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Productivity, technical efficiency and cropping patterns in the savanna zone of Nigeria

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Abstract

The productivity and technical efficiency (T.E) of small-scale farmers in Nigeria were studied using the stochastic frontier production function analysis. Primary data was collected using multi-stage sampling techniques, from some villages in Niger State, Nigeria. Results showed that farmers were in the rational stage of production (stage II) as depicted by the returns to scale (RTS) of 0.27. The technical efficiency of the sole maize farmers was lower (0.5266) compared to that of the mixed (yam/maize) cropping farmers (0.7172). A mean efficiency of 0.622 was observed for all farmers. Over 50% of the mixed crop farmers had T.E. exceeding 0.70 as compared to 100% sole farmers who had less than 0.60. The study further showed that years of schooling, farming experience and cropping pattern positively affected T.E while increase in the age led to decrease in T.E.

Key words: Productivity, technical efficiency, small-scale farmers, stochastic frontier production, mixed cropping.

Introduction

Mixed cropping is a popular system of cropping among tropical small-scale farmers. This practice of growing crops on the same piece of land is an ancient strategy for crop production. Norman[7] identified some reasons for farmers' engaging in mixed cropping which are still valid today. First, it leads to increase in the utilization of environmental factors. This has both space and time dimension. In terms of space, some crops need a reasonable large space between plants while different species have different water and nutrient requirements and different rooting habit. Thus, the cultivation of crops in mixture can maximize for any given area at the point in time, utilization of light, water and nutrients. Second, mixed cropping can lead to reduction of adverse conditions in the ecosystem. Although sole cropping tends to attract fewer types of diseases and insects, they are likely to be present in such quantities as to cause considerable damage. In mixed cropping, a greater variety of diseases and insects are likely to be present but damage may not likely to be acute. Also a denser plant population which usually results in crop mixtures help to control the incidence of weeds.

Mixed cropping may also lead to better soil production because of the fact that many crops overlap in terms of the time they are in ground. The growing of crop mixtures extends the period of the year in which the soil is protected by leaf cover and roots. This leaf cover also serve as soil nutrient. That is in a situation where leguminous crop is planted along with cereal. The leguminous crop will shed its leaves to produce a little amount of nitrogen back to the soil which stands for next farming operation. Other economic reasons such as dependability of returns and increased returns from the same piece of land may make farmers adopt mixed cropping.

This paper attempts to study technical efficiencies associated with two cropping patterns (sole and mixed) among small-scale farmers (who produce the bulk of Nigeria's food crops) in savanna zone of Nigeria. Nigeria's agriculture has not been able to meet up in its food production to meet the food requirement of the increasing population which is attested to by the fact that food production has increased in recent time at about 2.5% while the demand has increased at about 3.5% due to increase in population growth rate (Federal Office of Statistics, 1996). There is the need to find solutions to this food crises situation. A study of this nature can help provide a framework for policy formulation and better research orientation.

Analytical Framework

The stochastic frontier production function in efficiency studies is employed in this study. The modeling, estimation and application of stochastic frontier production functions to economic analysis assumed prominence in econometrics and applied economic analysis during the last two decades. Early applications of stochastic frontier production function to economic analysis include those of Aigner et al. [1] in which they applied the stochastic frontier production function in the analysis of the US agricultural data. Battese and Corra [3] applied the technique to the pastoral zone of Eastern Australia. More recently, empirical applications of the technique in efficiency analysis have been reported by Battese et al. [4], Ajibefun and Abdulkadri [2], Ojo and Ajibefun [9] and Ojo [8].

The stochastic frontier production function model is specified as follows:

$$\ln Yi = InBo + \Sigma Bj lnXji + Vi - Ui$$

where Yi is output in a specified unit, Xj denotes the actual vector and Bj is the vector of production function parameters.

The frontier production function F(XjBj) is a measure of maximum potential output for any particular input vector Xj. The Vi and Ui cause actual production to deviate from this frontier. The Vi is the systematic component, which captures the random variation in output, which are due to the factors that are not within the influence of the producers (e.g. temperature, moisture, natural hazards). The Vi is assumed to be independently, identically distributed with zero mean and constant variance $N(O,\sigma v^2)$. The stochastic frontier production function model is established using the maximum likelihood estimation procedure (MLE), a maximization technique[10]. The technical efficiency is empirically measured by decomposing the deviation into a random component (v) and an inefficiency component (U). The technical efficiency of an individual firm is defined in terms of the observed output (Yi) to the corresponding frontier output (Yi*) given the available technology, that is, TE = Yi/Yi*

$$\ln Bo + \sum \beta j \ln Xji + Vi - Ui$$

$$\ln \beta o + \sum \beta j \ln Xji + Vi$$

So that, $Od \leq TEd \leq 1$

Materials and Methods

Study area: The study was conducted in selected villages in Bida Local Government Area of Niger State, Nigeria. The state is one of the 36 states in Nigeria. It is located in savanna zone of middle belt Nigeria. The area is characterized by savanna type of vegetation made up of tall grasses and trees such as the locust bean tree, Aracin and Neem. The area is basically agrarian noted for cereal and tuber cultivation. The population is about 2.48 million (1991 Population Census Figures). The climate favours the cultivation crops. Rainfall lasts for about six months of the year starting in April, a period sufficient for the production of tubers and cereals. It is between 1000 mm and 1200 mm with high daily temperatures of over 32°C. The people are predominantly peasant farmers cultivating food and cash crops as well as livestock production. The people live mostly in organized settlements. Minna is the state capital. Other notable towns include Bida, Kontangora and Suleija.

Data collection: Data used for this study were primary data collected from 72 farmers purposively from small-scale farmers in four villages namely: Fembo, Kusotachi, Ndaloke and Mana. This was done through weekly visits to the farmers during the production period using trained enumerators who collected required data from the farmers. The first stage of the multi-stage sampling procedure involved a purposive sampling of the four villages in the Local Government Area based on intensity of crop cultivation and type (maize and yam/maize). The second stage involved a purposive sampling of 18 farmers (nine sole maize cultivators and nine yam/maize mixed cropping farmers). Data were collected with the use of a structured questionnaire designed to collect information on output, inputs, prices and some socio-economic characteristics of the selected farmers.

For proper accounting/valuation, family labour was valued taking the opportunity cost of labour if employed elsewhere. This was then converted to man-hours using a factor of 1 for matured males, 0.75 for matured females (15 - 60 years), 0.5 for young males (<15 years) and old women (>60 years). Due to the limited amount of fund available, only 72 farmers were involved in the study.

Output value: This was obtained by adding all cash receipts from the sale of maize or maize and yam, and the value consumed by the farmers' households with those given out as gifts.

Inputs: Inputs were categorized as those used for seeds, weeding and land preparation as these constituted major components of cost of enterprise production in the study area.

Socio-economic characteristics: These variables included age of farmers (years), experience of farmers in farming (years), years of schooling of farmers and cropping pattern (dummy for 0 = sole maize, 1= mixed cropping yam/maize).

Method of analysis: Descriptive statistics (mean, standard deviation) and stochastic production function were used to analyze the socio-economic characteristics, productivity and technical efficiency respectively. The production technology of the farmers was assumed to be specified by the Cobb-Douglas frontier production function [11], which is defined as

$$\ln Yi = \ln\beta o + \beta i \ln X1i + \beta_2 \ln X_2 i + \beta_3 \ln X_3 i + Vi - Ui$$

where Y= value of output per hectare (naira); X1= cost of seeds per hectare (naira); X2 = cost of land preparation per hectare (naira); X3 = cost of weeding per hectare (naira); Vi = random errors as previously defined; Ui = technical inefficiency effects as previously defined.

The technical inefficiency effects Ui is defined by

$$Ui = \sigma_o + \sigma_1 Z_1 i + \sigma_2 Z_2 i + \sigma_3 Z_3 i + \sigma_4 Z_4 i$$

where Z_i, Z_2, Z_3 and Z_4 represent age of farmers, years of schooling, years of farming experience and cropping pattern respectively. These are included in the model to indicate their possible influence on the technical efficiencies of the farmers.

The βs and σs are scalar parameters to be estimated. The variance of the random errors, σ_v^2 and that of the technical inefficiency effects σ_u^2 and overall variance of the model σ^2 are related thus: $\sum^2 = \sigma_v^2 + \sigma_u^2$. The ratio … $=\sigma_u^2/\sigma^2$, measures the total variation of output from the frontier which can be attributed to technical inefficiency [3]. The estimates for all the parameters of the stochastic frontier production function and the inefficiency model are simultaneously obtained using the program frontier version 4.1 [6]. For this study, two different models were estimated. Model 1 was the traditional response function in which the inefficiency effects are not present. It is a special case of the stochastic frontier production function model in which the total variation of output from the frontier output due to technical inefficiency is zero, that is, γ=0.

The two models were compared for the presence of technical inefficiency effects using the generalized likelihood ratio test which is defined by the test statistics, chi-square (χ^2)

$$\chi = -2\ln(Ho/Ha)$$

where χ^2 has a mixed chi-square distribution with the degree of freedom equal to the number of parameters excluded in the unrestricted model. Ho is the null hypothesis that γ=0. It is given as the value of the likelihood function for the frontier model and Ha is the alternative hypothesis the γ=0 for the general frontier model.

Results and Discussion

Major crop mixtures in savanna zone: Major crops grown in the middle belt (savannah zone) include: sole maize, yam/maize, maize/rice and other cereal based mixtures. However, maize based crop mixtures are common among farmers in the area.

Table 1 shows the returns to the two enterprises considered. While sole maize yielded 1.09 metric ton of grain equivalent, yam/maize yielded 1.22. The quantity of protein was also higher for yam/maize than sole maize. With a total production cost of 11,741.76 naira per hectare of sold maize, it cost 7,997.7 naira per hectare for yam/maize mixture. This is possible because some operations are performed on both yam and maize simultaneously thus leading to lower cost outlay for yam/maize mixture. It was observed that farmers devoted a large proportion of their farm size (as high as 60%) to mixed farming.

Estimates of the stochastic frontier production function parameters: The maximum likelihood estimates of the stochastic frontier production function are presented in Table 2. There was presence of technical inefficiency in maize production in the area. In that case Model 1 was rejected thus Model 2 was preferred for further econometric and economic analysis. The estimated gamma parameter (6) of Model 2 of 0.90 indicates that about 90% of the variation in maize output among the farmers was due to differences in their technical efficiencies.

Estimated elasticity of the explanatory variables of the general model (Table 3) shows that cost of land preparation and weeding were positive decreasing functions of these factors. This thus indicated that allocation and use of variables were in the stage II (economic relevant) of the production function. The elasticity of cost of seed was negative decreasing function of the factors also indicating excessive use of the variables i.e. stage III of the production function. This may be due to the fact that farmers rely more on old stocks of seeds for planting. Again, the extension process in Nigeria is witnessing a decline in activities now that the World Bank loans are no more there. Farmers may not be getting the right advice from frontline extension agents who may not be visiting the farmers to give advice as at when due. On the whole the return to scale (RTS) was 0.27 indicating a positive decreasing return to scale and that production was in the stage II of the production process. Farmers could improve the productivity of factors by reducing the quantity of seeds used for planting.

Technical efficiency analysis: The predicted farm specific technical efficiencies (TE) ranged between 0.50 and 0.99 with a mean of 0.622 (Table 4). In the short run, it is possible to increase production by 37.8%. However there is a striking difference between sole farmers and mixed crop farmers as the mean technical efficiencies of sole farmers was 0.526 while that for the mixed farmers was 0.717. Thus the mixed farmers were more efficient than the sole farmers. Farmers do know what strategy will best suit their conditions and circumstances. This is attested to by the higher efficiency of mixed farmers when compared to the sole farmers. Researchers are often apt to conduct investigations on sole crop and most recommended technologies available to farmers be often tailored toward sole cropping to the neglect of farmers' goals and strategies. The deciles range of the frequency distribution of the technical efficiencies of sole farmers ranged from 0.50 to 0.59 (Table 4). While 100% of the sole farmers are in this range, only 44% of the mixed farmers are in this category. Table 4 shows that over 50% of mixed crop farmers had technical efficiency exceeding 0.70.

Technical inefficiency analysis: The analysis of inefficiency model (Table 2) provided significant conclusions on the technical efficiencies of the farmers as regards the farming system. The coefficient of age was positive, indicating that age led to technical inefficiency or decrease technical efficiency of the farmers in the study area. It was expected *a priori*, that age will contribute to

Table 1. Returns from enterprises in grain equivalent.

Enterprise	Yield in grain equivalent (kg)	Quantity of protein	Total cost of production	Cost of production per kg of grain equivalent
Sole Maize	1091.5	104.4	11741.76	10.7
Yam/Maize	1228.1	117.5	7997.7	6.5

Table 2. Maximum likelihood estimates of the stochastic frontier production function for maize production in Nigeria.

Variable	Parameter	Model 1	Model 2
Constant	ɓ$_0$	-0.8972 (-0.614)	-0.7822 (-3.125)
Cost of seed (naira)	ɓ$_1$	-0.3270 (-0.8773)	-0.4277 (-1.3268)
Cost of land preparation (naira)	ɓ$_2$	0.4433 (-0.8608)	0.5767 (0.6894)
Cost of weeding (naira)	ɓ$_3$	0.1681 (0.5706)	0.1215 (0.1350)
Inefficiency model			
Constant	Ǔ$_0$	0	0.8288 (1.6641)
Age of farmers (years)	Ǔ$_1$	0	0.0045 (1.6304)
Years of schooling (years)	Ǔ$_2$	0	-0.0257 (-1.2544)
Farming experience (years)	Ǔ$_3$	0	-0.0224* (2.7798)
Cropping pattern	Ǔ$_4$	0	-0.3370 (-7.2667)*
Sigma squared	ŭ^2	0.0540	0.026
Gamma	ɔ	0.50	0.9
Log likelihood function	lif	0.4069	0.2782

Figures in parenthesis are t-values

Table 3. Elasticity of production and returns to scale (RTS).

Variable	Elasticities
Cost of seeds	-0.4277
Cost of land preparation	0.5767
Cost of weeding	0.1215
RTS	0.2706

Table 4. Decile range of frequency distribution of T.E of maize farmers.

Range	Sole		Mixed	
	Freq.	%	Freq.	%
0.20 - 0.29	0	0	0	0
0.30 - 0.39	0	0	0	0
0.40 - 0.49	0	0	0	0
0.50 - 0.59	36	100	16	44
0.60 - 0.69	0	0	1	2.7
0.70 - 0.79	0	0	5	13.9
0.80 - 0.89	0	0	2	5.5
0.90 - 0.99	0	0	12	33.3
Mean 0.622	0.5266		0.7172	

technical efficiency of farmers since age is expected to be correlated with adoption of technologies [5]. Thus age contributed positively to inefficiency because the older the farmer is the less efficient he/ she becomes in terms of technology adoption and supervision of farming activities generally.

On the other hand, years of schooling, farming experience and cropping pattern contributed to technical efficiencies. In other words, with more schooling years technologies could be easily understood and adopted, supervision precisely done and efficiency will increase. Also the farming experience with cropping pattern, as farmers change from sole cropping to mixed cropping his efficiencies increase because he will be maximizing the use of available land and other inputs such as man days of labour for operations such as weeding which always takes over 40% of total variable cost of farmers in Nigeria. At peak periods of farm operations when operations such as weeding are critical to crop output, labour is always a limiting factor because of increasing schooling of youths who always provide farm labour, rural-urban migration which has left the aged on the farm with limited abilities to till the land.

Conclusions and Recommendations

Technical efficiencies of farmers varied with the farming system. While age increases inefficiencies of farmers, years of school, farming experience and cropping pattern increased efficiencies. Mixed cropping practice enabled farmers to increase the nutritive value of food produced as well as financial returns on land. It also helps in input use on the farm. Therefore crop mixtures with potential of increasing soil fertility, nutritional and economic returns should be prompted for more sustainable food production in Nigeria.

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