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Research Article

Assessing Food Security of Maize Farming Households Using Stochastic Frontier Analysis in Selected Local Government Areas in Kaduna State, Nigeria

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Abstract

The study used stochastic frontier analysis to assess food security of maize farming households in selected Local Government Areas in Kaduna State, Nigeria. Multi-stage sampling was used in selecting the maize farming households out of which, 156 households were selected. Questionnaires were used to collected primary data for the study. A Stochastic frontier production analysis was used to measure the productive efficiency of the maize farming households by modelling the maximum possible output that can be produced with a given set of inputs. The log-likelihood extracts from the data reveals the existence of inefficiency on the part of the maize farming households. The data revealed a 23% random variation in the yield of the maize farming households due to technical inefficiency. The average technical efficiency of the maize farming households was 0.83 inferring that, they are able to obtain 83% of possible output from a given blend of production inputs. Therefore, in the short-run, there is minimal scope (17%) of increasing their production efficiencies, through technology adoption, best farming practices and precision farming. The estimated coefficients of all the parameters of production function (seeds, fertilizer, agrochemicals and labour) were positive with the exception of agrochemicals. Factors affecting the efficiencies of the maize farming households were educational level, household size and age. The positive output from the determinants and the production efficiency led the farming households to be food secure with 54.45%.

Keywords

Stochastic Frontier, Log-likelihood, Food Security, Farming Households, Efficiency, Precision Farming

1. Introduction

Food security challenges have become a major crisis issue identified by every government in Nigeria. The challenge of effective food security has remained a critical issue for consideration by various government administrations in Nigeria [17]. Nigeria as a country is facing major challenges with high population growth, a high number of people living in extreme poverty, rapid urbanisation, and stagnating agricultural productivity. Terrorist activities, armed banditry, desert encroachment and continuous fighting between pastoralists and farmers have affected much of the northern region of the country and reduced its capacity to meet up with its food production potentials, these has reduced the land under cultivation and capable of exposing the farmers to extreme food insecurity. According to Solomon and Bright. [18], attainment of

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food security is a core problem confronting farming households; especially rural populations due to low productivity in staple crop production, seasonal variability in food supply as well as price fluctuations.

Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life [5]. Household food security exists when all members, at all times, have access to enough food for an active, healthy life. Individuals who are food secure do not live in hunger or fear of starvation [8]. Food insecurity on the other hand is a very complex phenomenon due to a range of factors that vary in importance among social groups, across regions and countries, as well as overtime. These factors can be grouped into four clusters representing four areas of possible vulnerability which are the socio-economic and political environment, the performance of the food economy, care practices, health and sanitation [6]. Food insecurity is described as limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways [2]. Those individuals whose food intake decreases below their minimum calorie requirements are coming under the food insecure category, as well as the person who is physically not fit, or have some disease due to the lack of food and hunger or unbalance diet [6]. It occurs when there is a cyclical pattern of inadequate availability and access to food. This is associated with seasonal fluctuations in the climate, cropping patterns, work opportunities and disease [7].

The menace in Nigeria represents one of the most pressing humanitarian and developmental challenges in contemporary Africa, affecting millions across urban and rural divides characterized by limited or uncertain access to sufficient, safe, and nutritious food [12]. According to Hassan et al. [12], the scale of food insecurity has escalated dramatically in recent years, driven by multifaceted drivers including armed conflict, climate variability, and macroeconomic pressures. Insecurity in the northeast, northwest, and northcentral regions, particularly from insurgency, banditry, and farmer-herder clashes, has displaced millions, destroyed agricultural infrastructure, and disrupted supply chains. Furthermore, recurrent flooding, desertification, and erratic rainfall patterns have diminished crop yields and livestock productivity, while soaring inflation and naira devaluation have eroded purchasing power.

Maize farming households in Kaduna include average farm sizes of about 2.08 - 2.39 hectares, yields typically averaging 1.7 - 2.8 tons per hectare, and farming households consisting of between 8 to 10 people, farm holding is about 81.3% and maize production as at 2019 was 927,160 metric tons [10]. Agriculture is the primary source of livelihood in the State, and the sector remains the largest employer of labour, which is a crucial contributor to wealth, income, and poverty alleviation. Food insecurity in Kaduna State is a critical challenge, heavily driven by rural banditry, high input costs, and socio-economic which indicates that between 33% and 79% of rural and urban households experience varying levels of food insecurity [18].

2. Materials and Methods

The study was conducted Kaduna State, Nigeria. Kaduna State lies between latitudes 90 ℕ and 12 ℕ of the equator and between longitudes 6 ℇ and 9 ℇ of the prime meridian. The state occupies about 7 percent of the Nigerian land mass. The state is made up of 23 Local Government Councils and with a population of 6,133,503 people in 2006 [13]. With a projected growth rate of 3.2%, the population is estimated to reach 9,837,937 by 2026. The state experiences an average annual rainfall of 1,272.5 mm and relative humidity of 56.64%, while average daily temperatures range from 15.1 ℃ to 35.18 ℃ [9]. Multistage sampling technique was used in selecting respondents for the study. The first stage was purposive selection of the five (5) local governments on the basis of their maize farming households and they are; Kaduna North, Kaduna South, Igabi, Makarfi and Zaria Local Government Areas. Secondly, ten villages were purposively selected, two from each Local Government Area based on their intensity in maize production. Finally, a simple random sampling was employed in selecting farmers from each of the villages. Ten percent (10%) of the sample frame (1548) was used as the sample size. In all, 156 farmers were randomly selected.

Stochastic Frontier Production Analysis

The stochastic frontier production function is given implicitly as:

$$Y_i = f(x_i.\beta) + e_i \quad (1)$$

$$e_i = v_i - u_i \quad (2)$$

Where: Y_i = quantity of output of the i^{th} farm, x_i = vector of the inputs used by the i^{th} farm, β = a vector of the parameters to be estimated, e_i = composite error term, v_i = random error outside farmer's control and u_i =technical inefficiency effects.

Stochastic frontier production model is explicitly given as:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + (Vi\text{-}Ui) \quad (3)$$

Where: ln = the natural logarithm, Y = output of maize (kg/ha), β_0 = constant term, β_1- β_3 = regression coefficients, X_1 = quantity of seed (kg), X_2 =quantity of fertilizer (kg), X_3 = total labour used (man days), X_4 = quantity of agrochemical (litres) Vi = random variability in the production that cannot be influenced by the farmer. U_i = deviation from maximum potential output attributable to technically inefficiency.

$$U_i = \delta_0 + \delta_1 1n Z_1 + \delta_2 \ln Z_2 + \delta_3 \ln Z_3 + \delta_4 \ln Z_4 + \delta_5 \ln Z_5 + \delta_6 \ln Z_6 \quad (4)$$

Where: U_i = inefficiency effects, Z_1 = age of farmer (years), Z_2 = household size (number), Z_3 = formal education (years), Z_4 = source of capital (₦), Z_5 = access to extension services

(number of extension contact/period), Z_6 = membership of co-operative society (years), δ_0 = constant and δ_1-δ_6 = Parameters to be estimated.

3. Results and Discussion

3.1. Production Efficiency of Maize Farming Households

Maximum likelihood estimate of the stochastic frontier production efficiency model was carried out to determine the production efficiencies as well as the determinants of the inefficiencies of maize farming households in the study area. Sigma-square ($\sigma 2$) and Gamma (γ) were estimated to be 0.91 and 0.234 respectively and are both significant at 1%. The sigma square ($\sigma 2$) shows the correctness or goodness of fit of the model while the gamma (γ) shows the ratio of the variance of farm specific production efficiency to the total variance of production was 23.4 and indicates that about 23.4% of the variation in production among the maize farming households was due to differences in production efficiency of the farmers.

The study revealed that the coefficient of seed and fertilizer were positive and significant at 1%. This means that a unit increase in seed and fertilizer will translate into an increase in the production efficiency by 0.501 and 0.076 respectively. The coefficient of labour was 0.61 which is positive and statistically significant at 1% level. This showed that labour is an important variable in maize farming in the study area. This agrees with [11], where farmers made use of family labour in arable crop production for farm operations which show the importance of labour in farming, particularly in developing countries where mechanization is rare on small scale farms. It also agrees with [14] who stated that an increased household size of respondents helps to improve the human resource, that is, labour thereby increasing the efficiency of the farmers. Also, this form of labor, deeply ingrained in cultural traditions, ensures the transmission of skills and knowledge across generations, promoting a sense of ownership and responsibility among family members [14]. The estimated result of the inefficiency model is contained in Table 1. Generally, a negative sign on a parameter means that the variable reduces technical inefficiency, while a positive sign increases technical inefficiency. The results show that all the technical inefficiency variable except age and education were not statistically different from zero.

The coefficient of age in the inefficiency model is negative and statistically significant at 5%. This indicates that an increase in the age of maize farming household decreases technical inefficiency. This is line with findings of [15] who asserts that older farmers may have a wealth of experience gained from years of practical work in agriculture. The accrued experience could lead to better resource allocation decisions because older farmers could have encountered a wider range of situations and learned from past successes and failures. Years of education showed a negative relation with technical inefficiency and are significant at 5% level for maize farmers. The negative coefficient of education reveals that high level of education attained results in a reduction in technical inefficiency of maize farmers. This agrees with [15] who opined that more years of education led to increased allocative efficiency, thereby improving agricultural outcomes. Also, [4] analyzed data from multiple countries and found that education significantly contributes to agricultural productivity and efficiency.

Table 1. *Results of Maximum Likelihood Estimates of Stochastic Frontier Production Function of maize production.*

Variables	Parameters	Coefficients	Std. error	T-Value
Production Variable				
Constant	β_0	3.1857	0.5626	5.662***
Seed	β_1	0.5009	0.0854	6.090***
Fertilizer	β_2	0.0761	0.0301	2.527***
Agrochemical	β_3	0.031	0.082	0.376
Labour	β_4	0.6084	0.1627	3.740***
Inefficiency Variable				
Constant	Z_0	-0.3494	0.6330	-0.552
Age	Z_1	-0.024	0.098	-2.487**
Education	Z_2	-0.193	0.094	-2.053**
Household size	Z_3	-0.0545	0.0397	-1.375

Variables	Parameters	Coefficients	Std. error	T-Value
Extension contacts	Z_5	0.1521	0.2531	0.599
Amount credit borrowed	Z_6	0.00002	0.00006	1.000
Diagnostic Statistic				
Sigma-squared	(σ^2)	0.9067	0.3061	2.962***
Gamma	(γ)	0.2343	0.0316	7.394***
Log likelihood function	*L/f*	-154.585		
LR test		17.816		
Total number of observations		156		
Mean efficiency		0.83		

***P < 0.01, **P < 0.05, * P < 0.10

The independent samples t-test was conducted to analyze the impact of efficiency on food security indicated that there was significant difference between maize farming household's efficiency and their food security. The result exhibited that the technical efficiency score is negatively associated with food security and statistically significant at 5% ($p< 0.05$). The calculated t-value from the result was 12.51 which exceeds the critical value (t-critical two tail) of 1.58. This implies that the more technically efficient the maize farming households are in their farm operations the less food insecure they are exposed to. An increase in their efficiency would automatically lead to a reduction in the food insecurity status of the maize farming households. It was observed that improvement in the farm productivity of the smallholder farmers in Nigeria brought about improvement their income generation and consequently poverty reduction [3]. According to the mean efficiency of 0.809 (81%) revealed by the study, a specific mix of production inputs might yield around 81% of optimal output for maize farming households in the study area.

Table 2. *The result of t-test showing the impact of efficiency on food security of maize farmer.*

	Efficiency	Food security
Mean	0.809	0.336
Variance	0.136	0.474
Observations	156	156
t Stat	12.510	
t Critical two-tail	1.58*	

3.2. Food Security Status of Maize Farming Households

Table 3 below presented a summary of the date collected of food security indices of the respondents that was analysed. The maize farming households were separated into two distinct categories of being food secure or food insecure based on their per capita food expenditure. The maize farming household's expenditure with two-thirds of mean per capita expenditure as threshold to construct food-poverty line or food security line, this method of computing food security line was used in many studies, whose main focus is to determine the food security status of households [16]. The estimated food security line was ₦4,315.5. Therefore, maize farming households whose per capita expenditure fell below ₦4,315.5 were designated as food insecure while maize farming households whose mean per capita food expenditure equals or is greater than ₦4,315.5 are food secure. The results in Table 3, showed that about 54% of the maize farming households were food secure while about 46% were not food secure. The food insecurity gap and food surplus index which measure the extent of deviation from the food security line, showed that the food secure maize farming households exceeded the food security line by 47%, while 64% of food insecure maize farming households fell below the poverty line. Also, the mean per capita expenditure for all the maize farming households was ₦8,945.21 and ₦2,413.01, for food secure and food insecure maize farming households respectively. This empirical finding agrees with the results of [1].

Table 3. Food Security Status of Maize Farming Households.

Food security index	Food secure	Food insecure
Number of households	85	71
Percentage of household	54.49	45.51
Head count ratio (H)	0.545	0.455
Food insecurity gap/Surplus index	1.32	0.51
Mean Monthly Per capita expenditure	₦8,945.21	₦2,413.01

4. Conclusion and Recommendations

The study found out that majority of the maize farming households are food secure. The percentage of the food secure farming households was 54.49% with a mean technical efficiency of 0.83. the major determinants of efficiency of the maize farming households that significantly explained the technical efficiency were seed, fertilizer, labour, age and education. It is therefore based on these determinants that policy makers must come up with positive working strategies to curb food insecurity by providing basic farm inputs at the right time, place and the right price to encourage utilization which will ultimately translate into more output for the farming households. There is the need to encourage the use of technology to reduce manual labour and engage them in other activities, this will increase efficiency and give farmers more income to stay above poverty line, education should be encouraged through extension training and advocacy campaigns so that the farming households will have the technical skills for best farming practices and possible diversification for more income.

Author Contributions

Mohammed Maina: Conceptualizaion, Data curation, Resources, Methodology, Visualization, Writing – original draft

Aisha Simbiat Hussaini: Formal Analysis, Methodology, Data curation, Writing – review & editing

Conflicts of Interest

The author declare no conflict of interest.

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