A STOCHASTIC FRONTIER ANALYSIS OF BAMBARA GROUNDNUT PRODUCTION IN WESTERN KENYA

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Abstract

Bambara Groundnut (Vigna subterranean (L) Verd) is a palatable indigenous crop that is rich in nutrients (the ripe seed contains on average 10% water, 15-20% protein, 4-9% fat, 50-65% carbohydrate and 3-5% fibre), and therefore has immense potential as a food security crop. Despite this potential, and just as for many other indigenous crops, little research on the crop has been done. Although the crop is near extinct in Kenya, it is cultivated in a few Western province districts. The objective of the research was to determine the production efficiency of Bambara groundnut production in Western Kenya. The study hypothesized that Bambara groundnut production is technically inefficient. Given that very few farmers produced bambara groundnut, a census sampling procedure was used to pick as many farmers as would be found; this achieved 59 farmers. The SPSS was used to generate descriptive statistics while the stochastic frontier analysis was used to estimate the technical efficiency of bambara groundnut production. Results show that producers had an average technical efficiency of 38.4% indicating that bambara groundnut production was inefficient.

Keywords: Bambara groundnut, stochastic frontier analysis, technical efficiency, western Kenya

Subtheme: Farm Management

Introduction

Bambara groundnut (*Vigna subterranean (L.) Verd*), originated in the dry savannas in the north of Nigeria and in Cameroon. It has been widely cultivated in tropical regions since the 17th century. In addition to Sub-Saharan Africa, it is now found in many parts of South America, Asia and Oceania. It is an annual herbaceous plant. Its germination is hypogeal (the cotyledons remain underground) and fruiting as with groundnut (*Arachis hypogea*), is subterranean. However, the subterranean fruiting mechanism is different for in Bambara groundnut, the peduncle of the raceme elongates, and by positive geotropism, forces the tip of the inflorescence under the soil. In groundnuts, underground fructification is brought about by elongation of the ovary base, with formation of a peg.

About 40 days elapse between fruit-setting and pod ripening. The seeds contain 6.5% oil and 18% protein, values less than those observed in groundnut seeds, which have a minimum content of 34% oil and 22% protein. However, they are rich in carbohydrate (60%), with the protein having a high lysine content, which is a limiting amino acid in cereals (Baudoin and Mergeai, 2001). The Bambara groundnut is an important source of protein and energy for communities that live in humid, lowland regions of Sub-Saharan Africa. It is one of the indigenous crops grown in Butere, Mumias and Busia districts of Western province, Kenya. Despite the potential contribution to people's food security, little research on Bambara groundnut has been done. It is thought that, due to inadequate policy support, most research in Kenya has concentrated on high value cash and food crops at the expense of indigenous crops. This study aimed at providing knowledge on the technical efficiency of bambara groundnut in western Kenya.

The Study Objectives

The broad objective of this research was to perform an economic analysis of the Bambara groundnut production in western Kenya. Specifically, the study aimed at analyzing the technical efficiency of Bambara groundnut production.

The Research Hypothesis

The study hypothesized that bambara groundnut in Western Kenya is technically inefficient.

Methodology

A reconnaissance survey was done in KARI, Kakamega; Provincial Director of Agriculture's Office, Kakamega; and Butere district to familiarize with the study area and the study crop. Key informants in the agricultural research and development sector were interviewed. This enabled gathering of knowledge on research, extension and production issues of bambara groundnut. Finally, a survey of bambara producers in three of Western province districts (Butere, Mumias and Busia) was carried out.

The producers' sample frame consisted the set of bambara groundnut farmers in the three districts of Butere, Mumias and Busia. These districts in Western province were purposively chosen since they are the major producers of bambara groundnut. During the reconnaissance survey, it emerged that bambara groundnut production was grown by very few farmers concentrated in certain locations within the administrative divisions of respective districts. The producers were so few that a census approach was used to select all bambara groundnut producers in the three districts. This sampling yielded a total of 59 farmers. Primary data on farmer characteristics and on input-output variables in bambara groundnut production were collected by use of structured questionnaires.

The Battese and Coelli (1992) Technical Efficiency (TE) effects model was used. This is expressed as:

$$Y_{it} = X_{it}\beta + (V_{it} - U_{it}) \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where Y_{it}, X_{it}, β and V_{it} are as defined above and U_{it} ~N(m_{it}, σ_u^2), where $m_{it} = Z_{it}\delta$, Z_{it} is the vector of firm-specific variables which may influence the firms' efficiency. The FRONTIER software was used to estimate the model parameters where t=1 (cross-sectional data). The individual firm technical efficiencies were calculated from estimated stochastic production frontiers. The measure of technical efficiency relative to the production frontier is defined as:

$$EFF_i = E(Y_i^* | U_i, X_i) / E(Y_i^* | U_i=0, X_i), \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where Y_i^* is the production of the i^{th} firm, which will be equal to Y_i when the dependent variable is in original units and will be equal to exp(Y_i) when the dependent variable is in logs. In the case of a production frontier, EFF_i will take a value between zero and one. The efficiency measures can be shown to be defined as exp($-U_i$) when the dependent variable is logged and $(x_i\beta-U_i)/(x_i\beta)$ when it not. These expressions for EFF_i rely upon the value of the unobservable U_i being predicted. This is achieved by deriving expressions for the conditional expectation of these functions of the U_i, conditional upon the observed value of (V_i - U_i).

Model Specification

This study estimated two specific econometric models. The first investigated bambara production factors while the second investigated both production and management variables in the efficiency function. These are defined using the Cobb-Douglas functional form as:

$$ln(Y_i) = \beta_o + \sum_{i=1}^{7} \beta_i lnX_i + v_i - u_i \text{ .... (3)}$$

where Yi is the bambara output (kg/ha), β_i are parameters to be estimated and X_i are input variables such that:

X_1 = land area (ha) allocated to bambara groundnut production
X_2 = quantity of labour used (man days/ha) in ploughing
X_3 = quantity of labour used (man days/ha) in planting
X_4 = quantity of bambara groundnut seed used (kg/ha) in planting
X_5 = quantity of fertilizer used (kg/ha) in planting
X_6 = quantity of labour used (man days/ha) in weeding
X_7 = quantity of labour used (man days/ha) in harvesting
v_i = random variables assumed to be independently and identically distributed, iid N (0, δ_v^2) and independent of the u_i
u_i = non-negative random variables that account for technical inefficiency in bambara production such that for the given technology and levels of outputs, the observed output falls short of its potential output; and are assumed to be independently distributed as truncations at zero of the N(m_i, δ_u^2) distribution where $m_i = z_i\delta$, where:

$$z_i = \delta_o + \sum_{d=1}^{4} \delta_d D_i + \sum_{m=1}^{4} \delta_m z_{mi} \text{ .... (4)}$$

Here, D_is are the dummy variables for the district, season, formal education and land ownership arrangements.

D_1 = 1 for Busia district and 0 for Butere or Mumias district
D_2 = Season of production (1 for season 2 and 0 for season 1)
D_3 = Level of formal education (1 for secondary or tertiary and 0 primary level or below)
D_4 = Land ownership arrangements (1 for freehold and 0 for any other) and
Z_{mi} indexes 1-4 represent continuous variables representing the general experience and management abilities of the farmer:
Z_{m1} = number of years the farmer has been in bambara production,
$Z_{m2} =$ the farmers age,
$Z_{m3} =$ the proportion of bambara produce that was sold (cash incentive) and
$Z_{m4} =$ the number of field days attended by the framer in the last two years
δ_o, δ_d and δ_m are parameters to be estimated
The unknown variance parameters to be estimated in equation 3 are associated with the composite error term ε_i defined as $\delta_\varepsilon^2 = \delta_v^2 + \delta_u^2$ and in equation 2, the parameter associated with the variance of u_i is defined as $\gamma = \delta_u^2 / \delta_\varepsilon^2$.

γ has a value between 0 and 1. If inefficiency exists among farms, the estimated variance parameter γ will be different from zero. If it is zero, the error term expresses the traditional random variation that is not under the control of the farmer. Critical chi-square values are used to test if the estimated γ and the variables explaining inefficiency jointly equal zero.

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From the model specifications in equations 1 and 2, estimated technical efficiency of the i[th] firm is calculated as the observed bambara output divided by the potential maximal bambara output and measures their individual deviation from the frontier production curve thus:

$$TE_i = Y_i / Y_i^*$$

$$= \exp(\beta_o + \sum_{i=1}^{7} \beta_i lnX_i + v_i - u_i)$$

$$= \exp(-u_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\quad \exp(\beta_o + \sum_{i=1}^{7} \beta_i lnX_i + v_i)$$

Where Y_i^* is the estimated maximal bambara output of firm i. The two output measures Y_i^* and Y_i are modelled in a set-up including a production function and an inefficiency function. The production function contains the relationship between bambara output and the set of input factors, whereas the inefficiency function includes farmers' managerial variables that explain the variation in farm inefficiencies.

Results and Discussions

Farmers' Discrete Socioeconomic Characteristics

The respondents' gender analysis shows that both male and female farmers were well represented across districts with female farmers comprising 44% of the sample (table 1).

Table 1: Gender Statistics for the Surveyed Bambara Producers

District	Female		Male		Total	Frequency (%)
	Count	Frequency (%) within Gender	Count	Frequency (%) within Gender		
Busia	15	57.7	12	36.4	27	45.8
Butere	4	15.4	5	15.2	9	15.3
Mumias	7	26.9	16	48.5	23	39.0
Total	26	100.00	33	100.00	59	100.00

Source: Survey data, 2009

Table 2 presents the farmers' highest level of formal education while table 3 presents the land ownership statistics. In both Butere and Busia, the majority of bambara producers had attained primary level education while the majority of farmers in Mumias had attained secondary level of education. On the whole, the proportion of the respondents who had attained a certain level of education decreased from primary to secondary and to tertiary levels of education. Given that the minimum level of education attained was primary, it is expected that this farming community is capable of taking up and implementing technical agricultural messages passed onto them.

Table 2: The Level of Formal Education for Surveyed Bambara Producers

District	Primary		Secondary		Tertiary	
	Number	Frequency (%)	Number	Frequency (%)	Number	Frequency (%)
Busia	13	48.1	7	25.9	7	25.9
Butere	4	44.4	3	33.3	2	22.2
Mumias	8	34.8	13	56.5	2	8.7
Total	25	42.4	23	39.0	11	18.6

Source: Survey data, 2009

The land tenure statistics show that the majority of bambara groundnut producers (69.5%) operated under freehold tenure systems. This was followed by 'communal' tenure arrangements where the respondents farmed on pieces of land they did not own but belonged to a member of their family. Given the freehold tenure system, it is expected that the majority of farmers should be motivated to invest in agricultural development in their farms.

Table 3: Land Tenure Statistics for Surveyed Bambara Producers

District	Freehold		Communal		Hired	
	Number	Frequency (%)	Number	Frequency (%)	Number	Frequency (%)
Busia	23	85.2	1	3.7	3	11.1
Butere	5	55.6	2	22.2	2	22.2
Mumias	13	56.5	9	39.1	1	4.3
Total	41	69.5	12	20.3	6	10.2

Source: Survey data, 2009

Farmer Continuous Variables

Results of the farmer continuous variables show that farmers have a wide range in age spanning 56 years with a mean of 48. This indicates that the farmers are generally energetic and should generally be able to produce agricultural products. Given that the mean experience in production is 7.29 years, this crop is not new to them. Despite the positive indications, the hectarege still remains extremely low at a mean of 0.21 ha with a mean yield of 63.42 kg/ha. This is far away from the 300 to 800 kg/ha under traditional farming systems and about 3,000 kg/ha under commercial production realized in other parts of the world (Baudoin and Mergeai, 2001). Table 4 shows the summary statistics for farmers' continuous variables.

Table 4: Summary Statistics for Farmers' Continuous Variables

Variable	Min.	Max.	Mean	S.D.
Age of the respondent (years)	15.00	71.00	47.98	12.48
Respondent's years in bambara production	1.00	32.00	7.29	7.49
Hectares under bambara production in 2008	0.08	0.81	0.21	0.14
Bambara yield (kg/ha)	1.01	362.90	63.42	69.55
Number of extension visits received per month	0.00	15.00	1.94	3.24
Number of field days attended in the last 2 years	0.00	40.00	4.38	5.72
Fertilizer application rate (kg/ha)	0.00	250.00	49.33	78.39
Proportion of Bambara yield sold (%)	0.00	100.00	68.25	26.79

Source: Computation from Survey Data, 2009

The low average yields can be attributed to the low levels of input use, particularly of pesticides which were not used at all; and fertilizer which was sparingly applied by a few farmers.

Stochastic Frontier Analysis Results

The maximum likelihood estimates for the parameters in the Cobb-Douglas stochastic production frontier function for bambara groundnut producers are presented in table 5. To complement these results, supplementary analysis of the distribution of farms' technical efficiency was done (table 6).

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Table 5: Maximum Likelihood Estimates for Cobb-Douglas Stochastic Frontier Analysis

Variables	Parameters	Coefficients[1]	SE	t-ratio
Constant	β_o	6.8633	0.4590	14.9522
Land Area	β_1	-0.2646**	0.1328	-1.9926
Ploughing labour	β_2	0.2880**	0.1549	1.8591
Planting labour	β_3	0.1701***	0.0804	2.1167
Seed planted	β_4	0.0767*	0.0584	1.3132
Planting fertilizer	β_5	0.1298	0.2379	0.5456
Weeding labour	β_6	-0.0619	0.1179	-0.5248
Harvesting labour	β_7	-0.5860	0.0515	-0.0011
Sigma squared	δ^2	2.2646	0.2561	8.8418
Gamma	γ	0.9999	7.5752E-08	1.3201E07
Log likelihood function	λ	-67.4504		
LR test of the one sided error		16.7025		

Source: Computation from Survey Data, 2008

The first order coefficients β_1, and β_2, are statistically significant at 5%, while β_3, and β_4 are significant at 2.5% and 10% levels of significance respectively. The estimated value for β_1 (-0.2646), is the marginal impact for the quantity of land area allocated, interpreted as a 0.26% decrease in bambara groundnut yield due to a 1% increase in the land area allocated to the crop, other factors held constant. Similarly, value for β_2 (0.2880), is the marginal impact for the quantity of labour allocated to ploughing; a 0.28% increase in bambara groundnut output due to a 1% increase in the labour allocated to ploughing, other factors held constant.

The analysis shows that the mean technical efficiency among the farms stood at 38.42% with a maximum of 99.95%. This indicates that, on average, farms could increase their output by 61.58% using the same input bundle. A further analysis shows that bambara production is generally technically inefficient with only 13.79% of the farms having an efficiency above 75%. The majority of the farms (39.66%) have an efficiency below 25% (table 6).

Table 6: Distribution of Farms by Technical Efficiency

TE Range (%)	No Farms	Frequency (%)
TE<25	23	39.66
25<TE<50	18	31.03
50<TE<75	9	15.52
TE>75	8	13.79
TOTAL	58	100.00

Source: Source: Computation from Survey Data, 2008

Conclusions and Recommendations

The level of management of bambara groundnut farms is generally low with low levels of inputs application resulting in low yields. The technical efficiency is also low at an average on 38.4%. There is therefore room for improved yields by 61.58% using the same input bundle. It is recommended that adaptive research be carried out in bambara groundnut producing regions to develop agronomic practices that enhance its production. This should be coupled with an aggressive agricultural extension agency that promotes this indigenous crop that has potential to curb food insecurity.

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