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Impact of Policy Changes on Technical Efficiency on Farmers: Empirical Evidence From Nigerian Small Scale Food Crop Farmers

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Abstract

The study quantitatively determine the impact of policy changes on technical efficiency of small scale food crop farmers in Ondo State, Nigeria, using the stochastic frontier methodology. Given the specifications of the Cobb-Douglas Stochastic frontier models, the results show that the elasticity of mean value of farm output is an increasing function of land, labour and implements. The mean value of farm output is also estimated to be an increasing function of agrochemicals and seeds. The results indicate that an increasing returns-to-scale exists among the farmers. The analysis shows a wide variation in the estimated technical efficiencies, ranging between 0.22 and 0.89. The results of simulation on policy variables show that the level of technical efficiency would significantly increase with rising level of education, farming experience and amount of credit used and decline with the age of the farmers.

***Keywords*:** Stochastic frontier; Technical efficiency; Small-scale farmers; Nigeria

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Introduction

Nigerian agriculture is dominated by the small scale farmers who produce the bulk of food requirements in the country. Despite their unique and pivotal position, the small holder farmers belong to the poorest segment of the population and therefore, cannot invest much on their farms. The vicious circle of poverty among these farmers has led to the unimpressive performance of the agricultural sector. While several efforts have been undertaken to raise production level and productivity of these farmers, so as to achieve food security, such efforts have not yielded the desired results.

As the population density increases, farmers must produce even more food than before. With the population increases today, people are being pushed to new lands and many into marginal lands. One of the enormous challenges in the drive to increase food to feed the growing population will be to raise productivity and efficiency in the agricultural sector, more so that Nigeria's rapid population growth has outstripped the nation's capacity to grow food. From 1980 - 1990, Nigeria's population grew by 3.1% a year, while agricultural production lagged far behind - growing at just 2.5% a year (Ojo, 1990).

Given the various agricultural programmes and policies implemented over the years to raise farmers' production and productivity, it then becomes imperative to quantitatively measure the current level of and determinants of technical efficiency and policy options available for raising the present level of efficiency, given the fact that efficiency of

production is directly related to the overall productivity of the agricultural sector.

From the foregoing, there is crucial need to raise agricultural growth; as such growth is the most efficient means of alleviating poverty and protecting the environment. For Nigeria, raising productivity per area of land is the key to effectively addressing the challenges of achieving food security, as most cultivable land has already been brought under cultivation, and in areas where wide expanse of cultivable land is still available, physical and technological constraints prevent large-scale conversion of such potentially cultivable land.

Efficiency of a production system or unit means a comparison between observed and optimal value of its output and inputs. The comparison can take the form of the ratio of observed to maximum potential output obtainable from the given inputs or the ratio of minimum potential to observed input required to produce the given output or some combination of the two. In these two comparisons, the optimum is defined in terms of production possibilities, and efficiency is technical.

2. Literature review

Some efficiency studies in African agriculture include Adesina and Djato, 1997, Ajibefun and Abdulkadri, 1999, Obwona, 2000; Heshmati and Mulugeta, 1996; Seyoum *et al*. 1998; Weir, 1999; Weir and Knight, 2000; Mochebelele and Winter-Nelson (2000); Townsend *et al*, 1998; Ajibefun *et al*., 1996. Of these studies, none has investigated policy options for raising farmers' technical efficiency.

Adesina and Djato applied the stochastic frontier model to measure the relative efficiency of women as farm managers using the profit function. Their results show that the relative degree of efficiency of women is similar to that of men. Ajibefun and Abdulkadri (1999) estimated technical efficiency for food crop farmers under the National Directorate of Employment in Ondo State, Nigeria. Results of analysis indicated wide variation in the level of technical efficiency, ranging between 0.22 and 0.88. Heshmati and Mulugeta (1996) estimated the technical efficiency of Ugandan matoke-producing farmers and found that the farmers face technologies with decreasing returns to scale, with mean technical efficiency of 65%, but found no significant variation in technical efficiency with respect to farm sizes. Obwona (2000) applied the Cobb-Douglas frontier model in analysis of the determinants of technical efficiency differentials among small and medium scale tobacco farmers in Uganda. The results of the study show that education, credit accessibility and extension services contribute positively to the improvement of efficiency. Seyoum *et al.*, (1998) investigated the technical efficiency and productivity of maize producers in Ethiopia. Their findings showed that farmers that participate in programme of technology demonstration were more technically efficient than farmers that did not participate. Weir (1999) investigates the effects of education on farmers' productivity of cereal crops in rural Ethiopia, using average and stochastic frontier production functions. The results show substantial benefit of schooling for farmer's productivity in terms of efficiency gains, but with a threshold of at least four years of schooling before any significant effects on farm level technical efficiency. Weir and Knight (2000) studied the impact of education externalities on production and technical efficiency of farmers in rural Ethiopia. The findings indicated that the source of externalities to schooling was in the adoption and spread of innovations which shift out the production frontier. Mean technical

efficiency of cereal crop farmers was 0.55 and a unit increase in years of schooling increases technical efficiency by 2.1% point. Townsend *et al.*, (1998) used data envelopment analysis (DEA) to investigate the relationship between farm size, returns to scale and productivity among wine producers in South Africa. The study revealed that most farmers operate under constant returns to scale, with weak inverse relationship between farm size and productivity. Mochebelele and Winter-Nelson (2000) investigated the impact of labour migration on the technical efficiency performance of farms in the rural economy of Lesotho. Using the stochastic frontier production, the study revealed that households that sent migrant labour to South African mines were more efficient than households that did not send migrant labour to South African mines, with mean technical efficiency of 0.36 and 0.24, respectively. Ajibefun *et al.*, (1996) used the translog stochastic frontier production function to study the technical efficiency of smallholder food crop farmers in Nigeria. Their results indicated a wide variation in the level of technical efficiency of the farmers.

Outside Africa, a number of efficiency studies in agriculture have been carried out by various authors. Russel and Young (1983) applied a deterministic Cobb-Douglas frontier model to a cross-section of 56 farms in England. The results indicated technical efficiencies ranging between 0.42 and 1.0, with a mean technical efficiency of 0.73. Kontos and Young (1983) in their study used deterministic frontier production function to estimate data on 83 Greek farms during the 1980-81 cropping year. The predicted technical efficiencies range between 0.30 and 1.00, with a mean technical efficiency of 0.57. Aigner *et al.*, (1977) estimated the stochastic frontier production function for United State agricultural data covering 6 years and 48 states. For this application, the stochastic frontier production function was not significantly different from the traditional average response function. Battese and Corra (1977) carried out an empirical study involving data on Australian grazing industry survey and both deterministic and stochastic Cobb-Douglas production frontiers were estimated for the three states in the pastoral zone of Eastern Australia. They concluded that the variance of the inefficiency effect was found to be a highly significant proportion of total variability of the logarithm of the value of sheep production in all states. Kalirajan (1981) applied the stochastic frontier Cobb-Douglas function using data from 70 rice farmers in India. The variance of inefficiency effects was found to be a highly significant component in describing the variability of rice yields. Bagi (1982a) estimated a stochastic frontier Cobb-Douglas production function to determine whether there were any significant differences in the technical efficiencies of crop and mixed enterprise farms in West Tennessee. The variability of inefficiency effects was found to be highly significant and the mean technical efficiency of mixed enterprise farms was smaller than that of crop farms (0.76 and 0.85 respectively). Bagi and Huang (1983) estimated a translog stochastic frontier production function using same data on the farms considered in Bagi (1982a). The Cobb-Douglas stochastic frontier model was found not to be adequate representation of the data, given the specification of the translog model for both crop and mixed farms. The mean technical efficiencies of crop and mixed farms were estimated to be 0.73 and 0.67, respectively.

Kalirajan and Flinn (1983) used the translog stochastic frontier production function in the analysis of data on 79 rice farmers in the Philippines. The individual technical efficiencies ranged from 0.38 to 0.91. Bravo-ureta and Rieger (1990) estimated both deterministic and stochastic frontier production functions for a large sample of dairy farms in the North-eastern states of U.S.A for the years 1982. The stochastic frontier model has significant inefficiency effects for 1982 but not significantly different from the deterministic frontier in 1983. Battese and Coelli (1995) applied panel data model in the analysis of data for dairy farms in New South Wales and Victoria for three years. The estimated technical efficiencies ranged between 0.55 to 0.93 for New Wales farms and between 0.39 and 0.93 for Victoria farms. Battese and Tessema (1993) estimated stochastic frontier production function with time-varying technical inefficiency for Indian farmers. While the results show that technical efficiencies of farm varied widely, the hypothesis of time-invariant technical efficiency is not rejected in one of the three villages. Battese *et al.*, (1996) applied the stochastic frontier production function using panel data of wheat farmers in four districts in Pakistan. Their results show that the technical inefficiency effects are highly significant. The results also indicate that technical efficiency tends to be smaller for older farmers and those with greater formal schooling. It was also discovered that the levels of wheat production of farmers tend to approach their potential frontier production levels over time, though there was no evidence of technical change. The technical efficiencies were found to vary considerably over time such that the mean technical efficiencies ranged from 57% to 79% in the districts. Ajibefun *et al.*, (1996) estimated stochastic frontier production function for Japanese rice farm households using panel data covering 1984 to 1994. Given the translog frontier model, the Cobb-Douglas frontier function was found to be inadequate in the analysis of the data. The technical inefficiencies were found to be statistically significant but time-invariant. The analysis also indicated evidence of neutral technological change. Technical efficiencies of average rice farm households in the prefectures were quite high, with the mean technical efficiency of 74.5%.

3. Methodology

3.1. Study area and data

For this study, farm level data were collected from 200 small scale farmers in Ondo State. Ondo State is one of the 36 States of Nigeria located in the Southwestern part of Nigeria. Within the state, there are three distinct ecological zones- the mangrove forest to the south, the rain forest in the middle belt and the derived savanna to the north. The state is well suited for production of crops such as maize, cassava, yam, and cocoyam. The bulk of the agricultural products come from manually cultivated rain-fed crops. Mixed cropping system of farming is common in the state, as in other parts of the country. The selection of respondent farmers for this study was multistage sampling. In the first stage, the villages in the state were divided into five strata, based on farmers' economic, socio-cultural and geographical considerations, and one village was selected from each stratum. The second stage involved random selection of sample farmers from the selected strata. From each selected village, 40 smallholder farmers were interviewed, making a total of 200 sample farmers in all. Production resources were categorized into five groups: land, labour, implements, agrochemicals and seed. Generally, the major resources for farming in the study area are land, labour and simple farm implements. Land was measured in hectares; and human labour was

measured as quantity as well as the price of the resources. Depreciation values of implements were also taken into consideration.

3.2. The model

This study uses the stochastic frontier production function. The stochastic frontier production function model has the advantage in that it allows simultaneous estimation of individual technical efficiency of the respondent farmers as well as determinants of technical efficiency (Battese and Coelli, 1995).

The idea of frontier production can be illustrated with a farm using η inputs (X_1, $X_{2=}.....X_n$) to produce output Y. Efficient transformation of inputs into output is characterized by the production of function f(x), which shows the maximum output obtainable from various input vectors. The stochastic frontier production function assumes the presence of technical inefficiency of production. Hence, the function is defined by,

$$Y = f(x_i, \beta) \exp (v_i - u_i)$$
$$i = 1, 2\ldots\ldots\ldots\ldots..n \qquad (1)$$

where v is a random error which is associated with random factors not under the control of farmer. The model is such that the possible production Y_i is bounded above by the stochastic quantity $f(x_i, \beta) \exp (v_i)$, hence the term stochastic frontier. The random error v_i are assumed to be independently and identically distributed as $N(0, \sigma^2 v)$ random variables independent of the u_is.

Technical efficiency of an individual farmer is defined in terms of the ratio of the observed output to the corresponding frontier output, given the available technology.

Technical efficiency (TE) = $Y_i Y_i^*$

$$= f(x_i, \beta) \exp (v_i - u_i) / f(x_i, \beta) \exp$$
$$= \exp (-u_i) \qquad (2)$$

where Y_i is the observe output and Y_i^* the frontier output. Technically efficient farms are those that operate on the production frontier and the level by which a farm lies below its production frontier is regarded as the measure of technical inefficiency.

For this study, the production technology of small scale food crop farmers is assumed to be specified by the Cobb-Douglas frontier production function defined by:

$$\text{Log } Y = \beta_0 + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \beta_5 \log X_5 + V_1 - U_I - U_I \qquad (3)$$

Where,

Log represents the natural logarithm

Y represents the value of production of i-th farmer measured in Naira

X_1 represents the total area of land in hectares on which crops were grown

X_2 represents family labour in mandays

X_3 stands for the value of implements in Naira

X_4 represents the quantity of fertilizer used, in kilograms

X_5 stands for value of seed in Naira

B_is are coefficients to be estimated

V_is are assumed to be independent and identically distributed normal random errors, having zero mean and unknown variance, $\sigma^2 v$;

U_is are the determinants of technical efficiency, which are assumed to be independent of V_is such that U_is is the non-negative truncation (at zero) of the normal distribution with mean, u_i, and variance, σ^2, where u_is is defined by,

$$\mu_i = \delta_0 + \delta_{1Z1i} + \delta_{2Z2i} + \delta_{3Z3i} + \delta_{4Z4i} + \delta_{5Z5i} \qquad (4)$$

where z_1, z_2 z_3 z_4, are age, level of education, farming experience and amount of credit used by farm operator respectively. These variables are assumed to influence technical efficiency of the farmers, and δ_s are unknown scalar parameters to be estimated.

The variables age, level of education, farming experience, and amount of credit used are included in the model as determinants of technical efficiency, to indicate possible effects of farmers characteristics and input-use on technical efficiency in order to be able to come out with recommendations on how government policy formulation could be used to influence these amenable policy variables so as to enhance the technical efficiency of the farmers.

4. Empirical results

4.1. Summary statistics

Presented in Table 1 is a summary statistics of variables used in the stochastic frontier production function. The values in the summary statistics vary across the farms. The farmers involved in the study have relatively small farms. Farm sizes ranged between 0.493 and 2.20 hectares. Also both hired and family labours were extensively used by the respondents, though with wide variations across farms. The main reason for wide variation in the intensity of farm labour use could be attributed to variation in the types of crops grown by respondent farmers. For instance yam production is known to be traditionally associated with intensive labour-use, especially with mould-making, staking and other operations involved in yam farming.

Table 1: Summary statistics for variables in the stochastic frontier model for the small scale farmers

Variables	Mean	Standard Deviation.	Minimum	Maximum
Value of output (Naira)	28,303	39,199	1,395	74,250
Farm size (Hectares)	1.56	0.493	0.900	2.20
Total Labour (Mandays)	90	28.9	17	201
Hired Labour (Mandays)	39	50	8	104
Value of seed (Naira)	500	205.7	127	871
Implements (Naira)	400.2	534.76	140	1,536
Fertilizers (Kg)	52	38	21	300
Age (years)	38	5.9	21	70
Education (years)	4	6.2	0	12
Farming Experience	19	4.9	4	28.5
Family size	6	3.7	1	10

Table 2: Maximum likelihood estimates

Variables	Parameters	Co-efficient	Standard Error	t-ratio
Land	$\beta 1$	0.23	0.11	2.09
Labour	$\beta 2$	0.34	0.15	2.27
Implements	$\beta 3$	0.27	0.10	2.70
Agrochemicals	$\beta 4$	0.18	0.13	1.38
Seeds	$\beta 5$	0.24	0.11	2.18
Variance parameters				
	σ_s^2	0.19	0.011	17.27
	γ	0.87	0.23	3.78
Inefficiency Model				
Constant	δ_0	1.27	0.66	1.92
Age	$\delta 1$	0.21	0.10	2.10
Education	δ_2	-0.23	0.11	2.09
Experience	δ_3	-0.19	0.09	2.11
Farm credit	δ_5	-0.30	0.12	2.50

4.2. Results of Maximum likelihood Estimates

Inferences about stochastic frontier model are based on the maximum likelihood estimates, represented by the elasticity estimates. The variance parameters of the model are obtained in terms of:

$$\sigma^2 s = \sigma_u^2 + \sigma_v^2 \text{ and}$$
$$\gamma = \sigma^2 / (\sigma_v^2 + \sigma^2) \qquad (5)$$

The estimate for the γ parameter in the stochastic frontier model, 87%, is large. The value indicates the relative magnitude of the variance with the inefficiency effects. This implies that technical inefficiencies are highly significant in the analysis of the data. The production elasticity measures the proportional change in output resulting from a proportional change in the output resulting from a proportional change in the i-th input level, with all other input levels held constant. Presented in Table 3 are elasticity estimates and returns-to scale value.

Table 3: Elasticity and returns-to-scale for small scale farmers in Ondo State

Inputs	Elasticity
Land	0.23
Labour	0.32
Implements	0.26
Agrochemicals	0.18
Seeds	0.24
Returns-to-scale	1.23

The elasticity of mean values of output with respect to the inputs are estimated at the values of the means of the resources. The elasticity of mean value of farm output with respect to land, labour, implements,agrochemicals and seeds are 0.23, 0.32, 0.26, 0.18 and 0.24 respectively. Given the specifications of the Cobb-Douglas frontier models, the results show that the elasticity of mean value of farm output is estimated to be an increasing function of land, labour, and of implements. Also, the mean value of farm output is estimated to be an increasing function of agrochemicals as well as an increasing function of seeds. The returns-to-scale value, 1.23, implies that an increasing returns-to-scale exists among the farmers. The returns-to-scale parameter indicates what happens when all production resources are varied in the long run by the same proportion. Doubling the amount of production inputs will, more than double the value of the farm output. The implication of increasing-returns to scale in this study is that as the amount of production inputs is increased, the unit cost of output would decline. This means that though the farmers are using their production inputs within the rational zone of production function, they are still using the inputs at sub-optimal levels. Given the subsistent nature of these farmers, a recommendation for increase in size of operation purely based on economies of scale without consideration for technical efficiency of the farmers may be misleading. To examine this consideration, technical efficiency estimates for individual farmers were estimated from the Cobb-Douglas frontier production functions and the distribution of technical efficiency is presented in Table 4. Given the specification of the Cobb-Douglas stochastic frontier model in equation (1), the computed technical efficiencies vary widely among the sample farmers, with minimum and maximum values of 0.22 and 0.89 respectively and a mean technical efficiency value of 0.65. The distribution of the technical efficiency in table 4 clearly shows that the technical efficiency skewed more heavily in the

Table 4: Frequency distribution of technical efficiency estimates

Technical efficiency range	Frequency	% of total
0.10-0.29	15	7.5
0.30-0.49	50	25.0
0.50-0.69	99	49.5
0.70-0.89	31	15.5
0.90-1.00	5	2.5

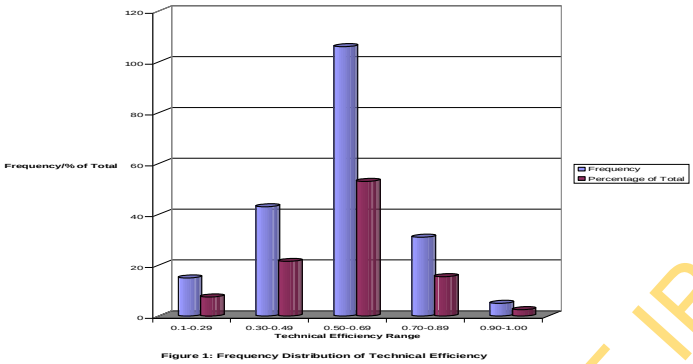

Figure 1: Frequency Distribution of Technical Efficiency

0.50 and 0.69 range, representing about 50% of the sample farmers. This is clearly shown in Figure 1. The wide variation in technical efficiency estimates is an indication that most of the farmers are still using their resources inefficiently in the production process and there still exists opportunities for improving on their current level of technical efficiency.

This led us to examine the issue of factors that determine technical efficiency. Given the results of the inefficiency model in the Cobb-Douglas frontier model, age of operator, level of education, farming experience and the amount of credit used in farming are individually significant determinants of technical inefficiency at 5% level. The implication here is that these variables significantly affect the level of technical efficiency of the respondent farmers. While the level of education, farming experience and amount of credit have negative coefficients, the age of operator has positive coefficient. The negative coefficients of level of education, farming experience and amount of credit imply that an *increase* in any of or in all of these variables would lead to *decline* in the level of technical inefficiency. An *increase* in the age of operator would lead to *increase* in the level of technical inefficiency. This implies that younger farmers are more technically efficient than older ones. This could be explained by the fact that younger farmers, apart from having greater physical strength required for farming, they are more likely to be receptive to improved farming techniques than the older farmers. The negative coefficient of farming experience implies that farmers with more farming experience are more technically efficient than farmers with less year of farming experience. Also, the negative coefficient of education implies that farmers with more education are more technically efficient than those with less education. This is *a priori* result, given that education will make farmers to be well aware of available improved farming practices and will be more receptive to such practices. The negative coefficient of the amount of credit implies that farmers who used more amount of credit are more

technically efficient than farmers who used less amount of credit. This could be explained by the fact that since most of the farmers are resource-poor, access to farm credit will enable them purchase those farm inputs they could not ordinarily afford without credit. Given that these variables are amenable to policy changes, government policy can be tailored to improve the current level of technical efficiency of the farmers. For instance, given that a younger farmer is more technically efficient than older one, government policy can be designed to attract younger farmers into farming. Also, agricultural policy could be designed to encourage experienced farmers to remain in the farming business. Finally, government could design suitable credit policy for the small scale farmers.

In order to determine the magnitude of change in the level of technical efficiency that could result from a change in government policies that influence the determinants of technical inefficiency simulation was performed on the identified variables which could be influenced by government policy.

4.3. Analysis of policy variables that affect technical inefficiency

Table 5 shows the simulation results, assuming a change in policy that influences the determinants of technical inefficiency. The simulation is done with an increase in the values of the policy variables by 5%, 10% and 20% and the observed changes in the level of technical efficiency.

The results of simulation of policy variables show that the mean technical inefficiency would *decline* with *rising* level of education, farming experience and amount of credit. An *increase* in the level of education from 5% through 20% *raised* the mean technical efficiency from the current level of 65% to 74%, while an increase in the level of farming experience from 5% through 20% led to *increase* in the mean technical efficiency from the current level of 65% to 73%. On the other hand an *increase* in age from 5% through 20% led to significant *decline* in the mean technical efficiency from 65% to 63%. The pattern of the changes in the level of technical efficiency as a result of percentage change in policy variables is presented in figure 2.

Table 5: Simulation results of variation in policy variables on mean technical efficiency

Variables	(Mean T.E =0.65)		
	+5%	+10%	+20%
Age of operator	0.65	0.64	0.63
Level of education	0.69	0.71	0.74
Farming experience	0.69	0.70	0.73
Amount of credit	0.67	0.68	0.69

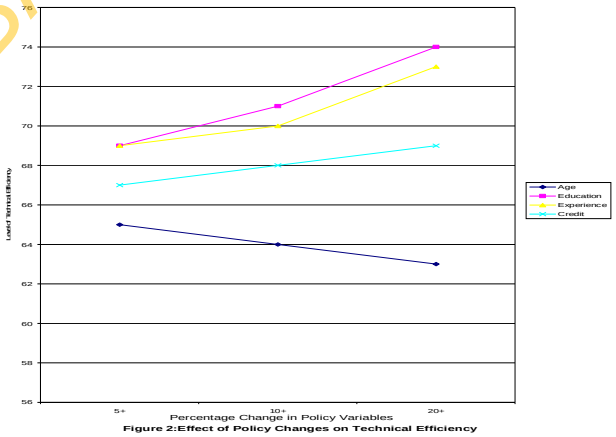

Figure 2:Effect of Policy Changes on Technical Efficiency

From the foregoing, it is important to note that education is one of the policy variables which can be used by policy makers to improve the current level of technical efficiency of farmers in Nigeria. Hence any agricultural policy in the country that would attract people with high level of education into farming and/or encourage illiterate farmers to undergo education/training would definitely lead to increase in the level of technical efficiency of the farmers. Also the analyses imply that any agricultural policy in the

country that would encourage experienced farmers to remain in the farming business (thereby gaining more experience) would also lead to increase in the level of technical efficiency of the farmers. It is also important to state that any agricultural policy that would attract young people into farming business would lead to increase in the level of technical efficiency, given that young and educated people are more receptive to agricultural innovation than the old and illiterate farmers.

5. Summary and conclusion

This study is on the analysis of the influence of policy variables on the level of technical efficiency of small-scale food crop farmers in Ondo State, Nigeria, using the stochastic frontier production function. The results of analysis show that level of education, farming experience and the amount of credit are important policy variables that significantly determine the level of efficiency of the farmers.

In conclusion, educational level of farmers as well as farming experience are important policy variables and determinants of efficiency which can be incorporated into the agricultural policy in Nigeria in order to raise the current level of technical efficiency and hence the level of productivity in the Nigerian agricultural sector.

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