2005), Onyenweaku and Nwaru (2005), Onyenweaku and Ohajianya (2005) and Okike (2000) all in Nigeria.

However, the coefficients of age, education, extension contact, household size and credit are all statistically insignificant indicating no relationship between these variables and technical efficiency in cocoyam production in the study area.

IV CONCLUSION

The results of this study reveal that technical efficiency in cocoyam production in Anambra State, Nigeria is relatively high. Individual levels of technical efficiency range between 69.01% and 98.42% with a mean of 92.96%, suggesting that opportunities still exist for increasing productivity and income of cocoyam farmers in the state by increasing the efficiency with which resources are used at the farm level.

Important factors directly related to technical efficiency are farm size, farming experience, fertilizer use and membership of farmers' associations/cooperative societies, while no significant relationship was found between technical efficiency and farmer's age, education, extension contact household size and credit. These results call for policies aimed at improving farmers' access to land, fertilizer, membership of farmers' associations/cooperative societies as well as targeting relevant policies at experienced cocoyam farmers as measures for increasing technical efficiency in the study area. Women play a significant role in cocoyam production in the study area .Therefore, policies designed to improve women access to land, fertilizer, credit, agricultural extension, new technologies, more education, and primary health care will be crucial in increasing technical efficiency.

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