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Measurement of allocative efficiency in Acha (*Digitaria exilis*) production among small-scale farmers in Kaduna state, Nigeria

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Abstract: The study examined the allocative efficiency of Acha production in Kaduna State, Nigeria, using 200 randomly selected Acha farmers through the use of structured questionnaire. Data were analyzed using descriptive statistics and the translog cost function of the stochastic frontier model. Results showed that most farmers were at their active ages (average of 40 years), 75% were literate with an average farming experience of 13 years. All inputs costs were positively related to total cost of production and were significant ($p<0.05$). Farmers were not operating at full cost efficiency level, as the mean cost efficiency was 0.89. This inefficiency was influenced by production experience, formal education, extension contact, credit access and co-operative membership. More opportunities exist for improvement of allocative efficiency by the Acha farmers.

Keywords: Efficiency, stochastic, small-scale, Acha farmers, Nigeria

INTRODUCTION

Acha *(Digitaria exilis),* is also known with other names such as fonio, iburu, findi, fundi, pom and kabug in different West African countries and has been reported to be the oldest West African cereal (Cruz, 2004). It is a cereal which grows well in Nigeria and is a staple food in some parts of Nigeria and across fifteen North West African countries. It is indigenous to the savannah regions of West Africa and grows so fast that it can be cultivated two to three times in a year since it matures within 120 days (Dachi and Gana, 2008; Abdullahi and Luka, 2003). It grows well in Nigeria, mostly cultivated around Plateau, Bauchi, Kaduna and Niger states. Nutritional experts have acknowledged it as exceptional, as it has relatively low free sugar and low glycemic content which makes it adequate as a suggested diet for diabetic patients (Cruz, 2004; Balde *et al.,* 2008; Jideani and Jideani, 2011). *In-vitro* starch digestibility and glycemic property of acha, iburu and maize porridge have also been reported by Jideani and Podgorski (2009).

The focus on Acha for this study is derived from the fact that its consumption is on the increase due to the increasing awareness of its nutritional value (Jideani and Jideani, 2011). Despite the crop's ancient heritage and widespread importance, knowledge about its production remains very scanty even within West Africa itself. The crop has received but a fraction of the attention accorded to maize, sorghum and pearl millet, and a mere trifle considering its importance in the economy and its potential for increasing food supply. Although its production has been described to be low ranging from 600-700kg/ha (Cruz, 2004; CIRAD, 2011) in West Africa, its contribution in reducing hunger should not be neglected. There have been many studies which determined the relative efficiency of farmers, such as Ohajianya *et al*. (2010), Onyenweaku and Okoye (2007), Ike and Inoni (2004), Rahman (2002), Wadud and White (2000) and Tzonvelekas *et al.* (2001), the only few that analyzed allocative efficiency focused on other crops other than acha. Even the few studies on Acha production have shown an increasing importance of the crop amidst growing utilization as food. A review by Jideani (2012) shows the need for more scientific investigation on acha, iburu and tamba cereal grains.

The central argument in this paper is that smallholder agricultural productivity in Nigeria can be re-capacitated through the efficient allocation of resources. Hence, the study aims at identifying the farmers' socioeconomic characteristics, estimating their allocative efficiency and its determinants using the stochastic frontier translog approach. The significance of this study is that it will provide information that can contribute to the policy debate on cost effective ways of raising smallholder productivity.

METHODOLOGY

Study area: The study was conducted in Kaduna State, Nigeria (between latitude 09^0 02' and 11^0 32'N of the equator, 06^0 15'and 80^0 50'E of prime meridian).

Sampling: Multi-stage sampling technique was used to select Acha farmers across three Local Government Areas (Jaba, Kachia and Kagarko) which were purposively selected on the basis of being the prominent Acha producing areas of the State. Simple random sampling was then employed in selecting 200 Acha farmers for data collection.

Data Collection: The information collected include socioeconomic characteristics of farmers (age, farm size, educational background, output, experience and household size of the farmer), the major components of costs of inputs (land area under cultivation (ha), labour in man-days, cost of fertilizer, cost of seeds, cost of agrochemicals and cost of farm implements employed in production) and total value of output (sum of cash receipt from selling farm products including that consumed in the household). Information on the questionnaire covered 2012 farming season while interviews were conducted by trained enumerators.

Analytical Tools: Descriptive statistics (mean, frequency, percentage and standard deviation) and inferential statistics (the empirical stochastic frontier production model specified in a translog cost function) were used to analyse the data.

Theoretical Framework and Model Specification

Frontier efficiency model has been used extensively in measuring the level of efficiency in farms. Considering the works of Battese and Coelli (1995), the stochastic frontier translog cost functions as used by some authors (such as Kibaara, 2005) were employed in the analysis for this study. The stochastic frontier production function can be written as:

$$Y_i = f(X_i\beta)e^{(v_i-\mu_i)}$$
$$i = 1, 2, 3, ..., N \quad \text{..............................} \ (1)$$

Where Y = output of the i^{th} farm, X_i = vector of inputs, β = vector of parameters, v_i = random error term, and u_i = inefficiency term. The term v_i is the symmetric component which accounts for random variation in output due to factors outside the farmer's control such as measurement errors, weather condition, drought, strikes, luck, etc. It is assumed to be independently and identically distributed normal random variables with constant variance, independent of μ_i. On the other hand, μ_i is assumed to be non-negative exponential or half-normal truncated (at zero) $N \sim (\mu_i, \sigma^2)$ random variable associated with farm-specific factors, which leads to the i^{th} firm not attaining maximum efficiency of production; μ_i is associated with technical inefficiency of the farmer (Coelli *et al*., 1998; Battese and Rao, 2002). N represents the number of farms involved in the cross sectional survey. Technical efficiency (TE) of an individual farm is defined in terms of the ratio of the observed output to the corresponding frontier output, conditioned on the level of inputs used by the farm. Technical inefficiency (TI) is therefore defined as the amount by which the level of production for the firm is less than the frontier output.

$$TE = \frac{Y_i}{Y_i^*} = \frac{f(X_i\beta)e^{(v_i-\mu_i)}}{f(X_i\beta)e^{v_i}} = e^{-\mu} \quad \text{..................} \ (2)$$
$$TI = 1 - TE$$

Where, $0 \le TE \le 1$ with 1 defining a technically efficient farm, Y_i is the observed output and Y_i^* the frontier output. Technically efficient farms are those that operate on the production frontier and the level by which a farm lies below its production frontier is regarded as the measure of technical inefficiency; if μ_i equals zero, then TE equals one and production is said to be technically efficient. Technical efficiency of the i^{th} farm is therefore a relative measure of its output as a proportion of the corresponding frontier output. A farm is technically efficient if its output level is on the frontier, which implies that Y_i/Y_i^* equals one in value.

Several studies specified a Cobb-Douglas production function to represent the frontier function. The Cobb-Douglas function however, restricts the production elasticities to be constant and the elasticities of input substitution to unity (Wilson, *et al*., 1998). Also, there are times when the marginal effect of a variable depends on another variable, hence the need to choose functional forms that include interaction terms (Asteriou and Hall, 2011). The translog cost model is specified as

$$\ln Y_t = \alpha_0 + \sum \alpha_k \ln X_{ki} + \frac{1}{2}\sum\sum \alpha_{kj} \ln X_{ki} \ln X_{ji} + (v_t - \mu_t)$$
$$\text{..............} \ (3)$$

where, ln denotes natural logarithms, y and x variables are defined in Table 1, α's are parameters to be estimated. The inefficiency model is estimated from the equation given below.

$$\mu_t = \delta_0 + \sum \delta_m \psi_i \quad \text{.............................} \ (4)$$

The variables ψ_i are the inefficiency variables.

This study therefore employed the stochastic frontier cost function using the translog functional form which is given by:

$$\ln C_t = \beta_0 + \sum \beta_k \ln P_{ki} + \frac{1}{2}\sum\sum \beta_{kj} \ln P_{ki} \ln P_{ji} + (v_i + \mu_i)$$
$$\text{..............} (5)$$

Where C_i represents the total input cost of the i^{th} farms; f is a suitable function such as the Cobb-Douglas function; P_i represents cost of inputs employed by the i^{th} farm in food crop production measured in naira; β is the parameter to be estimated,

v_i and μ_i are the random errors and assumed to be independent and identically distributed truncations (at zero) of the $N \sim (\mu_i, \sigma^2)$ distribution as earlier defined. These were obtained using the computer programme, frontier version 4.1 (Coelli, 1996). The *a priori* expectation is that the estimated coefficients of the function provide some explanation for the relative efficiency levels among individual farms. The allocative efficiency of individual farmers is thus defined in terms of the ratio of the predicted minimum cost (C_i^*) to observed cost (C_i) ranging between 0 and 1.That is:

$$\text{AE}_i = \frac{C_i^*}{C_i} \quad \text{.......} (6)$$

$$= \frac{F(X_i\delta)e^{(v_i+\mu_i)}}{F(X_i\delta)e^{v_i}} = e^{\mu} \quad \text{.......} (7)$$

Therefore, the parameters, variables and the interactions that were included in the production function model are shown below:

$$In\ C = In\ \beta_0 + \beta_1 In\ P_1 + \beta_2 In\ P_2 + \beta_3 In\ P_3 + \beta_4 In\ P_4 + \beta_5 In\ (P_1)^2 + \beta_6\ (P_2)^2 + \beta_7\ In\ (P_3)^2 + \beta_8\ In\ (P_4)^2 + \beta_9\ In\ (P_1 * P_2) + \beta_{10}\ In\ (P_1 * P_3) + \beta_{11}\ In\ (P_1 * P_4) + \beta_{12}\ In\ (P_2 * P_3) + \beta_{13}\ In\ (P_2 * P_4) + \beta_{14}\ In\ (P_3 * P_4) + (V+U) \quad \text{.......} (8)$$

Where,
ln = natural logarithm to base e
C_i = total cost of Acha production (N)
X_1 = cost of labour used in crop production (N)
X_2 = cost of seeds (N)
X_3 = cost of fertilizer (N)
X_4 = cost of agrochemicals (N)
β_0 = intercept
$\beta_{1\text{-}14}$ are the coefficients of the variables and their interactions
v_i = assumed independently distributed random error or random stocks which are outside the farmer's control
u_i = technical inefficiency effects which captures deviation from the frontier.

The inefficiency model is estimated from the equation:

$$\mu_t = \delta_0 + \sum \delta_m Z_i \quad \text{.......} (9)$$

$$u_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + W \quad \text{.......} (10)$$

The variables Z_i are the inefficiency variables considered to be:
Z_1 = production experience (number of years)
Z_2 = years of formal education (number of years)
Z_3 = membership of association (dummy: 1if a member, 0 if not a member)
Z_4 = access to credit (dummy: 1if accessed, 0 if no access)
Z_5 = extension contact (number)
Z_6 = household size (number of persons)
Z_7 = off-farm income (N)

RESULTS AND DISCUSSION

Socioeconomic characteristics of Acha farmers

The socioeconomic characteristics of the respondents are presented in table 1. The study revealed that majority (68%) of the respondents were men. Most of the respondents (55%) were above 35 years, with a mean age of 40.3 years. This implies that majority of the farmers were youths; an economic active age that can make positive contribution to agricultural production. Most respondents (64.5%) had major occupation as farming, implying that Acha production is just another form of diversification in farming. This contributed widely to the use of family labour by the households as the wives and children constituted the labour force. The literacy level among the farmers in the study area was average, as majority (75%) had at least one form of formal education or the other. Ohajianya *et al.* (2010) also observed that formal education has a positive and significant influence on maize farmers' allocative efficiency. Almost half (42%) of the respondents had up to 20 years farming experience with an average of 13 years. Just as the saying 'experience is the best teacher'; this shows that the managerial ability of the farmers can be inferred to be reasonably good. The study also revealed an average land size of 0.9ha which were mostly acquired through inheritance. The household size of respondents ranged between 1 and 15 with an average of 8 members. A large household size also means more mouth to feed, such that for a given farm size large households could produce a smaller market surplus (Minot *et al.*, 2006). However, in traditional agriculture, the larger the household size the more labour force is available for farm activities.

Table 1: Descriptive statistics of respondents' socioeconomic characteristics

Variables	Frequency	Percentage	Mean
Sex			
Male	146	68.00	
Female	64	32.00	
Total	200	100	
Age			
35 and below	90	45.00	
36 and above	110	55.00	40.3
Total	200	100	
Household size			
1-5	22	11.00	
6-10	118	59.00	

Variables	Frequency	Percentage	Mean
11-15	60	30.00	8.0
Total	200	100	
Level of education			
Tertiary	29	14.50	
Secondary	56	28.00	
Primary	64	32.00	
No formal education	51	25.50	
Total	200	100	
Production experience			
20 and below	116	58.00	
21 and above	84	42.00	13
Total	200	100	
Farm size(ha)			
≤1	138	69.00	
>1	62	31.00	0.9
Total	200	100	
Major occupation			
Farming	129	64.50	
Otherwise	71	35.50	
Total	200	100	
Membership			
of	57	28.50	
Association	143	71.50	
Yes	200	100	
No			
Total			

Table 3: Estimates of the Stochastic Frontier Cost Model for Acha Farmers

Variable	Parameter	Coefficient	Std Error
Cost Model			
Constant	A	0.144	0.112**
Lnseedcost	X_1	0.226	0.014**
Lnlabourcost	X_2	0.679	0.012**
Lnfertilizercost	X_3	0.033	0.002**
Lnagrochemcost	X_4	0.009	0.002**
(lnseedcost)^2	X_1^2	0.031	0.001**
(lnlabourcost)^2	X_2^2	0.016	0.001**
(lnfertilizercost)^2	X_3^2	0.004	0.0001**
(lnagrochemcost)^2	X_4^2	0.001	0.0001**
*lnlabcost*lnfertcost*	X_2X_1	0.008	0.002**
lnlabcost lnagrochemcost*	X_2X_3	0.011	0.010
lnlabcost lnseedcost*	X_2X_4	0.046	0.003**
lnfertcost lnagrochemcost*	X_3X_1	0.016	0.012
lnfertcost lnseedcost*	X_3X_4	0.021	0.011*
*lnagrochemcost*lnseedcost*	X_4X_1	0.063	0.026**
Diagnostic Statistics			
Sigma Square	σ^2	0.134	0.010**
Gamma	γ	0.981	0.103**
Log Likelihood Function	LLF	-69.92	

**P<0.05, **P<0.01*

Cost Function Analysis

The estimates of stochastic frontier cost function of Acha farmers in the study area are shown in table 3. The variance ratio (γ = 0.973) and total variance (δ^2 = 0.134) are statistically significant at 1% level. The total variance estimates goodness of fit and the correctness of the specified distributional assumption of the composite error term. The variance error of 0.981 implies that 98% of disturbance in the system is due to inefficiency, one-sided. All the variables included in the model at the first order level had direct (positive) relationship with the total cost of production. This shows that the farmers operate in stage one of the classical production function and thus increased labour demand, procurement of Acha seeds, fertilizer and agrochemicals should be encouraged since the factors are under-utilized.

This means that the total cost of Acha production increases by the value of each coefficient as the quantity of each variable is increased by one, *ceteris paribus*.

Seed cost (X_1):- This shows estimated coefficient of 0.226 which is statistically significant at 1%, showing direct effect on cost allocation. The positive relationship of seed cost and allocative efficiency indicates that a unit increase in seed cost will result to an increase in total cost of production by 0.226. This is in line with the *a priori* expectation.

Labour cost (X_2) had a significant (p<0.01) positive (0.679) relationship to total cost of Acha production. The implication of this is that the total cost of producing Acha is increased as more labour is put into use. Similar result of positive relationship between labour and allocative efficiency was obtained by Ogundari *et al.* (2006) in their study on economies of scale and cost efficiency in small scale maize production in Nigeria.

Fertilizer cost (X_3):- This shows estimated coefficient of 0.033 and is statistically significant at 1%, showing direct effect on cost allocation. The positive relationship of fertilizer cost and total cost indicates that a unit increase in fertilizer cost will result to an increase in total cost of production by 0.033.

Cost of agrochemicals (X_4) shows estimated coefficient of 0.009 which is statistically significant at 1%, also showing direct effect on cost allocation. This positive relationship indicates that a unit increase in the cost of agrochemicals will result to an increase in total cost of production by 0.009.

The second order terms which show possible non-linear changes of the effects over time revealed that all the coefficients of the square term (own interactions) are statistically significant at different levels. The cross interactions also maintained strong statistical significance, except for X_2X_3 and X_3X_1 variables which were not. The own second derivatives and the cross second derivatives all showed direct (positive) relationships with total cost of production.

Determinants of Allocative Inefficiency

The inefficiency variables and their contribution to allocative inefficiency is as shown on table 4. Although only five (5) of the variables were significant, the coefficients of the variables are negatively signed, implying that total cost of production is increased by the magnitude (or coefficient) of each variable as the quantity of each variable is increased by a unit.

Production experience (Z_1) was negatively signed implying that cost inefficiency decreases with higher production experience. This means that experience affects allocative (cost) efficiency positively (p<0.05). This is in conformity with the assumption that farmers' allocative efficiency is affected by experience since different levels of experience affect ability to obtain and process information on input cost (Ogundari *et al*., 2006 and Giroh *et al.,* 2011).

Formal education (Z_2) is inversely related to allocative inefficiency. This indicates that the higher the level of education of Acha farmers the lower the cost inefficiency vis-à-vis higher cost efficiency. That is, farmers with more years of schooling allocate their input cost more efficiently than their counterparts with lower years of schooling. This is in line with the expectation that educational level affects financial planning which invariably affects cost efficiency. Paudel and Matsuoka (2009) obtained a similar result in their study on cost efficiency estimates of maize production in Nepal using Chitwan district as a case study.

Table 4: Inefficiency Estimates of the Stochastic Frontier Cost Model

Variables	Parameters	Coefficients	Standard error
Constant	δ_0	-1.679	0.0001**
Production experience	δ_1	-0.211	0.102**
Formal education	δ_2	-0.446	0.182**
Association	δ_3	-0.231	0.135*
Access to credit	δ_4	-0.108	0.053**
Extension contact	δ_5	-0.175	0.084**
Household size	δ_6	-0.164	0.796
Off farm income	δ_7	-0.213	0.192

**P<0.10, **P<0.05*

Membership of association (Z_3):- The coefficient estimated had a negative sign and was significant at 5%, implying that membership of association directly relates with allocative efficiency. In other words, it means that those who have stayed longer in the association tend to allocate their cost of input more efficiently than those who have fewer years of membership vis-à-vis non members of association. This could be so because information on price of inputs flows among members easily; and benefits such as credits are granted as a result of long membership in the association. This agrees with the notion that association serve as information link to farmers as a result of exchanging ideas and experiences among members (Olagunju, 2008).

Access to credit (Z_4):- The estimated coefficient of access to credit was negatively related to cost inefficiency and was significant at 5%; also implying that it positively affects cost efficiency.

Farmers who have access to credit are likely to be more cost efficient than those who do not. This is so because credit helps farmers to purchase the needed inputs on time.

Access to extension contact (Z_5):- the value of the estimated coefficient was negatively related with allocative inefficiency and statistically significant. Farmers with access to extension contact tend to be more cost efficient than their counterparts without extension contact. The result confirms the assertion that extension agents serve as educators and information bearers on new innovations to clientele, implying that farmers get information on input prices from extension agents.

Allocative Efficiency Distribution of Acha Farmers

The allocative efficiency distribution indices revealed that 89% of the sampled farmers allocate their cost efficiently at 50% and below. The allocative efficiency distribution of sampled farmers ranged from 43% to 98% with mean of 84%. The distribution seemed to be skewed to the right. This shows a wide distribution of allocative efficiency among the farmers in the area. However, none of the respondents had a 100% allocative efficiency index. Even with the mean of 0.84, about 52% of the farmers were frontier farmers since their efficiency scores were ≥80%; the average farmer needs a cost savings of about 19%, that is, [(1 – 0.84/0.98)*100] to attain the status of the most allocatively efficient farmer. This implies that resources could be allocated to their best alternative uses and prices could as well be allowed to perform their functions in the use of inputs.

Table 4: Estimates of allocative efficiencies of Acha farmers

Efficiency	Frequency	Percentage
0.40-0.49	1	0.50
0.50-0.59	2	1.00
0.60-0.69	30	15.00
0.70-0.79	61	30.50
0.80-0.89	84	42.00
0.90-0.99	22	11.00
Total	**200**	**100**
Minimum		**0.43**
Maximum		**0.98**
Mean		**0.84**

CONCLUSION AND RECOMMENDATION

It can be concluded from findings of the study that Acha farmers in Kaduna State were not operating at full allocative efficiency level. All the cost variables were significant to the total cost of production. However, the total cost of production has the highest response to labour cost, followed by seed cost, fertilizer cost and cost of agro-chemicals. Hence, opportunities exist for improvement of allocative efficiency. Not being a member of the association, credit inaccessibility and extension contact led to the misallocation of resources in Acha farming. Based on the findings, it is recommended that:

1. Credit services should be extended to Acha farmers to enable them purchase farm inputs, increase farm holding and hire labour for farming activities.
2. Extension services to the Acha farmers should be intensified so as to extend improved practices that will help reduce production costs and improve productivity.
3. The farmers should make use of benefits of membership of farmer associations by pulling their resources together to help themselves obtain inputs such as seeds, fertilizer and agrochemicals.

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