ESTIMATION OF TECHNICAL EFFICIENCY IN PEASANT SORGHUM PRODUCTION IN NIGER STATE, NIGERIA

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ABSTRACT

The study examined the estimation of technical efficiency of peasant sorghum production in Niger State, Nigeria using stochastic frontier production function analysis. Primary data were obtained through the use of questionnaire from seventy-five farmers in Niger State, Nigeria. Cobb-Douglas production function was used to represent the production frontier of the sorghum farms. The study showed that the levels of technical efficiency ranged from 51% to 79% with m[illegible]3.2%, which suggests that average sorghum output falls 36.8% short of the maxim[illegible]sible level. From the results obtained, although farmers were generally relatively efficient, they still have room to increase the efficiency in their farming activities as about 3[illegible] percent efficiency gap from optimum (100%) remains yet to be attained by all farmers. Therefore, in the short run there is room for increase in technical efficiencies on sorghum farms in the study area.

KEYWORDS: ***Stochastic Frontier Production Function, Efficiency Measurement.***

Introduction

Agriculture constitutes a significant area in terms of employment of labour, contribution to Gross Domestic Product (GDP) and until early 1970 agricultural exports were the main sources of foreign exchange earnings (Amaza and Olayemi, 2002). During the 1960s, the growth of the Nigerian economy was derived mainly from Agricultural sector. The contribution of agriculture to the GDP which stood at an average of 56% in 1960-1964 declined to 47% in 1965, 1969 and more rapidly to 32% in 1996-1998 (Amaza and Olayemi, 2002). The agricultural sector's changing share of GDP is partly a reflection of the relative productivity of the sector.

Sorghum grain ranks fifth in the world after wheat, rice, maize and barley (FAO, 2006). Sorghum like many grains, has a diversity of uses, including human consumption and animal feed. Sorghum is used for human nutrition all over the world (Carter et al, 1989). Wikipedia, (2006) reported that sorghum is a major crop for many poor farmers especially in Africa, Central America and South Asia. It further stated that grain sorghum is used for flours, porridges and side dishes, malted and distilled beverages and specialty foods such as popped grain. Sorghum is also considered to be a significant crop for animal feeds. Fry *et al* (1992) reported that sorghum can be as a substitute for feed composition for layer bird at 60% without egg yolk malting.

Sorghum grain ranked fifth in the world (FAO, 2006), however, in terms of area of land under food crop production in Nigeria, sorghum ranks fifth (after millet, cowpea, cassava and yam) (Imolehin and Wada, 2000). Kolawole and Scoones (1994) identified the major sources of decline in food production(sorghum inclusive) in the country as: fluctuation of water table; and attendant dangers of flooding; inadequate water supply at the end of the dry season; high cost of water lifting devices; lack of shortage of agrochemicals; lack of improved seeds and high cost of labour among others.

The Federal Ministry of Agriculture (1993) estimated that annual supply of food crops (including sorghum) would have to increase at an average annual rate of 5.9% to meet food demand, and reduced food importation significantly. The constraint to the rapid growth of good production seems to be mainly that of low crop yields and resource productivity. In view of this, production efficiency of small holder farms has important implications for development strategies adopted in most developing countries where the primary sector is still dominant. An improvement in the understanding of the levels of production efficiency and its relationship with a host of farm level factors can greatly aid policy makers in creating efficiency enhancing policies as well as in judging the efficacy of present and past reforms. Hence, this study becomes crucial in examining the estimation of technical efficiency of peasant sorghum production in Niger State, Nigeria since increase out and productivity are directly related to production efficiency (Amaza and Olayemi, 2002).

Conceptual Framework: Farell, (1957) distinguishes between technical and allocative efficiency through the use of a frontier production and cost function respectively. He defined technical efficiency as the ability of a firm to produce a given level output with a minimum quantity of inputs under certain technology and allocative efficiency as ability of a firm to choose optimal input levels for a given factor prices. In Farrell's Framework, economic efficiency (EE) is an overall performance measure and is equal to the product of TE and AE (that is EE = TE x AE).

However, over the years, Farrell's methodology has been applied widely, while undergoing many refinements and improvements. Such improvement is the development of stochastic frontier model that enables one to measure firm level efficiency using maximum likelihood estimate. The Stochastic frontier model incorporates a composed error structure with a two sided symmetry and one sided component. The one sided component reflects inefficiency while two sided component capture random effects outside the control of production unit including measurement errors and other statistical noise typically of empirical relationship.

In this study, Battese and Coelli (1995) model was used which builds hypothesized efficiency determinants into the inefficiency error component so that one can identify focal points for action to bring efficiency to higher levels.

The general form of the model is expressed as:

(1)

Where

is the production (on the logarithm of the production) of the *ith* firm;

X_i is a vector of (transformations of the) input quantities of the *ith* firm;

is a vector of unknown parameters;

The V_i are random variables which are assumed to be iid and independent of the U_i which are non-negative random variables which are assumed to account for technical inefficiency in production and are often assumed to be iid.

It is further assumed that the average level of technical inefficiency, measured by the mode of the truncated normal distribution (i.e. *Ui*) is a function of factors believed to affect technical inefficiency as shown below:

(2)

Where

Z_i is a column vector of hypothesized efficiency determinants and andare unknown parameters to be estimated. It is clear that if U_i does not exist in equation (1) or , the stochastic frontier production function reduces to a traditional production function. In that case, the observed units are equally efficient and residual output is solely explained by unsystematic influences. The distributional parameters, U_i and are hence inefficiency indicators, the former indicators, the former indicating the average level of technical inefficiency and the latter the dispersion of the inefficiency level across observational units.

Given functional and distributional assumptions, the values of unknown coefficients in equations (1) and (2), i.e β_0, β_1, δ_0, δu^2 and δv^2 can be obtained jointly using the maximum likelihood method (ME). An estimated value of technical efficiency for each observation can then be calculated as exp(-U)

The unobservable value of V may be obtained from its conditional expectation given the observation value of (V, U) (Yao and Liu, 1998).

METHODOLOGY

Study Area: The study was conducted in Niger State of Nigeria. The State is located within latitudes 8°-10° north and longitudes3°-8° east of the prime meridian with land area of 76,363 square kilometers and a population of 4,082,558 people (Wikipedia, 2008). The State is located within latitudes 8°-10°North and longitudes3°-8° east of the prime meridian. The state is agrarian and well suited for production of arable crops such as maize, yam, cassava and cassava because of favourable climatic conditions. The annual rainfall is between 1,100mm 1,600mm with average monthly temperature ranges from 23°C and 37°C (NSADP, 1994). The vegetation consists mainly of short grasses, shrubs and scattered trees.

Sampling Technique: The data mainly from primary source were collected from Munya Local Government which was purposively selected because of prevalence of the crop in the area. The data were generated through the use of structured questionnaires designed in line with objectives of the study. A total of seventy-five farmers were systematic randomly sampled to give each farmer an equal chance of being selected and interviewed.

Empirical Models: The stochastic frontier production function is expressed as follows:

Where

Ln = Natural logarithm;

I = ith sampled smallholder farm;

Y = Value of farm output from farm I;

Xs = input variables in the model, and

X_1 = Farm Size (in hectares);

X_2 = Labour (in man-day);

X_3 = Fertilizer (kg);

X_4 = Herbicides (litres);

X_5 = Seeds (kg);

B_3 = Input coefficients for the resources used in production;

U_i = Farmer specific characteristics related to production efficiency;

V_i = Statistically disturbance term.

The explicit form of the Cobb-Douglas functional form is written thus:

Where Y_1, X_1, X_2, X_3, X_4 and X_5 are as defined earlier. The V_i's are assumed to be independent and identically distributed (iid) normal random errors having zero mean and unknown variance. U_i's are non-negative random variables called technical inefficiency of production of the respondent farmers which are assumed to be independent of the V_i's such that U_i's are the non-negative truncation. (at zero) at the normal distribution with mean μ and variance δ^2

$$\mu = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i}$$

Z_1, Z_2 and Z_3 are the age, family size and level of education of the ith farmers respectively and the βs and δs are known scalar parameters to be estimated.

The variables age, family size and level of education are included in the model for the technical inefficiency effects to include positive effects of farmers characteristics on the efficiency of production.

The technical efficiency of the farmers is expressed as:

$$TE_I = \exp(-U_i)$$

RESULTS AND DISCUSSION

Production Analysis: The summary statistics of the variables for the frontier estimation is presented in Table1. They include the sample mean and the standard deviation for each of the variables. The mean of 5790.93kg of sorghum per annum was obtained from the data analysis with a standard deviation of2199.55.

Table1: summary statistics of the variables in stochastic frontier model

Variables	Minimum	Maximum	Mean	Standard Deviation
Output (kg)	2700	12000	5790.93	2199.55
Farm Size (ha)	1	3	1.26	0.45
Labour (Man-days)	450	500	488	21.50
Fertilizer (kg)	50	100	56.31	15.57
Herbicide (Litres)	1	12	3.64	2.06
Seed (kg)	2	5	2.76	0.94
Age (years)	23	70	35.82	10.11
Family Size	1	25	7.67	4.83
Education Level (years)	1	5	1.93	1.42

Source: Field Survey, 2007

The large size of the standard deviation conforms to the fact that most farms operate at different scale of operation. Analysis of the inputs also revealed an average farm size of 1.26ha per farmer an indication that the study covered small scale, family managed farm units. The average labour of 488 man-days shows that sorghum farmers depend heavily on human labour to do most of the farming operations.

The analysis of other input variables shows the mean values of 56.31kg, 3.64litres and 2.76 for fertilizer, herbicide and seed respectively. All these findings point to the characteristic nature of subsistence farming that dominate agricultural production in Nigeria.

Variable representing the demographic characteristics of the farmers employed in the analysis of the determinant of technical efficiency include age of the farmers, family size and education level of the farmers. The average age of the farmers, family size and year of schooling were 35.82, 7.67and 1.93 respectively, meaning that the farmers were relatively young and uneducated.

The model specified is estimated by the maximum likelihood approach using a computer programme FRONTIER 4.1c developed by Coelli, (1996). The estimates are presented in Table2. the estimated coefficient for land is positive (0.197) and statistically significant at 5 percent level. This conforms with *apriori* expectations, indicating that the level of technical inefficiency of the small holder croppers tend to increase for the larger farms. Also, the elasticity is positive as expected suggesting that a 1 percent increase in land will induce an increase of 0.2 percent in the farm output and vice versa. The coefficients of fertilizer and seed are positive and statistically significant at 10 percent and 1 percent respectively. These results agree with previous work by Fasasi, (2007), Amaza and Olayemi, (2002).

Table2: Maximum Likelihood Estimates of Parameters of the Cobb -Douglas Frontier Function for Small Scale Sorghum Farmers in Niger State.

Variables	Parameters	Coefficients	t-ratio
General Model			
Constant	β_0	0.167	3.360***
Farm Size (ha) (X_1)	β_1	0.197	1.541***
Labour (Man-days) (X_2)	β_2	-0.151	-1.923$^{N.S}$
Fertilizer (kg) (X_3)	β_3	0.263	1.540*
Herbicide (Litres) (X_4)	β_4	0.013	0.201$^{N.S}$
Seed (kg) (X_5)	β_5	0.602	4.955***
Inefficiency Functions			
Constant	δ_0	0.622	0.521
Age (years)	δ_1	-0.114	-0.289
Family Size	δ_2	-0.131	-1.292*
Education Level (years)	δ_3	-0.461	-0.170*
Diagnosis Statistics			
Sigma-square δ^2		0.8718	5.70***
Gamma γ		0.3387	2.25***
Log likelihood function		-0.15	

**Significant at 10% level; **Significant at 5% level; ***Significant at 1% level.*
NS = Not significant.

The estimated coefficients of the inefficiency function provide some explanations for the relative efficiency levels among individuals' farms. Since the dependent variable of the inefficiency function represents the mode of inefficiency, a positive sign of an estimated parameter implies that the associated variable has a negative effect on efficiency and a negative sign indicates the reverse. The negative coefficient for age and family size implies that aged farmers and the farmers with large family in sorghum production are more technically efficient than the young ones with small family size meaning that as the age and family size increase in the study area, the technical inefficiency of the farmers decreases. This is in conformity with the assumption that farmers' age affects the production efficiency since farmers different ages have different level of experience ability to obtain and process information.

Also, negative coefficient for education implies that the farmers level of technical inefficiency declines with more education. This result conforms with previous works by Parik et-al, (2007).

The sigma squre (0.8718) is large and statistically significant at 1 percent. This indicates a good fit and the correctness of the specified distributed assumption of the composite error term. The technical efficiency analysis of sorghum production revealed that technical inefficiency effects existed in sorghum production in the study area as confirmed by the gamma value of 0.3387 that is significant at 5 percent level (Table 2). The gamma () ratio indicates that relative magnitude of the variance δ^2, associated with technical inefficiency effects. Hence, 0.3387 implies that about 34 percent variation in the output of sorghum farmers was due to differences in their technical efficiencies.

Technical Efficiency Estimates of the Farmers

The technical efficiency indices are derived from the MLE results of the stochastic production function, using computer programme FRONTIER 4.1. The indices in table3 show that the technical efficiency of the sampled farmers is less than 1 (less than 100%), implying that all the farmers in the study area are producing below the maximum efficiency frontier.

Some farmers demonstrated a range of technical efficiency of 0.79 (79%) while the wort farmer has a technical efficiency of 0.51 (51%). The mean technical efficiency is 0.6321

(63.21%), implying that on the average, farmers in the study area were able to obtain a little over 60percent of potential sorghum output from a given mix of production inputs. From the results obtained, although farmers were generally relatively efficient, they still have room to increase the efficiency in their farming activities as about 37 percent efficiency gap from optimum (100%) remains yet to be attained by all farmers.

Table3: Distribution of Technical Efficiency Indices among Farmers in the Study Are a

Efficiency Class Index	Frequency	Percentage
0.00 - 0.10	0	0
0.11 – 0.20	0	0
0.21 – 0.30	0	0
0.31 – 0.40	0	0
0.41 – 0.50	0	0
0.51 – 0.60	32	43
0.61 – 0.70	30	40
0.71 – 0.80	13	17
0.81 – 0.90	0	0
0.91 – 1.00	0	0
Total	75	
Mean	0.632	
Maximum value	0.79	
Minimum value	0.51	

Source: Computed from MLE Results

Summary and Conclusion

This empirical study is on estimation of technical efficiency of peasant sorghum production using stochastic frontier production function. A Cobb-Douglas production frontier was estimated by maximum likelihood estimation method to obtain ML estimates and inefficiency determinants. The MLE results reveal that TE of sorghum farmers varied due to the presence of technical inefficiency effects in sorghum production. The variables of size of farmland, fertilizer and seed were found to be the significant production factors that associated with changes in the output of sorghum. The distribution of the technical efficiency indices revealed that most of the farmers are moderately technically efficient with mean TE index of 0.632 (about 57% of the farmers have technically efficiency above 60%). The results of the inefficiency model show that the variables of age, family size and years of education significantly increase the farmers technical efficiency.

The policy implication of this study is that there is scope for raising the present level of technical efficiency of sorghum production in the study area given the wide variation in the level of technical efficiency i.e. the mean technical efficiency of 0.632 could be increased by 37% through better use of available resources.

References

Amaza, P.S.and Olayemi, J.K. (2002). Analysis of Technical Inefficiency in Food Crop Production in Gombe State, Nigeria. *Journal of Applied Economic Letters*, Vol. 9 pp. 51-54.

Battese, G.E and Coelli T.J. (1995). " A Model for Technical Inefficiency Effects in Stochastic Frontier Production for Panel Data." Empirical Economics 20; 325-345.

Carter, P.R.; Hicks, D.R.; Oplinger, E.S.; Doll, J.D.; Bundy, L.G.; Schuler, R.T.; and Holmes, B.J. (1989). "Grain Sorghum (Milo)." Alternative Field Crops Manual. Retrieved May 18, 2008 from www.hort.purdue.edu/newcrop/afcm/sorghum.html.

Coelli, T.J, (1996): "A Guide to FRONTIER version 4.1c: A Computer programme for Stochastic Frontier production and Cost Function Estimation": Working paper

96/07, Centre for Efficiency and Productivity Analysis Dept. of Econometrics, University of New England, Armidale, Australia

FAO. (2006). Animal Feed Resources Information System (AFRIS). The Food and Agriculture Organization of the United Nations, "Sorghum bicolor". Retrieved May 18, 2008 from www.fao.org/ag/aga/agap/frg/afris/data/314.htm.

Farrell, J.M. (1957). "The Measurement of Productive Efficiency". *Journal of Royal Statistics.* 120, (Part III); 253-290

Fasasi, A.R. (2007), Technical Efficiency in Food Crop Production in Oyo State, Nigeria. Journal of Human Ecology 22(3): 245-249

Federal Ministry of Agriculture (1993). In Amaza, P.S.and Olayemi, J.K. (2002). Analysis of Technical Inefficiency in Food Crop Production in Gombe State, Nigeria. *Journal of* Applied Economic Letters. Vol. 9 pp. 51-54.

Fry, J.L.,Herrick, G.M., Price, G.M., and Hams, R.H. (1997). Effects of bird resistant sorghums and tannic acid on yolk molting. Poultry Sciences. 51: 1540-1543.

Imolehin, E.D. and Wada, A.C. (2000). Meeting Rice production and Consumption Demand of Nigeria with Improved Technologies, International Rice Commission Newsletters: Vol. 49 FAO Rome.

Kolawole, A. and Sconnes, I. (1994). Fadama Land Use and Sustainability in Northern Nigeria. An Overview. Strategies for Sustainable Use of Fadama Land in Northern Nigeria. TCID and CSER ABU, Zaria, Nigeria. Pp. 29-34

Niger State Agricultural Development Progrmme (1994). Impact Study Final Report. Pp 24

Parikh, A F. Ali and Shah, M. K. (1995): Measurement of economic efficiency in Pakistan agriculture. *American Journal of Agricultural Economics*, 77:675 685

Wikipedia contributors (2006). Sorghum. Wikipedia, The Free Encyclopedia. Retrieved June 15, 2006 from http://en.wikipedia.org/wiki/Sorghum

Wikipedia, (2008), Encyclopedia. Retrieved June10, 2008 from http://en.wikipedia.org/wiki/Niger_State

Yao,S and Z. Liu (1998): Determinant of Grain Production and Technical Efficiency in *China.Journal of Agricultural Economics*. Vol.49, No.2, pp171-184.