Technical efficiency in rain-fed maize production in Adamawa state Nigeria: Stochastic approach

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Abstract— *The study analysed the technical efficiency of rain-fed maize cultivation in Adamawa state, Nigeria using stochastic approach. The study was based on primary data collected from 140 respondents using simple random sampling for the period of 2014-15 Kharifmaize. The result reveals that resources were under-utilized in rain-fed maize cultivation in Adamawa state, Nigeria. Moreover, the mean technical efficiency of 0.69 indicates that an average farmer in the study area have the scope for increasing technical efficiency by 31 per cent in short-run under the existing technology. The study therefore, recommends that government should pay more attention on the land consolidation programme. It will help farmers to adopt improved agronomic practices and enhance the production and productivity of rain-fed maize production in Adamawa state.*

Keywords— Technical efficiency, Inefficiency parameters, Rain-fed Maize, Data, Random sampling.

I. INTRODUCTION

Maize (*Zea mays*) or corn is a cereal grain believed to have originated in central Mexico 7000 years ago from wild grass. It is third most important grain after rice and wheat and one of the cheapest foods and food ingredient available in the world. Maize is distinguished by its female inflorescence, called corncob where the seeds (kernels) are grouped along one axis. It is an important cereal in many developed and developing countries of the world and widely used for animal feed and industrial raw materials in developed countries whereas it is a staple food in many developing countries as it provides half of the daily intake of calories and about eighteen per cent protein depending on the variety. Maize tolerates wide range of geographical environments. This makes it to be the most widely grown crop in the world and its greater weight is produced each year than any other grain.

Nigeria is the largest producer of maize in Africa and ranked 13th in the world with a total production of 7.3 million MT in 2015; (a 2.67 per cent decrease from previous year, based on sizeable carryover supplies and declines in market prices).Nigeria’s maize production had a humble beginning; it stayed around one million ha through the early 1980s. Accelerated growth started in the mid-1980s, when hybrids were introduced, exceeding the 5 million ha mark in the mid-1990s, following the introduction of early varieties; it declined or remained slow during the late 2000s, mainly due to drought and erratic rainfall, but picked up thereafter. Currently it occupies the largest area of cultivated land in the country.

Despite the importance of maize in the nutrition of people, it is not always available at a required quantity in Adamawa state. This may not be unconnected to the fact that many farmers depend mainly on traditional method of farming and therefore, does not make use of the available resources effectively. With abundant fertile agricultural land and favorable weather condition for rain-fed maize production, yet Nigeria import maize product. It is expected that the findings from this study entitle “Technical efficiency of rain-fed maize cultivation in Adamawa state, Nigeria using stochastic approach”, will provide useful information and technical advice to rain-fed maize farmers in Adamawa state Nigeria

II. METHODOLOGY

2.1 Sampling procedure

Purposive and simple random sampling was used for the selection of states, local government areas, villages and the respondents in the study area.

2.1.1 Selection of study area

In Nigeria maize is predominantly a rain-fed crop. Adamawa state was purposively selected because is one of the states where maize production under rain-fed condition is high and have best ecological condition (Guinea savannah zone) that favor's the cultivation of the crop.

Two out of the 21 local government areas of the state were purposively selected for the study, on the basis of their maximum production of maize under rain-fed condition. Eight villages from Fufore and seven from Ganye were purposively selected from each of the sampled local government areas for the study, on the basis of their maximum area under rain-fed maize production.

Thereafter, a list of rain-fed maize farmers was prepared for each sampled villages and 140 rain-fed maize farmers were randomly selected using random table.

2.2 Sources and period of data collection

From randomly selected 140 respondents, primary data related to socio-economic parameters, inputs (quantity and price) used for rain-fed maize cultivation, output, market price of output etc. were collected through personal interview using pre-tested schedule in the study areas. Secondary data were collected from relevant published research articles as well as Adamawa Agricultural Development Programme [1] report.

The primary data for the present study was collected for 2014-2015 (Kharif maize) in the study area.

2.3 Technical Efficiency

In analyzing technical efficiency in rain-fed maize production, inferential statistics involving the use of stochastic frontier production was used. The use of stochastic frontier production function has some conceptual advantages in that it allows for the decomposition of the error term into random error and inefficiency effects rather than attributing all errors to random effects [13]. It is specified as:

$$Y_i^* = f(X_i; \beta) \exp(V_i - U_i) \quad (1)$$

Where;

Y_i^* = Production of the i^{th} firm

X_i = Vector of input quantities of the i^{th} firm

β =Vectors of unknown parameters

V_i = These are random variables which are assumed to be normally distributed $N(0,\delta^2 v)$ and independent of U_i. It assumed to account for random factors such as weather, risk and measurement error.

U_i = These are non-negative error term having zero mean, and constant variance i.e. $N(0,\delta^2 U)$ [13]. It measures the technical inefficiency effects that fall within (because of errors could be controlled with effective and adequate managerial control of the farm) the control of the decision unit.

2.3.1 The empirical stochastic frontier production model

The Cobb-Douglas production function was used to specify the production technology of the farms. The empirical stochastic frontier model is specified as:

$$InY_{ij}=\beta_0 + \beta_1 InX_{1ij} + \beta_2 InX_{2ij} + \beta_3 InX_{3ij} + \beta_4 InX_{4ij} + \beta_5 InX_{5ij} + \beta_6 InX_{6ij} + V_{ij} - U_{ij} \quad (2)$$

Where,

Y_{ij} = Output of maize (Kg)

X_1 = Size of farm (ha)

X_2 = Quantity of seed (Kg)

X_3 = Hired labour (man-days)

X_4 = Family labour (man-days)

X_5 = Agro-Chemicals (liters)

X_6 = Quantity of fertilizer (kg)

V_i and U_i as previously defined.

Operational definition of the variables of empirical stochastic production function for rain-fed maize production is as follows:

a. Output of maize (Y_{ij}): This is the total quantity of maize in kilogram produced per hectare by farmers.

b. Farm size (X_1): This is the size of land used in producing maize crop by the farmers. It was measured in hectare.

c. Quantity of seed (X_2): This is the quantity of seed used in planting by the farmers. It was measured in Kilograms.

d. Hired labours (X_3): This is the total labour provided by people who were paid to work on the farm. It was measured in man-days.

e. Family labour (X_4): This is the total labour provided by family members in the production of maize. It was measured in man-days. A man-day of labour is equal to eight hours of work per day.

f. Agro-chemicals (X_5): These are quantities of chemicals used by farmers in the production of maize to protect the crop from insects' pests, diseases as well as weeds. It was measured in liters.

g. Quantity of fertilizer(X_6): Is the quantity of inorganic fertilizer that was used in growing maize. It was measured in kilograms.

The technical efficiency of maize production for the i^{th} farmer was calculated with an output oriented method as the ratio of Actual (observed) output relative to the Potential (maximum feasible) output:

$$TE = Y_i^*/ Y_i$$

$$TE = f(X_i; \beta) \exp(V_i - U_i) / f(X_i;\beta) \exp(V_i)$$

$$TE = \exp(-U_i) \tag{3}$$

Variance parameters are:

$\delta^2 = \delta^2 V + \delta^2 U$ and $\gamma = \delta^2 U / \delta^2$

Where: Y_i^* isactual output and Y_i is potential output

δ^2, γ, βs are unknown parameters that were estimated.

This efficiency measure takes values between 0 and 1 with smaller ratios reflecting greater inefficiency. The inefficiency model is defined by,

$$U_i = \delta_o + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 \tag{4}$$

Where,

U_i = Thetechnical inefficiency of the i^{th} farmer

Z_1= Farmer's age (years)

Z_2= Farmer's sex (dummy, where one indicates male and zero female)

Z_3= Farming experience (years)

Z_4= Farmer's education (years)

Z_5= Family size (Number)

Z_6= Extension contacts (dummy, one contacted, zero otherwise)

Z_7= Credit availability (dummy, where one indicates those that accessed credit and zero otherwise)

Where δ_1, δ_2,----δ_7 are unknown parameters to be estimated [3].

III. RESULTS AND DISCUSSION

Maximum Likelihood Estimate (MLE) of the parameters of the stochastic frontier production model used in estimating technical efficiency of rain-fed-maize farmers in Adamawa state, Nigeria is presented in Table 1. The result reveals that nearly all variables (farm size, seed, hired labour, agro-chemicals and fertilizer) of the estimated coefficients of the parameters of production function in Adamawa state were positive which confirm to apriori expectations and were statistically significant at 1 and 5 per cent level respectively while family labour was negative and not significant. The sigma squared and the gamma (0.163), (0.876) were statistically significant at five and one percent respectively. The sigma squared indicates the goodness of fit and correctness of the distributional form assumed for the composite error term. The Gamma implies the existence of technical inefficiency among rain-fed maize farmers and account for 88% of the variations in the output level of maize produced in study area. This confirms that in the specified model, there was presence of one-sided error component. It also implies that the effect of technical inefficiency was significant and that a classical regression model of production functions based on ordinary least squares estimation would be an inadequate representation of the data. Thus, the variance parameters confirm the relevance of the stochastic production function. The variables that were statistically significant can be discussed thus:

The elasticity of production with respect to farm size in Adamawa state 0.819 was positive and statistically significant at one percent level. This implies that farm size positively influenced the output of rain-fed maize in the study area. Thus, an increase of one percent in farm size will result to an increase in output of maize by 0.819 percent in the study area. This suggests that land was a significant factor associated with changes in maize production in the study area. The finding support the reports earlier made by previous researchers [9; 6] that there was positive and significant relationship between maize output and farm size.

The coefficient of seed (0.112) was positive and statistically significant at one percent level. This implies that one percent increase in seed would lead to increase in maize yield by 0.112 percent. This implies that seed is a positive factor influencing maize output in Adamawa state. It indicates that higher seed rate would result in high crop population and subsequently higher yield. The finding concurs with the report by [9] that seed was a positive determinant of maize output among maize farmers in Ogbomoso south LGA in Oyo state Nigeria and Nandi north district, Kenya respectively.

The elasticity of production with respect to agro-chemicals (0.175) was positive and statistically significant at one percent level. Agro-chemicals positively influenced the output of rain-fed maize in the study area as they protect the crop from insects' pests, diseases as well as weeds. Hence, it is an essential input used for increasing maize production by preventing loss before and after harvesting. Thus, besides the large growing population and scarcity of land available for cultivation, pesticides industry has a vital role to play in the agricultural sector. The present findings corroborate the report by [14] that herbicides have significant effect on maize output.

The elasticity of production with respect to fertilizer 0.175 was positive and statistically significant at five per cent level. The use of fertilizer will improve soil fertility leading to increase in yield of maize. However, fertilizer make its best contribution to the enhancement of soil fertility only if it falls within a hierarchical system of good technological measures and the doses used are related to crop plants, soil, climate and culture technology. Although use of fertilizer is yield enhancing, the economic return from use of this input is low due to high cost of the input. The result of the study is in conformity with the work of [11] who found fertilizer to be significant in white maize production.

The elasticity of production with respect to hired labour (0.001) was positive and statistically significant at one percent level. This implies that one percent increase in man days of hired labour, *ceteris paribus*, would lead to increase in maize yield by 0.001 percent. The quick and effective weeding by hired laborers may be responsible for the increased productivity of rain-fed maize in the study area. Accordingly, the production of maize in the area does not involve much of farm mechanization but used traditional technology that relies heavily on hired labour. This study is consistent with the findings of [6] who reported that there is positive and significant relationship between maize output and hired labour.

TABLE 1
MAXIMUM LIKELIHOOD ESTIMATE OF THE COBB-DOUGLAS STOCHASTIC FRONTIER PRODUCTION FUNCTION MODEL FOR RAIN-FED MAIZE FARMERS IN ADAMAWA STATE.

Variables Production Factors	Parameter	Adamawa state	
		Coefficient	t-ratio
Constant	β_o	2.6939	16.3400*
Farm Size (X_1)	β_1	0.8187	10.0500*
Seed(X_2)	β_2	0.1115	2.8500*
Hired labour (X_3)	β_3	0.0008	2.8500*
Family labour (X_4)	β_4	-0.0103	-0.7800
Chemicals (X_5)	β_5	0.1753	2.7770*
Fertilizer (X_6)	β_6	0.1753	2.2500**
Inefficiency Model			
Age (Z_1)	δ_1	-1.3640	-1.6383
Sex (Z_2)	δ_2	-0.0990	1.7644***
Experience (Z_3)	δ_3	1.0886	1.8074***
Education (Z_4)	δ_4	-0.1121	-2.9045*
Family Size (Z_5)	δ_5	0.1832	1.4907
Extension (Z_6)	δ_6	-0.2454	1.9580***
Credit (Z_7)	δ_7	-0.3157	2.0411**
Variance Parameters			
Sigma-Square (δ)		0.1625	2.5531**
Gamma (Υ)		0.8764	3.8900*

Estimates are significant at1% level
***** Estimates are significant at 5% level***
****** Estimates are significant at 10% level***

The result of the parameters of the stochastic frontier production function discussed above implies that farm size, seeds, hired labour, agro-chemicals and quantity of fertilizer were significant factors in Adamawa state.

The inefficiency parameters included in the model specifically, those related to farmers' socio-economic characteristics were also presented in Table 1. The signs in the inefficiency model were explained in the opposite way such that a negative sign indicates increase in technical efficiency while positive sign indicates decrease.

The estimated coefficient of gender (-0.099) carried the expected negative sign and was statistically significant at ten per cent level. This implies that increase in the number of male farmers will increase the efficiency in rain-fed maize production; so we can say that male farmers were relatively more efficient in maize production in the study area. Considering that planting, weeding, harvesting and other crop management operations are labour-intensive, this result is not surprising. Female farmers also have relatively less access to productive resources like loan and land. The result is in agreement with the findings of [7] that gender was an important determinant of efficiency among smallholder maize farming communities in Zimbabwe.

The estimated coefficient of extension contacts was (-0.245) negative and statistically significant at ten percent level. This indicates that continuous contacts with extension agents tends to increase technical efficiency of rain-fed maize farmers in the study area; since they provide guidance on issues such as new technologies, production and marketing related information. This finding support the reports earlier made by previous researchers [10;4;7] that increase in extension services tends to increase the technical efficiency of a farmer.

The estimated coefficient of credit availability was (-0.316) carried the expected negative sign and was statistically significant at five per cent level. The study shows that credit had positive impact on technical efficiency of rain-fed maize farmers in the study area. Therefore, availability of credits with low interest rate at a right time will increase farmers' technical efficiency. As earlier stated majority of them operated at subsistence level below two hectare hence, provision of credit to these set of farmers translate to increase in the use of agricultural technologies such as improved seed, fertilizers, herbicides as well as machines. [2] also obtained similar result that credit had positive impact on technical efficiency of maize producing households in northern Ghana.

The estimated coefficient of farming experience does not possess the expected negative sign though it was significant. This means that increase in this variable will increase technical inefficiency of rain-fed maize farmers. Farmers with more years of experience, more especially those in the rural areas may likely not going to accept new innovation and would prefer to use their previous knowledge. The finding from this study is in contrast with what [5] earlier reported that highly experienced farmers tend to be more technically efficient. In other words, the older the farmers, the more experience they have and the less the technical inefficiency they will be.

The estimated coefficient of age was (-1.364) carried the expected negative sign but was statistically insignificant. Considering the age bracket of the rain-fed maize farmers, older farmers were more technically inefficient than the younger ones. Younger farmers were more dynamic in terms of technology adoption that will impact on their efficiency. It is possible that older farmers may rely on their previous experiences which affect their willingness to adopt new technologies. It implies that increase in the number of younger farmers will enhance the technical efficiency in rain-fed maize production in the study area. This finding support the report earlier made by [2] that age have significant jolt on maize producing households in northern Ghana

3.1 Technical efficiency of rain-fed maize farmers

The distribution of technical efficiency of the farmers in the study area reveals that 7.14 percent had technical efficiency of less than 50 and about 43.57 per cent had technical efficiency of above 69 (Table 2). The mean technical efficiency was 0.69 which indicates that the average farmer produced about 69 per cent of maximum attainable output for a given input levels. This indicates that in the short run, there is scope for increasing technical efficiency in rain-fed maize production by 31 per cent in Adamawa state. This implies that to improve the technical efficiency of the rain-fed maize farmers, their knowledge, skills and awareness level need to be improved. The present finding corroborate with the study by [8; 12] who also reported high mean technical efficiency in maize production

TABLE 2
TECHNICAL EFFICIENCY OF THE RAIN-FED MAIZE FARMERS

Efficiency	Adamawa state	
	Frequency	Percentage
0.40-0.49	10.00	7.14
0.50 -0.59	33.00	23.57
0.60 0.69	36.00	25.72
0.70 –0.79	22.00	15.71
0.80 –0.89	24.00	17.14
0.90 –1.00	15.00	10.72
Total	**140.00**	**100.00**
Minimum efficiency	0.41	
Maximum efficiency	0.96	
Mean efficiency	0.69	

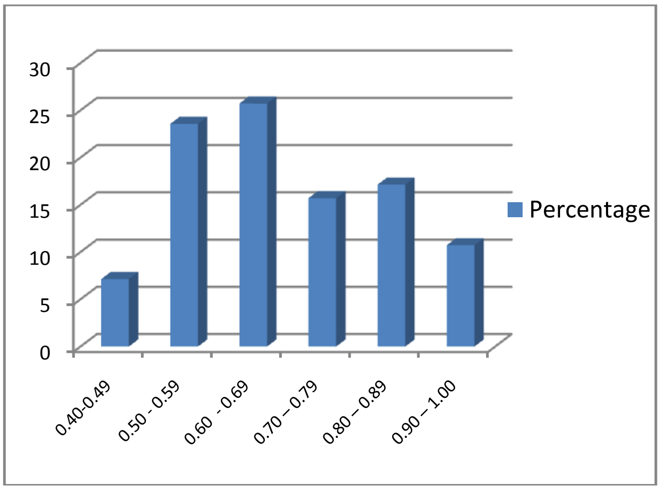

FIGURE 1: TECHNICALEFFICIENCY DISTRIBUTION OF RAIN-FED MAIZE FARMERS IN ADAMAWA STATE.

IV. SUMMARY AND RECOMMENDATIONS

The study reveals that rain-fed maize output responds positively to increases in farm size, seed, hired labour, agro-chemicals and fertilizer. The result of inefficiency parameters indicates that gender, education, extension contacts and credits availability decreased technical inefficiency. The findings of the study suggest that inputs like the land holding size has positive impact on the rain-fed maize production in the study area, the land holding size of maize growers were very small with three to four parcels. Therefore, government should pay more attention on the land consolidation programme. It will help farmers to adopt improved agronomic practices and enhance the production and productivity of rain-fed maize production in Adamawa state.

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