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Analysis of Policy Issues in Technical Efficiency of Small Scale Farmers Using the Stochastic Frontier Production Function: With Application to Nigerian Farmers

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ANALYSIS OF POLICY ISSUES IN TECHNICAL EFFICIENCY OF SMALL SCALE FARMERS USING THE STOCHASTIC FRONTIER PRODUCTION FUNCTION: WITH APPLICATION TO NIGERIAN FARMERS*

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ABSTRACT

The purpose of this study was to analyse the determinants of technical efficiency of small scale farmers in Nigeria and the effect of policy changes on technical efficiency, using the stochastic frontier methodology. Results of analysis indicates that the farmers have an average farm size of 1.56 hectares. It is also indicated that both family and hired labour were extensively used in farm production. The analysis shows a wide variation in the estimated technical efficiencies, ranging between 0.18 and 0.91, and a mean value of 0.63, indicating a wide room for improvement in the technical efficiency. The results of simulation of policy variables show that the level of technical efficiency would significantly increase with rising level of education and farming experience.

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 and productivity of these farmers so as to achieve food security, such efforts have had negative implications for the environment.

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

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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' efficiency 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 potentially cultivable land.

From the available literature, only few studies have been carried out on technical efficiency of farmers in the African setting. Such studies includes Adesina and Djato, 1997; Ajibefun and Abdulkadri, 1999; Ajibefun, Battese and Daramola, 1996. Of these studies, none has investigated policy options for raising farmers' technical efficiency.

STUDY AREA AND DATA

For this study, farm level data were collected on 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 comes 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. 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 in mandays (for family and hired labour). Implements, seeds, and agrochemicals were each measured as quantity as well as the price of the resources. Depreciation values of implements were also taken into consideration.

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 function can be illustrated with a farm using n inputs (X_1, X_2 ......X_n) to produce output Y. Efficient transformation of inputs into output is characterized by the production 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,

$$Y_i = f(x_i, \exists) \exp (v_i - u_i) \quad i = 1, 2, ...n \qquad (1)$$

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 $f(x_i, \exists) \exp (v_i)$, hence the term stochastic frontier. The random error v_i are assumed to be independently and identically distributed as $N(0, \Phi^2 v)$ 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*

$$= f(x_i, \exists) \exp (v_i - u_i) / f(xi, \exists) \exp (v_i)$$

$$= \exp (-u_i)$$

(2)

where Y_i is the observed 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 foodcrop farmers is assumed to be specified by the Cobb-Douglas frontier production function defined by,

$$\text{Log } Y = \exists_o + \exists_1 \log X_1 + \exists_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \beta_5 \log X_5 + V_I - U_I \quad (3)$$

where

Log represents the natural logarithm

Y represents the value of production of i-th farmer measured in Naira[1]

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

$\exists_i$s are coefficients to be estimated

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

[1] At the time of collection of the data for this study 1 US $ exchanges for 100 Naira.

The U_is are the technical inefficiency effects, 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,Φ^2, where u_is is defined by,

$$\mu_i = *_o + d_1 z_{1i} + *_2 z_{2i} + *_3 z_{3i} + *_4 z_{4i} + *_5 z_{5i} \qquad (4)$$

where z_1, z_2, z_3, z_4, z_5 are age, level of education, farming experience, farm size and family size of farm operator respectively. These variables are assumed to influence technical efficiency of the farmers, *s are unknown scalar parameters to be estimated.

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

RESULTS

Summary Statistics

Presented below is a summary statistics of variables used in the stochastic frontier production function. The values in the summary statistics vary across the two zones. The farmers involved in the study have relatively small farms. Farm sizes for both zones ranged between 0.493 and 2.20 hectares. Also both hired and family labour were extensively used by the respondents, though with wide variations within and between zones. 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 out put (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

Results of Maximum likelihood Estimates

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

$$\sigma^2 s = \sigma_u^2 + \sigma_v^2 \quad \text{and}$$

$$\gamma = \sigma^2 / (\sigma_v^2 + \Phi^2) \qquad (5)$$

The estimate for the (parameter in the stochastic frontier model (87%) is quite 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 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 Nigeria

Inputs	Elasticity
Land	0.23
Labour	0.34
Implements	0.27
Agrochemicals	0.18
Seeds	0.24
Returns-to-scale	1.26

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, 0.34, 0.27, 0.18 and 0.24 respectively. Given the specification 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, an increasing function of labour, and an increasing function 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, 1.26, indicates an increasing returns-to- scale. The returns-to-scale parameter indicates what happens when all production resources are varied in the long run by the same proportion. The implication of increasing-returns-scale in this study means increasing productivity per unit of input. The farmers are not using their resources efficiently. They can still increase their level of output at the current level of resources.

Technical Efficiency Estimates

Given the specification of the Cobb-Douglas stochastic frontier model in equation (1), the predicted technical efficiency vary widely among the sample farmers, with minimum and maximum values of 0.18 and 0.91 respectively and a mean technical efficiency value of 0.63. Table 4 presents the frequency distribution of technical efficiency of the sample farmers.

Table 4: Frequency Distribution of Technical Efficiency Estimates.

Technical efficiency Range	Frequency	% of Total
0.1 - 0.29	15	7.5
0.30 - 0.49	43	21.5
0.50 - 0.69	106	53.0
0.70 - 0.89	31	15.5
0.90 - 1.00	5	2.5
Total	200	100

The distribution of the technical efficiency in table 4 clearly shows that the technical efficiency skewed heavily in the 0.50 and 0.69 range, representing 53% of the sample farmers. 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.

Given the results of the inefficiency model in the Cobb-Douglas frontier model, age of operator, level of education, and farming experience of operators 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. However, family size and farm size did not significantly influence technical inefficiency. While the level of education, farm size and farming experience have negative coefficients, age of operator, and family size have positive coefficients, respectively. The negative coefficients of level of education, farm size and farming experience 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 value of variables with positive coefficients (age of operator and family size) implies that an increase in the value of these variables would lead to *increase* in the level of technical inefficiency. In order to determine the magnitude of change in the level of technical efficiency, that could result as a result of change in government policies that influence the determinants of technical inefficiency, a simulation analysis was performed on the identified variables which could be influenced by government policy.

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 variables by 5%, 10% and 20% and the observed changes in the level of technical efficiency is as presented below.

Table 5: Simulation Results of Variation in Policy Variables on Mean Technical Efficiency.

Variables		(Mean T.E =0.63)	
	+5%	+10%	+20%
Age of operator	0.65	0.64	0.63
Level of education	0.67	0.69	0.72
Farming experience	0.67	0.68	0.71
Family size	0.65	0.65	0.64
Farm size	0.67	0.68	0.69

The results of simulation of policy variables show that the mean technical inefficiency would *decline* with rising level of education, farming experience and farm size. An increase in the level of education from 5% through 20% *raised* the mean technical efficiency from the current level of 67% to 72%, 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 67% to 71%. On the other hand an increase in farm size from 5% through 20% only led to *marginal increase* in the mean technical efficiency. An increase in age and family size of operator from 5% through 20% led to significant *decline* in the mean technical efficiency from 65% to 63% and from 65% to 64% respectively.

The implication of the foregoing analyses is 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. The current government policy which encourages a maximum of four children per woman will on the long run lead to decline in family size, especially among the farming families. A decline in family size is expected to result in increase in the level of technical efficiency (Table 5), given that the farmers have small farm size and most family members are underemployed on the farm.

Conclusion

In conclusion, education 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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