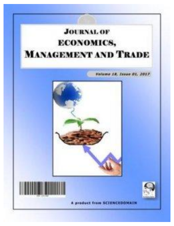

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Technical Efficiency of Cocoyam Production in Kaduna State, Nigeria: A Stochastic Production Frontier Approach

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Authors' contributions

This work was carried out in collaboration between all authors. Author SA designed the study, performed the statistical analysis, wrote the protocol, managed the analyses of the study and wrote the first draft of the manuscript. Authors OY, SAS and TBA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Aims of the study were to describe socio-economic characteristics of cocoyam farmers, determine the technical efficiency of cocoyam producers and identify socio-economic factors influencing technical efficiency of cocoyam producers in Kaduna state.
Study Design: Primary data were collected from cocoyam producers through the use of structured questionnaires.
Place and Duration of Study: This study was carried out in three local government area in Kaduna state, Nigeria between August and November 2013 cropping season.
Methodology: Multistage purposive and random sampling techniques were employed for data collection.

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Results: The study showed that 34% of the respondents fall within the age range of 30 and 39 years. The majority of the farmers (50%) had no formal education. The household size ranged from 6-10 persons, whereas (73%) were not members of cooperative society. Results indicated that except for fertilizer, all other factors were significant ($P < 0.01$). The mean technical efficiency is 63% while the range is 11-93%

Conclusion: The findings of the study revealed that none of the sampled cocoyam farms reached the frontier threshold. Also, amount of credit received was the socio-economic variable responsible for the variation in technical efficiency of the cocoyam producers. It was therefore recommended that timely and adequate supply of fertilizer should be made available to farmers at affordable price in order to enhance the production of cocoyam.

Keywords: Technical efficiency; cocoyam; stochastic production frontier; Kaduna State.

1. INTRODUCTION

Nigeria's domestic economy is partly determined by agriculture which accounted for 40.9% of the Gross Domestic Product (GDP) in 2010 [1]. Agriculture has been an important sector in the Nigerian economy in the past decades and is still a major sector despite the oil boom. Basically it provides employment opportunities for the teeming population, eradicates poverty and contributes to the growth of the economy. Despite these however, the sector is thus characterized by low yields, low level of inputs and limited areas under cultivation [2]. Nigeria is an agrarian economy with 70% of its people dependent on agriculture [3]. The Government of Nigeria has been trying to achieve food security at both house hold and national level through its mechanized approach.

Root and tuber crops which are among the most important groups of staple foods in many tropical African countries [4] consistute the largest source of calories for the Nigeria population [5]. Cassava (*Manihot esculenta*) is the most important of these crops in terms of total production, followed by yam (*Dioscorea* spp), cocoyam (*Colocasia* spp and *Xanthosoma* spp) and sweet potato (Ipomoea batatas) [5].

Cocoyam (*Colocasia esculenta* and *Xanthosoma mafafa* (L) Okeke) are important carbohydrate staple food particularly in the southern and middle belt areas of Nigeria [6]. Nutritionally cocoyam is superior to cassava and yam in the possession of higher protein, mineral and vitamin contents in addition to having more digestible starch [7,8]. Cocoyam which ranks third in importance and extent of production after yam and cassava is of major economic value in Nigeria [9]. Edible cocoyam cultivated in the country is essentially species of *Colocasia* (taro) [10] and *Xanthosoma* (tannia). The average production figure for Nigeria is 5,068,000mt which accounts for about 37% of total world output of cocoyam [11]. Small scale farmers, especially women who operate within the subsistence economy grow most of the cocoyam in Nigeria.

It is highly recommended for diabetic patients; the aged, children with allergy and for other persons with intestinal disorders [12]. According to [13], boiled cocoyam corms and cormels are peeled, cut up, dried and stored or milled into flour. The flour can be used for soups, biscuits, bread and puddings for beverages. The peels can also be utilized as feed for ruminants.

Despite the importance of cocoyam, more research attention have been given to cassava and yam [14,15]. [16], Observed that research on cocoyam has trailed behind cassava and yam as root crops in Nigeria and other countries [17]. noted that the totality of published scientific work on cocoyam is insignificant when compared with those of rice, maize, yam and cassava. However, [16] asserted that it was only in the last decade that policy makers and national agricultural research systems began to show systematic interest in the crop because of concern over biodiversity. There is a declining trend in cocoyam production as well as a shortage of its supply in domestic markets as a result of a number of technical, socio-economic and institutional constraints, which need to be addressed. Cocoyam farmers are generally found on a small scale and its production has been undermined.

Arising from the forgoing, there is need to have a look into the production of cocoyam, one of the major roots and tuber crops in Nigeria which is fast becoming an extinction crop. This is due to the general believed that most families no longer consume it because it is not readily available for consumption even during its season, as a result of reduction in its production level. This study therefore measured the technical efficiency of cocoyam producers in Kaduna state.

Production of cocoyam has not been given priority attention in many countries probably because of its inability to earn foreign exchange and its unacceptability by the high income countries for both consumption and other purposes [18]. Most of what is produced is consumed locally [19]. The production 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.

1.1 Theoretical Framework

Efficiency measurements involve a comparison of actual performance with optimal performance located on relevant frontier. Since the true frontier is unknown, an empirical approximation is required. The approximation is normally called a “best practice” frontier. Approximation of the best practice frontier can be done using parametric or non parametric techniques. Both techniques put emphasis on optimizing behaviour subject to constraints.

Data Envelopment Analysis (DEA) is a non-parametric technique. It builds a linear piece-wise function from empirical observations of inputs and outputs, without assuming any a priori functional relationship between the inputs and outputs. Efficiency measures are then calculated relative to this surface. Testing of hypothesis is not possible and this method does not suffer multicollinearity and heteroscedasticity. The Stochastic Frontier Approach (SFA), also referred to as the econometric frontier approach, specifies a functional form for the cost, profit, or production relationship among inputs, outputs, and environmental factors, and it allows for random errors. Parametric methods are susceptible to misspecification errors. The advantage is that it becomes possible to test hypotheses.

Variation in output by different producers, caused by technical inefficiencies can be captured through specification of production function. Technical efficiencies can be estimated using Stochastic Frontier Approach (SFA) or Data Envelopment Analysis (DEA). DEA assumes that there are no random effects in production. The current study therefore employed the stochastic production frontier approach because most farmers operate under uncertain condition [20]. Review of literature revealed that Cobb-Douglas and Translog production function are the widely used forms in agriculture. However, translog production function specification suffers from multicollinearity problem as a result of the square and interaction terms of the inputs used [21]. The current therefore estimated a Cobb-Douglas production function, specified as: $Y_i = (x_i \beta) + v_i - u_i$

Where Y_i is the output; x_i is a vector of inputs quantities used in production; β is a vector of parameters of the production function. The frontier production function $\{f(x_i, \beta)\}$ measures the maximum potential output from a vector of inputs. The error component v_i and u_i causes deviations from the frontier.

v_i is the systematic error component which captures random deviations from the frontier, caused by factors beyond the farmers' control such as temperature and natural hazards. It is assumed to be independently and identically distributed with a mean of zero and constant variance –N $(0, \sigma_v^2)$ and independent of u_i.

u_i is a non-negative error component that captures deviations from the frontier caused by controllable factors. It represents the inefficiencies in production. It is assumed to be half normal, identically and independently distributed with a mean of zero and constant variance –N $(0, \sigma_v^2)$.

Cobb-Douglas production function is adequate in the representation of the production process since we are only interested in the efficiency measurement, and not production structure [22] Furthermore, Cobb-Douglas production function has been widely applied in estimating farm efficiencies [19,21,23-29].

2. MATERIALS AND METHODS

2.1 Study Area

This study was conducted in Kaduna state of Nigeria. Kaduna state lies in the north western part of the country's geopolitical zone, about 200 km away from Abuja the federal capital. The state lies between latitudes 90°N and 12°N of the equator and between longitudes 6°E and 9°E of the prime meridian. Kaduna state shares boundaries with Katsina and Kano state to the north. Plateau to the north east, Nasarawa and

Abuja to the south and Niger and Zamfara state to the west [30]. The state occupies an area of approximately 68,000 square kilometers or 7% of Nigeria's land mass. The state has 23 Local Government Areas [31]. The mean annual rainfall shows a marked decrease from South to North (1,524 mm to 635 mm). Two distinct seasons occur in the state; the rainy season and the dry season. The relative humidity is constantly below 40% except in few wet months when it goes up to an average of 60%. The duration of dry season is 5-7 months which normally starts from October. The state is agrarian and well suited for the production of arable crops such as maize, yam, millet, and sorghum because of a favourable climatic condition. Livestock production is also practiced in the state. Rearing of goats, sheep, cattle and different classes of poultry as well as marketing of their products is practiced in the state. The people of the state live mostly in organised towns and cities [32]. A large variety of non-agricultural occupations also exit.

The total population of the state is 6.11 million [31]. Based on annual population growth rate of 3.2%, the projected population of the state was about 7.33 million people in 2012. Within the state there are a number of establishments ranging from companies, research institutes, higher institutions and colleges.

2.2 Sampling Procedure

Multistage sampling techniques were used to select respondents for this study. The first stage involved a purposive selection of the three (Giwa, Kudan and Ikara) local governments based on predominance of cocoyam production among the farmers. Secondly, 9 villages were purposively selected, Three (Giwa, Yakawada, Guga; Gimbawa, Kwasallawa, Malikanchi; and Musawa, Hunkuyi, Kudan) from each local government area based on their intensity of cocoyam production. Finally, a simple random sampling was employed in selecting farmers from each of the villages. Fifty percent (50%) of the sample frame (248) was used as the sample size. In all, 124 farmers were randomly selected for the study.

2.3 Data Collection and Analysis

Primary data were used for this study. These were collected with the aid of structured questionnaires. The information collected includes labour input, fertilizer input, seed, farm size and farmer's socio-economic characteristics such as age, household size, educational status, amount of credit received, number of extension contacts, years spent on the cooperative, and income.

2.4 Model Specification

Empirical model specification for the determinants of technical efficiency is as follows;

$$\ln Y_{i} = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + V_i - U_i$$

Where subscript i refers to the observation of ith farmers,

In = Logarithm to base e,
Y = Output of cocoyam of the ith farmers (kg)
X_1 = Farm size (hectare)
X_2 = Seed (kg)
X_3 = Fertilizer (kg)
X_4 = Labour (Man-hour)

The inefficiency effects, V_i is a random error term assumed to be independently and identically distributed as N (0, σ_V^2). U_i represents technical inefficiency and is identically and distributed as a truncated normal with truncations at zero of the normal distribution [33]. The U_i is defined as:

$$U_i = \delta_0 + \delta_1 \ln Z_{1i} + \delta_2 \ln Z_{2i} + \delta_3 \ln Z_{3i} + \delta_4 \ln Z_{4i} + \delta_5 \ln Z_{5i} + \delta_6 \ln Z_{6i}$$

Where:

U_i = Technical inefficiency of the ith farmer
Z_1 = Age of the farmer (years)
Z_2 = Years of education of the ith farmer
Z_3 = Household size of the ith farmer (Numbers of people)
Z_4 = Cooperative Association of the ith farmer (Years of participation)
Z_5 = Extension Contact of the ith farmer (Number of contacts)
Z_6 = Access to Credit by the ith farmer

3. RESULTS AND DISCUSSION

The socio-economic characteristics of the respondents are presented in Table 1. The study revealed that 34% of the respondents fall within the age range of 30 and 39 years. The mean age of the farmers was 34 years; this implies that the majority of the farmers were younger, who can contribute positively to agricultural production for the next two decades. This result is consistent with the findings of [34] who observed that youth constitute the majority of the cocoyam farmers, and younger farmers are more flexible to new ideas and risk; hence they are expected to adopt innovations more readily than older farmers. The majority of the farmers (50%) had no formal education. This indicates that the farmers' educational level is low. According to Oyekele [35], education has a positive and significant impact on farmers' efficiency in production. The literacy level greatly influences the decision making and adoption of innovation by farmers, which may bring about increase in production of the crop. The educational level of farmers does not only increase his productivity but also increase his ability to understand and evaluate new techniques. The majority of the farmers (30%) had household size with 6-10 members. The average household size was 13 persons implying that there is appreciable source of family labour supply to accomplish various farm operations. According to the report of Zalkuwi et al. [36], there is a positive and significant relationship between household size and farmers' efficiency in production. However, the absolute number of people in a certain family cannot be used to justify the potential for productive farm work. This is because it can be affected by some important factors namely; age, sex and health status. This shows that a reasonable number of the respondents have a large household size. Higher household size provides enough persons for family labour and less money will be needed to pay for hired labour. About (73%) of cocoyam farmers do not participate in any cooperative association. According to them, their non-membership is due to being small scale and unawareness of any association while 27% participated with average of 2.4 times per year. The effect of this result is that most of the cocoyam farmers in the study area do not enjoy the assumed benefits accrued to co-operative societies through pooling of resources together for a better expansion, efficiency and effective management of resources and for profit maximization. Ekong [37] stated that membership of cooperative societies have advantages of accessibility to micro-credit, input subsidy and also as avenue in cross breeding ideas and information. (85%) of cocoyam farmers in the study area have no access to extension service while (15%) have access to extension service with average of 0.4/ year. This could be attributed to low extension agent-farmers' ratio in the study area.

3.1 Summary of the Level of Inputs and Output in Cocoyam Production in Kaduna State

The summary statistics of the variables obtained from the cocoyam farmers in the study area are reported in Table 2. The average yield per hectare was 8240.73 kg. This was obtained by using an average of 0.82 hectare of farm size, 875.93 kg of seed, 402.19 kg of fertilizer and 20.05 man-days of family labour for maximum labour applied while the minimum labour used was 5.00 man-days. This shows that agricultural production in the study area is traditional and labour intensive

3.2 Maximum Likelihood Estimates Results of the Frontier Production Function (Technical Efficiency) of Cocoyam production

The model specified was estimated by the maximum likelihood (ML) method using FRONTIER 4.1 software developed by Coelli [38]. The ML estimates and inefficiency determinants of the specified frontier are presented in Table 3. The study revealed that the generalized log likelihood function was 102.58. The log likelihood function implies that inefficiency exist in the data set. The value of gamma (γ) is estimated to be 94% and it was highly significant at 1% level of probability. This is consistent with the theory that true γ-value should be greater than zero. This implies that 94% of random variations in the yield of the farmers were due to the farmers' inefficiency in their respective sites and not as a result of random variability. Since these factors are under the control of the farmer, reducing the influence of the effect will greatly enhance the technical efficiency of the farmers and improve their yield. The value of sigma squared ($\boldsymbol{\sigma^2}$) was significantly different from zero at 10% level of probability. This indicates a good fit and correctness of the specified distributional assumptions of the composite error terms.

However, input variables such as farm size, seed and labour were significant at 1% level of probability and hence play a major role in cocoyam production in the study area. Farm size was positively related to output, which means the larger the farm size, the larger the output. This may be due to availability of supply of labour in the study area. However, this agrees with the findings of Mignouna et al. [39] who observed that land size is positively related to output. Seed and labour were also positively related to output. An increase in the quantity of seed used up to a certain maximum leads to an increase in the output of cocoyam. These may also be due to availability of supply of labour in the study area. This is in line with the findings of Wakili [40] who observed that the estimated coefficient of seed and labour inputs were positive as expected and significant at 1% level while fertilizer was not statistically significant; it means that fertilizer has not effect on the output of cocoyam. It could be due to improper application methods and timing of application. Essentially, cocoyam is a staple food and farmers always ensure food security for the family first; thus at that critical period they might use the fertilizer more for the food crop leading to insignificant relationship between fertilizer and cocoyam output.

Table 1. Socio-economic characteristics of cocoyam farmers

Variable	Frequency (N = 124)	Percentage
Age (years)		
20-29	32	25.8
30-39	42	33.8
40-49	17	13.7
50-59	20	16.0
60 above	13	10.4
Mean	**40**	
Educational status		
No formal education	62	50.0
Primary education	11	8.9
Secondary education	34	27.4
Tertiary education	17	13.7
Household size		
1-5	28	22.5
6-10	37	29.8
11-15	23	18.5
16-20	19	15.3
21 above	17	13.6
Mean	**13**	
Membership of cooperative society		
Non members	90	72.6
1-5	21	16.9
6-10	4	3.2
11-15	4	3.2
16 above	5	4.0
Mean	**2**	
Extension contact		
No contact	105	84.7
1-3	16	12.8
4-6	3	2.4
Mean	**0.4**	
Access to credits		
Personal savings	116	93.5
Borrowing	8	6.5

N = Number of respondents

Table 2. Summary of input and output

Variables	Mean	Std. Dev.	Min	Max
Seed	875.93	2171.03	50.00	21000.00
Fertilizer	402.19	722.51	0.00	7200.00
Labour	20.05	14.94	5.00	96.00
Yield	8240.73	10281.1	300.00	48000.00

In determination of technical inefficiency in the model, age of respondents, numbers of household size, membership of cooperative association and number of extension contacts were not statistically significant. Age was negatively related to technical efficiency. This implies that older people involved in the farm decision making process, will reduce technical efficiency and increase inefficiency. However, this contradicts the findings of Rahman and Umar [41] that showed a positive and significant relationship between age and technical efficiency. Years of education and credit shows no relationship with efficiency but credit was statistically significant at 5% level. This could be attributed to the fact that government seldom grants financial credit to large numbers of farmer. Ekong [37] asserts that credit is a very strong factor that is needed to acquire or develop any enterprise; its availability could determine the extent of production capacity. it also agrees with findings of Nasiru [42] who noted that access to micro-credit could have prospect in improving the productivity of farmers and contributing to uplifting the livelihoods of disadvantaged rural farming communities. Household size, cooperative membership and extension contact were also negatively related to efficiency though, not significant. This implies that farmers become inefficient with increase in the number of household size. This may be due to the fact that farmers with large household size has more people to feed with less income left to acquire inputs for production. These findings agree with the findings of Rahman and Umar [41]. Cooperative membership was also negatively related to technical efficiency. Extension contact was due to the fact that there is a very low extension agent-farmers' ratio in the study area.

Table 3. ML estimates and inefficiency function

Variables	Parameters	Coefficient	Standard error	T-value
Production Function				
Constant	β_0	1.5307	0.4983	3.0718***
In Farm size	β_1	0.3679	0.0610	6.0299***
In Seed	β_2	0.1589	0.0408	3.8911***
In Fertilizer	β_3	0.1019	0.1140	0.89360
In Labour	β_4	0.3792	0.0324	11.689***
Inefficiency Variable				
Constant	d_0	0.8012	1.2866	0.6227
Age	d_1	-0.0692	0.05101	-1.1356
Education	d_2	0.0082	0.0335	0.2471
Household size	d_3	-0.4867	0.3756	1.2960
Cooperative	d_4	-0.00000002	0.000009	-0.0029
Extension contact	d_5	-0.5655	0.4973	-1.1371
Access to credit	d_6	0.2126	0.0929	2.2867**
Diagnostic Statistic				
Sigma-squared	(σ^2)	1.6516	0.9891	1.669*
Gamma	(γ)	0.9393	0.04273	21.9821***
Ln(likelihood function)		-102.5818		
LR test		51.7625		
Total number of observations		124		
Mean efficiency		0.6339		

Source: Computer printout of frontier

*Note: All explanatory variables are in natural logarithms. A negative sign of the parameters in the inefficiency function implies that the associated variable has positive effect on technical x efficiency and a positive sign indicate the reverse is true. Asterisk indicate significance ***1%,**5%, *10%.*

3.3 Frequency Distribution of Technical Efficiency Estimates of cocoyam Farmers

The frequency distribution of the technical efficiency estimates for cocoyam farmers in the study area are presented in Table 4. The study revealed that 66% of the farmers had technical efficiency (TE) of 0.81 above while 34% of the farmers operate at less than 0.8 efficiency level. The mean technical efficiency for the 124 sampled farmers in the study area was 0.63. The farmer with the best practice has a technical efficiency of 0.93 while 0.24 was for the least efficient farmers. This implies that on the average, output fall by 7% from the maximum possible level due to inefficiency. The study also suggest that for the average farmer in the study area to achieve technical efficiency of his most efficient counterpart, he could realize about 18 percent cost savings while on the other hand, the least technically efficient farmers will have about 82 percent cost savings to become the most efficient farmer.

Table 4. Frequency distribution of technical efficiency estimates from the stochastic frontier model

Efficiency level	Technical frequency	Percentage (%)
< 0.2	0	0
0.21-0.40	11	8.87
0.41-0.60	14	11.29
0.61-0.80	17	13.71
0.81-1.00	82	66.1
Total	124	100
Minimum	0.24	
Maximum	0.93	
Mean	0.63	

4. CONCLUSION

The paper estimates the farm level technical efficiency and its determinants using the stochastic parametric method of estimation. The parameters of the ML estimates and inefficiency determinants were asymptotically efficient, unbiased and consistent and were obtained using Cobb-Douglas production function estimated by maximum likelihood estimation technique. Cocoyam farmers have a mean age of 34 years and are active and productive. The important factor inputs that increase farm outputs are land, labour, planting materials and inorganic fertilizer. The farm specific technical efficiency distribution reveals that none of the farmers reached the frontier threshold. Thus within the context of efficient agricultural production, output can still be increased by 37 percent using available inputs and technology.

5. RECOMMENDATIONS

Seed and labour contributed significantly to the production of cocoyam. Therefore, it is recommended that timely and adequate supply of seed and labour should be made available to farmers at affordable price in order to enhance the production of cocoyam. Also, the level of efficiency of some farmers was very low due to improper management of resources; it is therefore recommended that farmers should be trained and advised on proper and efficient utilization of resources (seed, farm size and labour) in order to improve their efficiency in production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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