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Increasing production efficiency of ginger for poverty alleviation in Kaduna state, Nigeria: A stochastic frontier approach

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Abstract

The study analysed the technical efficiency of ginger production among farmers in Jema's, North Central Nigeria. A multi-stage simple random sampling technique was used to obtain a sample of 100 farmers. Data generated were analysed using the stochastic frontier production function. The result shows that fertilizer, herbicides and labour were significant determinants of farm output. The result also shows that the maximum efficiency of the ginger farmers was 0.98 while minimum efficiency was 0.55 with mean efficiency of 0.77.The result of the inefficiency effects model showed that none of the variables has significant effect on the technical efficiency of the farmers. Thus, most of the technical inefficiency is accounted for by factors that are not captured in the model. Implications are that ginger enterprise should be made more attractive by the provision of modern farm technologies and farmers' cooperative societies should be involved in the supply of production inputs to prospective farmers. Farmers should further be motivated through adequate markets for ginger to enhance their production and increased living standards.

Keywords:Efficiency; Ginger; Kaduna State; Stochastic

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1. Introduction

Ginger (Zingiberofficinale Roscoe) has been grown in Nigeria since about 1927 and since then it has steadily increased in importance as a valuable commodity. Being one of the cash crops grown in the country, ginger has a great foreign exchange potential. Its price in the world market has remained attractive. Ginger at the moment has both high domestic and international consumption rating compared with other export commodities. On the domestic scene, ginger is gaining acceptance as a flavouring agent favourably competing with curry and magi cubes. Therefore, with the emphasis on local sourcing of raw materials, it is envisaged that ginger will be industrially utilized on a large scale, considering its high demand in confectionary, beverages and pharmaceutical industries in Nigeria.

Notwithstanding, ginger production has not been an exception to the declining performance of agricultural production in Nigeria, hence it has not been able to realize its full potential as an export crop and a major foreign exchange earner. As observed by Erinle (1989), the absence of scientific research to back up the efforts of the farmers was among the factors limiting increased production. Also, Abaluet. al. (1979) conducted a survey of agriculture in Kaduna State and found out that ginger production efficiency was very low with an estimated yield of only 5 tons per hectare of fresh ginger. In China and India, yields range between 10 and 29 tons per hectare depending on the variety. Arising from the above undesirable scenario, this study will attempt to:

(i) Determine the determinants of farm output in ginger crop farming in the study area; and
(ii) Determine the socio-economic determinants of resource use efficiency in ginger crop farming in the study area.

2. Theoretical framework

The modelling, estimation and application of stochastic frontier production function to economic analysis assumed prominence in econometrics and applied economic analysis following Farrell's (1957) seminar paper where he introduced a methodology to measure technical, allocative and economic efficiency of a firm.

According to Farrell, technical efficiency (TE) is associated with the ability of a firm to produce on the isoquant frontier, while allocative efficiency (AE) refers to the ability of a firm to produce at a given level of output using the cost-minimising input ratios .Thus defining economic efficiency (EE) as the capacity of a firm to produce a predetermined quantity of output at a minimum cost for a given level of technology (Bravo et al., 1997). Farrell's methodology had been applied widely, while undergoing many refinement and improvements. One of such improvement is the development of stochastic frontier model which enables one to, measure firm level technical and economic efficiency using maximum likelihood estimate - a corrected form of ordinary least square (COLS). Aigner*et al.,* (1992) and Meeusen and Van den Broeck (1997) were the first to proposed stochastic frontier production function and since then many modifications had been made to stochastic frontier analysis.

The most popular methods of measuring efficiency, are parametric (the stochastic frontier method) and the non-parametric (Data Envelopment Analysis) which assumes the presence of inefficiency effects in the production system. Coelli (1995) compared the two methods and reported that the stochastic frontier function is preferred because of its ability to deal with stochastic noise and the incorporation of statistical hypothesis tests pertaining to production structure and the degree of inefficiency. Therefore the frontier production function differs from the Ordinary Least Square estimation in the structure of the error term. Bravo-Ureta and Pinheiro (1997), Ajibefun and Abdulkadri (1999), Sharma et al. (1999) and Ajibefun et al. (2002) used the stochastic parametric model to estimate efficiencies in agricultural production in their studies. The model may be expressed below:

2.1. Model Specification

The frontier model is presented as:

$$Y_{it} = \beta_0 + \sum_{j=1}^{k} \beta_j X_{jit} + (V_{it} - U_{it}) \qquad , i = 1, \dots, N, t = 1, \dots, T \qquad (1)$$

The predictions of individual firm's technical efficiencies from the estimated stochastic production frontiers are defined as:

$$EF_{it} = exp(-U_{it}) = E[exp(-U_{it})/Ei] = \left\{\frac{1-\emptyset[\eta_{it}\sigma_i^* - (\mu_i^*/\sigma_i^*)]}{1-\emptyset[-\mu_i^*/\sigma_i^*]}\right\} \exp\left[-\eta_{it}\mu_i^* + \frac{1}{2}\eta_{it}^2\sigma_i^{*2}\right] \qquad (2)$$

where,

E*i* represents the (T*i* x 1) vector of E*it*'s associated with the time periods observed for the *i*th firm, where,

E*it* = V*it* – U*it*,

$$\mu_i^* = \frac{\mu\sigma_v^2 - \eta_i E_i \sigma^2}{\sigma_v^2 + \eta_i \eta_i \sigma^2} \qquad (3)$$

$$\sigma_i^{*2} = \frac{\sigma_v^2 \sigma^2}{\sigma_v^2 + \eta_i \eta_i \sigma^2} \qquad (4)$$

where,

η_i represents the (T*i* x 1) vector of η_{it}'s associated with the time periods observed for the *i*th firm, and Φ(.) represents the distribution function for the standard normal random variable. The Cobb-Douglas functional form was used to estimate the technical efficiency in the stochastic production frontier. The function requires few independent variables. The specific model estimated is in the form:

$$\ln Y = \ln\beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \epsilon \qquad (5)$$

where,

Y denotes (the logarithm of) the production of the *i-th* firm in the *t-th* time period;
X*s* represents the k-th (transformations of the) input quantities;
βstands for the output elasticity with respect to the *k-th* input.

3. Methodology

3.1. The study area

Jema'a Local Government is located between the Latitude of 9˚10' - 9˚30' N and longitude of 8˚00' - 8˚30' E. The Local Government is bounded in the East by Kagoro in Kaura Local Government, in the North by Zonkwa in ZangonKataf Local Government, while in the West by Jaba Local Government. To the South it shares border with Nassarawa State and in the South-East by SangaLocal Government respectively. The Local Government population is projected to be about 278, 735.The Local Government is situated in the low Savannah plains of Plateaus and has 190.5cm of rainfall annually, which makes the area very productive for various food crops, such as Maize, Guinnea corn, Millet, Yam, Cocoyam, Rice, Cashew, Vegetables etc. These are cultivated in great quantity and cash crops like; Ginger, Palm produce, Groundnut, Kolanut, Coffee, Soyabean, Cotton etc.

3.2. Sampling procedure

A systematic sampling method was adopted in a way that after every five (5) houses, a questionnaire was administered, that is, after the first, second, third and fourth houses were counted, the fifth house was administered a questionnaire and that was adopted in all the five selected districts of the study area. This was adopted in view of the fact that all households in the study area own at least, a farm of ginger.

3.3. Data collection

Primary data were collected from 100 ginger farmers for the 2012 farming season in 2013. Questionnaires were systematically distributed to the farmers in the five (5) districts of the study area, 20 questionnaires were distributed in each district, namely: Kpadan district, Kanock district, Kwagiri district, Barde district and Asso district.

3.4. Analytical Techniques

The data were subjected to Cobb-Douglas stochastic frontier production and cost functions using the maximum likelihood method, which is specified as follows:

$$Y = X_{it}\beta + E_{it} \qquad (6)$$

where,

$$E_{it} = V_1 - U_1 \quad (7)$$

Taking logarithm of both sides, the equation becomes

$$\ln Y = \beta_0 + \beta_1 \ln(X_1) + \beta_2 \ln(X_2) + \beta_3 \ln(X_3) + \beta_4 \ln(X_4) + \beta_5 \ln(X_5) + V_1 - U_1 \quad (8)$$

where,

Y = quantity of ginger produced/kg
β_1 = coefficient of the parameter estimated
X_1 = planting materials (kg)
X_2 = quantity of fertilizer (kg)
X_3 = herbicides (litres)
X_4 = labour (mandays)
X_5 = cost of transportation (₦)
V_1-U_1 are as defined earlier

Coelli (1995) expressed the cost function as follows:

$$Y_i = x_1\beta + (V_i + U_i) \qquad ,i=1,\ldots,N. \quad (9)$$

where,

Y_i is the (logarithm of the) cost of production of the i-th firm;
$X_i$input prices and output of the i-th firm;
$\beta$is a vector of unknown parameters;
$V_i$is a random variable which is assumed to be *iid*$N(0,\sigma v^2)$, and independent of the
U_i which is non-negative random variables which is assumed to be *iid*$(0,\sigma u^2)$.

Taking logarithm of both sides, the equation becomes:

$$\ln Y = \beta_0 + \beta_1 \ln(X_1) + \beta_2 \ln(X_2) + \beta_3 \ln(X_3) + \beta_4 \ln(X_4) + \beta_5 \ln(X_5) + V_1 - U_1 \quad (10)$$

where,

Y = quantity of output/kg
β_1 = coefficient of the parameter estimated;
X_1 = amount spent on planting materials (₦)
X_2 = cost of fertilizer (₦)
X_3 = cost of herbicides (₦)
X_4 = cost of labour (₦)
X_5 = cost of transportation (₦)
V_1-U_1 are as defined earlier.

In this cost function, the U_i now defines how far the firm operates above the cost frontier. If allocative efficiency is assumed, the $U_i$is closely related to the cost of technical inefficiency.

The inefficiency model based on Battese and Coelli (1995) specification was,

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + W_i \quad (11)$$

where,

Z_1 = age of the farmer (number of years)
Z_2 = educational level of farmers (years of schooling)

Z_3 = experience of the farmers (number of years spent farming ginger)
Z_4 = household size (number of people in the farmer's house)
Z_5 = extension contact (dummy: 1=yes, 0=otherwise) and
W_i = error term.

3.5. Returns to scale

In other to determine the returns to scale, the sum of output elasticities with respect to each resource was computed. Elasticities are estimated because they permit the evaluation of the effect of changes in the amount of an input on the output. According to Olayide and Heady (1982), when:

$\sum EPi = 1$, we have constant returns to scale;
$\sum EPi < 1$, we have decreasing returns to scale;
$\sum EPi > 1$, we have increasing returns to scale.

4. Results and discussion

4.1. Productivity and technical efficiency

The regression parameters and diagnostic statistics were estimated using the maximum likelihood estimation (MLE) technique (Table 1). From the maximum likelihood estimates of the stochastic frontier function, it is possible to draw conclusions about the magnitude and direction of each variable on the technical efficiency of ginger farmers in the study area.The sigma squared (σ^2) indicates the goodness of fit and correctness of the distributional form assumed for the composite error term while gamma (γ) indicates the systematic influences that are unexplained by the production function and the dominant scores of random error. This means that the inefficiency effects make significant contribution to the technical efficiencies of ginger farmers. The estimated gamma (γ) parameter of 0.96 indicates that about 96% of the variation in the value of farm output of ginger farmers was due to differences in their technical efficiencies.Thus, the hypothesis that the parameter estimate of $\gamma = 0$ is rejected. The result shows that inefficiency effects were present and significant. This was confirmed by the test of hypothesis using the Log Ratio Test. The Log Ratio (LR) test is 10.40 while the critical value of the chi-square at 1% level of significance with 6 degrees of freedom χ^2 (1%, 6) was 13.03.

The signs of the coefficients of the stochastic frontier conform to the a*priori* expectation, with the exception of the negative estimate of planting materials variable. Three explanatory variables show significant relationship with technical efficiency while two did not. The positive relationship implies that increase in any of these variables by a unit will lead to an increase in technical efficiency of the farmer's vis-à-vis the output.

The production elasticity with respect to fertilizer is 0.26. By increasing the quantity of fertilizer by 1%, value of farm output will only increase by 0.26%. The coefficient of herbicides was positive and significant at 1% level. This implies that herbicides are important in ginger farming. If herbicides are increased by 1%, value of farm output will only increase by 0.77%. The implication of this is that the value of farm output is highly inelastic to herbicides and farm output cannot be significantly increased by increasing the use of herbicides.The coefficient of labour was significant and had a positive sign. This shows the importance of labour in ginger crop farming in the study area. It appears thatlabour will continue to play important role in ginger farming, affecting its efficiency, until those factors constraining mechanization are removed. The magnitude of the coefficient of labour shows that total value of farm output is inelastic to the level of labour used. If labour is increased by 1%, value of farm output will improve marginally by 0.23%.

The sum of the coefficients (output elasticity) of the variables of the Cobb-Douglas stochastic frontier production model is 0.248, and is less than unity, suggesting decreasing returns to scale.

4.2. Technical Inefficiency Model

The result of the inefficiency effects model showed that none of the variables has significant effect on the technical efficiency of the farmers. Thus, most of the technical inefficiency is accounted for by other natural, economic and environmental factors that are not captured in the model. These factors include land quality, disease and pests infestations, government policies weather and so on.

Table 1. Technical Efficiency of Ginger Farmers

Variable	Parameter	Coefficient	Standard –Error	T-Ratio
Constant	β_0	0.3419	2.3613	1.4480
Planting material	β_1	-0.4302	0.1431	-0.3005
Fertilizer	β_2	0.2597***	0.0574	4.5236
Herbicides	β_3	0.7676***	0.1091	7.0374
Labour	β_4	0.2303*	0.1402	1.6426
Transportation	β_5	0.0693	0.2129	0.3257
Inefficiency Model				
Constant	Z_0	0.4080	0.5228	0.7805
Age	Z_1	-0.0254	0.0219	-1.1581
Education	Z_2	0.0981	0.4567	0.2148
Household size	Z_3	0.0145	0.0522	0.2787
Farm size	Z_4	0.4560	0.4365	1.0447
Sigma-squared	σ^2	0.7600***	0.2910	2.6117
Gamma	γ	0.957***	0.0139	6.8912
Log likelihood function	-56.823***			
LR test	10.402***			

Source: Computed from frontier 4.1 print-out
***significant @ 1%, ** significant @ 5%, * significant @ 10% levels.

4.3. Farm level technical efficiency scores

The frequency distribution of predictive individualfarm level technical efficiency score is shown in Table 2.The Table shows that over 49% of the ginger farmers in the study area have technical efficiency scores of over 91% while 19% have a technical efficiency score ranging between 81-90% with an average score of 77%.

Table 2. Frequency Distribution of Farm Specific Efficiency Indices

Efficiency indices (%)	Frequency	%
51-60	08	8
61-70	10	10
71-80	14	14
81-90	19	19
91-100	49	49
Total	100	
Minimum	55.04	
Maximum	98.03	
Mean	76.54	

5. Conclusion and recommendation

This paper looked at the resource use efficiency in ginger crop farming. Stochastic frontier production function was used to estimate technical efficiency of ginger crop farming in the study area. Productivity analysis shows that fertilizer, herbicides and labour are significant determinants of farm output in ginger crop farming. The result of the inefficiency effects model showed that none of the variables had significant effect on the technical efficiency of the farmers. Thus, most of the technical inefficiency is accounted for by other natural, economic and environmental factors that are not captured in the model. Farm level technical efficiency scores shows that the farmers had a mean technical efficiency scores of 77%. The maximum technical efficiency was 98.03% and the minimum was 55.04%.

The findings of this study have implications for poverty alleviation through increased income. The study therefore recommends that ginger enterprises should be made more attractive by the provision of modern farm technologies. Farmers should form cooperative societies for purposes of getting production inputs and also to market their products to both local and international markets.

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