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TECHNICAL EFFICIENCY OF CEREAL PRODUCTION IN NORTH CENTRAL NIGERIA: A CASE FOR MAIZE, RICE AND SORGHUM FARMERS

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ABSTRACT

This study estimated technical efficiency levels of cereal crops producers. The study employed the translog stochastic frontier model to estimate efficiency levels of maize, rice and sorghum producers in the survey area. Findings revealed that maize and sorghum farmers were operating in the efficiency range of 0.50 to 0.98, while for rice farmers efficiency estimates ranged between 0.71 and 0.98. Furthermore, it was also observed that a majority of the rice farmers operate in the range 0.91 and 0.98 efficiency levels. Also, about 18% of the farmers operate in the efficiency range of 0.81 and 0.90, while just about 14% operate in the range of 0.96 and 0.98 efficiency levels for rice production. Findings suggest that, all things been equal, most of the cereal crops producers could improve their current levels of production by adjusting their input combination.

Keywords: Efficiency, Resource use, Sorghum, Maize, Rice

INTRODUCTION

There is a general agreement that a sustainable economic development depends on the improvement of productivity in the agricultural sector, particularly among small-scale producers (BINAM *et al*., 2004; MSUYA, 2008). Accordingly, a good number of empirical researches (e.g. OGUNDARI AND OJO, 2005; AMAZA *et al*., 2006; SHEHU *et al*., 2010; ABBA, 2012; MICHAEL, 2011) have been conducted with focus on the driving forces underlying low production levels characterising smallholder farmers in developing countries. Most of these studies show that the presence of shortfalls in efficiency means that output can be increased without requiring additional conventional inputs and new technologies (BINAM *et al*., 2004). Put another way, improving the livelihood of farm households depends on a competitive and market oriented agricultural practice that is driven by efficient resource usage. Hence, the allocation of resources within the farm enterprise is basically hinged on availability and paucity of same. Farmers are efficient in the allocation and use of resources within the farm enterprise to certain degree; and this contributes to the profitability of the farm endeavour they engage in. Due to its importance to the overall success of the farm business, measuring the technical efficiency and the improvement of same is paramount. As well, empirical measures of efficiency are necessary in order to determine the magnitude of the gain that could be obtained by improving performance in production with a given technology (BINAM ET AL., 2004).

The level of efficiency at which farm households operate plays a role in the total productivity achieved on the farm. To improve production, inputs have to be combined in the right proportion and quantity, where the over/under utilization of certain inputs are corrected given the prevailing production condition. Moreover, the reduction of waste in the production process is vital to the overall sustainability vis-a-vis profitability of the farm. The correction of under/over utilization of certain inputs can be effected through the knowledge of efficiency status of the farmers. Through this exercise, leakages will be identified which is a step to finding solution for reduction or curtailment. Against such background, this study is aimed at estimating the technical efficiency and the role of factor inputs to the inefficiency levels in cereal crops production in North Central Nigeria.

LITERATURE REVIEW

Ogundari and Ojo (2005), in their study technical efficiency of mixed -crop farming in Nigeria using farm-level survey data reported 87% efficiency by more than half of the farmers in allocating their resources. Shehu et al. (2010) in their study of yam farmers in the Benue region of Nigeria reported technical efficiency measures varying from 0.67 to 0.99 with a mean of 0.95. They also asserted that land, seed yam, family labor and fertilizer to be the major factors influencing changes in yam output. Michael (2011) in a study of yam producers in Osun State Nigeria reported technical efficiencies within the range 0.34 and 0.96 with a mean of 0.69; indicating farmers' ability to obtain about 70% potential output from a given mix of inputs. Heshmati and Mulugeta (1996) estimating the technical efficiency of Ugandan matoke also reported a decreasing returns-to-scale with mean technical efficiency of 65%. They also found no significant variation in technical efficiency with respect to farm sizes. In study in Côte d'Ivoire, Sherlund et al. (2002) investigated efficiency among smallholder rice farmers while controlling for environmental factors that affect the production process. They reported an increase in the estimated mean technical efficiencies from 36% to 76% when environmental factors are included. Seyoum et al. (1998) analyzed technical efficiency and productivity of maize producers in Ethiopia. Using a Cobb–Douglas stochastic production function, they reported a mean technical efficiency of 94% for project participant and 79% for non participant. Weir (1999) reported an average technical efficiency range between 0.44 and 0.56, among Ethiopian farm households. Weir and knight (2000) again, in a study in Ethiopia reported a mean technical efficiency among cereal crop farmers of 0.55. Binam et al. (2004) in a study of groundnut and maize farmers in Cameroon reported mean technical efficiencies within the range of 73% and 77%. Furthermore, Mochebelele and Winter-Nelson (2000) using the stochastic production function (translog and Cobb–Douglas), reported mean technical inefficiencies of 0.36 and 0.24 respectively among the rural farmers in Lesotho. Abba (2012) using the stochastic frontier production function, which incorporates a model of inefficiency effects reported that land, seed, and fertilizer were the major factors that influence changes in sorghum output. The technical efficiency of farmers varied from 0.16 to 0.92 with a mean technical efficiency of 0.73.

MATERIALS AND METHODS

Data for the study were collected through a cross sectional survey where multistage sampling technique was employed. A total of 460, 359, and 323 maize, sorghum, and rice farmers (multiple sampling was allowed) were sampled for the study respectively. The study area covered ten Local Government Areas in five states (including the Federal Capital Territory) in the North Central Region of Nigeria.

To account for input usage and determine the influence of each of the factors of production on total output; a translog stochastic production frontier (SPF) model was utilized for the analysis. The use of frontier production function avails a better estimation procedure of production and efficiency parameters. Frontier production functions make possible the determination of technical inefficiency, (the cause(s) of the inefficiency) and the means by which it may be reduced through the adjustment of the inputs concerned thereby improving output given the prevailing technology (Battese, 1992). The translog stochastic frontier production function has an additional unobservable random variable associated with the technical inefficiency of individual farms in addition to the random error as obtained in an ordinary least square regression model (Battese and Sumiter, 1997).

The functional form of the translog stochastic production frontier is of the form:

$$\ln q_i = \alpha_0 + \sum_j^4 \alpha_j \ln x_{ji} + \frac{1}{2}\sum_{j=1}^4 \sum_{t=1}^4 \alpha_{jt} \ln x_{ji} \ln x_{ti} - u_i + v_i \qquad 1$$

Where; q ≡ the quantity of crop in question, x_i ≡ a vector of input quantities, α ≡ the parameter vector, and u_i ≡ a one sided error (technical inefficiency) term and v_i ≡ a stochastic error term also referred to as white noise. The term v_i is assumed to be independent and identically distributed. The function was estimated in STATA through the Maximum Likelihood method where consistent estimates for α, λ, σ were obtained. The expected value of u_i given the composed error term $(u_{j,t} + v_{j,t})$ is as presented in equation 2;

$$E\left[{}^{u_i}/_{e_i}\right] = \frac{\sigma\lambda}{(1+\lambda^2)}\left[\frac{\phi\left({}^{e_i\lambda}/_{\sigma}\right)}{\Phi(-e_i\lambda/\sigma)} - \frac{e_i\lambda}{\sigma}\right] \qquad 2$$

Where; $\sigma = (\sigma_u^2 + \sigma_v^2)^{1/2}$, $\lambda = {}^{\sigma_u}/_{\sigma_v}$, $e_i = v_i - u_i$, $\phi(.)$ and $\Phi(.)$ are the standard normal distribution and cumulative density function, respectively. The variance parameters (Lambda $\lambda = {}^{\sigma_u}/_{\sigma_v}$), model variance (sigma σ), variance of the stochastic (σ_v^2) and inefficiency model (σ_u^2) were estimated by the model. The function was estimated empirically as:

$$\ln q = \ln lnd + \ln lb + \ln sd + \ln fert$$

$$+{}^1/_2 \ln^2 \ln d + \ln lnd \ln lb + \ln lnd \ln sd + \ln lnd \ln fert$$

$$+ {}^{1}\!/_{2}\ln^{2}lb + \ln lb \ln sd + \ln lb \ln fert$$

$$+ {}^{1}\!/_{2}\ln^{2}sd + \ln sd \ln fert$$

$$+ {}^{1}\!/_{2}\ln^{2}fert + \ln fert \qquad 3$$

Where; q ≡ output (kg) per hectare, lnd ≡ land size (hectare), lb ≡ labour (manday), sd ≡ Seed (Kg), and Fert ≡ fertilizer (Kg).

The translog production function was chosen over the Cobb Douglas based on the premise that it is flexible, and does not impose assumptions of constant elasticity of production or constant elasticity of substitution between/among inputs. Furthermore, the stochastic model estimates technical efficiency more effectively as compared to the deterministic model. Furthermore, unlike the Cobb-Douglas production function where the elasticity values can be readily obtained from the coefficients of the regression, the translog model coefficients are not readily interpretable. The estimated regression coefficients in the translog model were used to estimate the elasticity of production. To obtain the elasticity values of production with respect to the various inputs, the partial derivative of equation 4 was taken with respect to the particular input in question. Furthermore, inserting the regression coefficients of the respective inputs and their mean logarithmic value in the equation completes the exercise. The derivative then yields the elasticity values thus;

$$\partial \ln q_i / \partial \ln x_i = \varepsilon_i = \alpha_0 + \sum_j \alpha_{ij} \ln x_j = \frac{\frac{dq}{q}}{\frac{dx_j}{x_j}} = \frac{dq}{dx_i}\frac{x_i}{q} \qquad 5$$

In the case of one output four inputs production function of the translog form sixteen (16) coefficients were estimated in this study for each of the crop enterprises. Furthermore as is the case with production functions, the presence of multicollinearity among the explanatory variables may tend to affect the efficiency of the estimates of the regression. Hence to check for the presence of multicollinearity the variance inflation factor (VIF) for the explanatory variables was estimated, all VIF values estimated were found to be below 10 hence, going by the rule of thumb (Hair *et al*., 1995; Kennedy, 1992; Neter *et al*., 1989), it was concluded that multicollinearity was no serious threat to the analysis (Gujarati, 2003; Robert, 2007).

Technical Efficiency

Technical efficiency of the half normal type was estimated using equation 6, where the difference between one (1) and the inefficiency term was the technical efficiency measure. In the equation below (6) the value "one" represents full efficiency, hence the subtraction of the error term gives the efficiency level of a particular farm or production process.

$$TE_i - 1 - E\left[{}^{u_i}\!/_{e_i}\right] \qquad 6$$

Where: TE_i ≡ technical efficiency and E[·] ≡ the error term representing inefficiency measure.

Technical Inefficiency

The level of inefficiency recorded by a farmer may be due to several factors, among which is the human factor (Amaza *et al*., 2006); this arises from the inability of the farmer to allocate the production resource accordingly due to deficiency in education (*Ogundari and Ojo, 2005*), lack of experience or maybe gender. Apart from the human factor the physical inputs used in production also contributes a part to the general inefficiency recorded by the farm: Hence, the need to ascertain the factor(s) contributing to the inefficiency for possible readjustment or correction. In order to determine the production factors that are not efficiently utilized, and thus contribute to technical inefficiency, the relationship in the function below is estimated;

$$\boxed{\mu_{jt} = z\delta + W_{jt}} \qquad 7$$

Where; μ ≡ inefficiency term, Z ≡ farm specific variables, δ ≡ parameters to be estimated, W ≡ a random variable. Empirically, relating to the input endowment and usage by the farm households, equation 8 was estimated to capture the relationship of each of the input use with the inefficiency term.

$$\boxed{\mu = \delta_1 z_1 + \delta_2 z_2 + \delta_3 z_3 + \delta_4 z_4 + w} \qquad 8$$

Where; μ ≡ inefficiency term, Z_1 ≡ Land, Z_2 ≡ labor, Z_3 ≡ seed, Z_4 ≡ fertilizer, and W ≡ a random variable.

RESULTS AND DISCUSSION

Estimation of the responsiveness of crop yield to input variation requires the determination of elasticity values for the respective factor inputs. The determination of the responsiveness of yield to factor inputs reveals the interaction between and among inputs and hence the efficiency of the relationship. Table 1 presents the stochastic production parameters for maize, rice and sorghum crops obtained from the stochastic translog model.

The coefficients of the first order parameter estimates of the translog stochastic frontier for the inputs were all significant at various levels however these are not discussed because they do not have any economic interpretation (Richard and Jerry, 1986). Hence the output elasticity estimates for each of the inputs were calculated at variable means (Awudu and Eberlin, 2001).

The estimated elasticity values for each input in the stochastic frontier production function for the various crops as listed in Table 2 reveals labor and seed to have the highest elasticity values of 0.31 respectively for maize. Land was also observed to have the second highest elasticity in maize crop production. In the case of rice, labor has the highest elasticity value of 0.46; also for this crop, land has the second highest elasticity value. Considering sorghum, the observation is the same as was obtained in rice production, with labor having a very high elasticity value of 0.70 as compared to values obtained for maize and rice crops.

Furthermore, land has the second highest elasticity value of 0.38. Fertilizer was found to have the lowest elasticity values for all the crops with a negative value in the case of sorghum. Hence, the elasticity estimate for the case of fertilizer was a negative decreasing function in sorghum crop production; indicating an over utilization of the input characterizing a stage three situation in the production process. The result suggests that the use of fertilizer in sorghum production by farmers in the region is yielding a negative effect on total output, though the effect can be said to be negligible. Hence, other inputs held constant the reduction or efficient use/ application of fertilizer in sorghum production will be beneficial to the farmers. All inputs analyzed for all the crops were inelastic with estimates of less than one. Summations of the partial elasticity of production with respect to every input for all crops for a homogenous function are 1.06, 1.01, and 1.14 for maize, rice, and sorghum respectively.

Table 1: Stochastic Frontier Production Estimates for Cereals Production

	Maize	Rice	Sorghum
Intercept	0.437	0.228	0.100
	(0.040)	(0.036)	(0.020)
Land	0.256 ***	0.354 ***	0.069*
	(0.049)	(0.058)	(0.038)
Labor	0.183***	0.386 ***	0 .605***
	(0.046)	(0.059)	(0.047)
Seed	0.383 ***	0.092***	0.242***
	(0 .049)	(0.032)	(0.040)
Fertilizer	0.187 ***	0.163**	0.064**
	(0.038)	(0.040)	(0.022)
0.5Land2	-0.230***	0.139*	0.071
	(0.051)	(0.060)	(0.053)
Land* Labor	0.115*	0.099	-0.184**
	(0.049)	(0 .062)	(0.053)
Land* Seed	0.301***	0 .098*	0.067
	(0.053)	(0.056)	(0.050)
Land* Fertilizer	-0.069 **	0 .029	-0.017
	(0.022)	(0.029)	(0.013)
0.5Laborb2	0.060	-0.061	0.543***
	(0.079)	(0.091)	(0.086)
Labor * Seed	0.079***	0.088	-0.393***
	(0.059)	(0.059)	(0.070)
Labor *Fertilizer	-0.063	-0.099**	0.018
	(0.019)	(0.032)	(0.018)
0.5Seed2	-0.048	-0.267 ***	0.339
	(0.069)	(0.059)	(0.101)
Seed* Fertilizer	0.069***	0.011	-0.017
	(0.019)	(0.024)	(0.017)
0.5Ferilizer2	0.077***	0.069***	0.100***
	(0.017)	(0.019)	(0.020)
Lambda	4.252	1.365	1.744
sigma_v	0.048	0.171	0.108
sigma_u	0.202	0.234	0.188
sigma2	0.043	0.084	0.047
Log Likelihood	-266.00	20.420	146.900

SOURCE: ESTIMATED FROM SURVEY DATA Values in parenthesis are standard errors ***, **, * significant at 1%, 5% and 10% level respectively.

Table 2: Cereal Crops Production Elasticity

	Maize	Rice	Sorghum
Land	0.26	0.28	0.38
Labor	0.31	0.46	0.70
Seed	0.31	0.16	0.12
Fertilizer	0.17	0.11	-0.06
Returns to Scale	1.06	1.01	1.14

SOURCE: ESTIMATED FROM SURVEY DATA

The partial elasticity values are the return to scale for each of the crop under study. The implication of this assertion is that when the factors of production are varied by the same proportion, the values reveal by how much total output will increase *ceteris paribus*. The determination of the scale at which production was taking place was achieved through the assessment of the magnitude of the function coefficients. If the function coefficient is more than one, increasing returns-to-scale is said to prevail; less than or equal to one indicates decreasing or constant returns-to-scale respectively.

A glance at the function coefficients for rice crops reveals a constant returns-to-scale; suggesting a proportional increase in output when the inputs are increased. While the observation with respect to maize and sorghum show an increasing return to scale. Ogundari and Ojo (2005) *reported in a study* among mixed-cropping farmers in Nigeria a return-to-scale of 1.115 (increasing return to scale). Amaza *et al*. (2006) reported in a study in food crop production in Borno State of Nigeria a positive relationship between land area and output. They also reported positive effects of fertilizer and hired labor on output. Also, Heshmati and Mulugeta (1996) reported a decreasing returns-to-scale among Ugandan matoke farmers. While, Michael (2011) reported a return to scale of 1.119 (increasing returns to scale) among yam farmers in Osun state Nigeria. Townsend *et al.* (1998) using data envelopment analysis reported a constant returns-to-scale for wine producers in South Africa. The use of fertilizer in sorghum production indicates an excess based on the sign of the coefficient. Therefore, fertilizer usage among sorghum producers needs to be reduced, while for rice and maize, the input can be increased.

Technical Efficiency

Technical efficiency been a vital component of productivity provides a measure of performance for a farm (Farrel, 1957). This concept portrays the maximum attainable output of an enterprise given a set of inputs (Coelli *et al*., 1998). The concept involves the assessment of a number of enterprise (farms), where the farm operating at the production frontier is said to be efficient compared to those operating below. The farms operating below can improve their efficiency through the increase in output using the same input or producing the same quantity of output with less input. The efficiency estimates for maize, rice and sorghum farmers range between 0.50 and 0.98, 0.71 and 0.98, 0.50 and 0.95 respectively (Table 3).

Table 3: Distribution of Technical Efficiency Levels of Cereal Producers (%)

Tech. Eff.	Maize	Rice	Sorghum
Less than 0.50	0.70	-	3.40
0.50 -0 .60	1.50	-	3.80
0.61 - 0.70	6.80	-	12.20
0.71 -0 .80	25.60	1.40	33.10
0.81 - 0.90	51.90	18.50	40.60
0.91 - 0.95	13.10	66.20	6.90
0.96 - 0.98	0.40	14	-
1	-	-	-
Average Tech. Eff.	0.82	0.91	0.77

SOURCE: ESTIMATED FROM SURVEY DATA

From the results, it is obvious that majority of the farmers engaging in the production of maize and sorghum operate within the efficiency region of 0.81 and 0.90, with a few of the farmers (13.1% and 6.9% for maize and sorghum, respectively) in the range 0.91 and 0.95 with just 0.4 percent operating in the range 0.96 and 0.98 in the case of maize only. While efficiency levels of maize and sorghum producers are observed below the 0.61 range, in the case of rice producers none of the farmers operates below the 0.71 efficiency level. Furthermore, majority of the rice producers operate in the range 0.91 and 0.95 efficiency stage, these represents about 66.2% of the respondents. Also, about 18% of the farmers operate in the efficiency range of 0.81 and 0.90, while just about 14% operate in the range 0.96 and 0.98 efficiency range in rice production. It was observed that none of the farmers in any of the crop operation has an efficiency status of 1. It was therefore asserted that none of the farmers operates a 100% efficient enterprise for the crops under investigation, however, a good number operate above the 90% efficiency level. Therefore, it can be said that the farmers can increase their output by improving on their efficiency rating in the various crop enterprises. Amaza *et al*. (2006) reported a mean farmers' technical efficiency index of 0.68 in Borno State.

Contribution of factor inputs used in production to technical inefficiency

In as much as it is necessary to measure technical efficiency indices to ascertain the performance of a farm, it is not sufficient in itself; hence identifying factors responsible for the inefficiency indices recorded is vital for decision making at the farm level and of course policy. Against this backdrop the study sought to identify the contribution of factors inputs used by the farm households in the production of the cereal crops to the inefficiency levels observed. Hence analysis was carried out with the factor inputs serving as explanatory variables for the inefficiency recorded in the crop enterprises. Table 4 presents the result of the analysis.

From the result, land does not contribute to the level of inefficiency observed in sorghum and maize production however, it does the opposite in rice production. Furthermore, labor has a negative sign in sorghum and rice production, therefore it does not contribute to the inefficiency observed in these enterprises. Finally the coefficient for seed has a negative sign and hence does not contribute to the inefficiency observed in rice production

Table 4: Contribution of Factors of Production to Technical Inefficiency (sigma u)

	Maize	Rice	Sorghum
Intercept	-1.096	-4.145	-5.886
	(0.159)	(0.485)	(0.478)
Land	-0.441*	1.733***	-0.816***
	(0.184)	(0.320)	(0.368)
Labor	0.421	-2.60***	-2.392**
	(0.170)	(0.529)	(0.352)
Seed	-0.089	-0.709*	0.971
	(0.180)	(0.393)	(0.505)
Fertilizer	-0.005	-0.037	-0.045
	(0.053)	(0.179)	(0.130)

SOURCE: ESTIMATED FROM SURVEY DATA Values in parenthesis are standard errors ***, **, * significant at 1%, 5% and 10% level respectively.

CONCLUSION

Going by the inferences obtained from this study, it is asserted that cereal farmers in the region can improve crop production efficiency through better input mix; this can be achieved in the case of sorghum and maize by reducing land in the present input combination. It is therefore recommended that farmers be sensitized and educated on the need to adequately allocate resource on the farm as this will improve their productivity.

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