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APPLICATION OF A STOCHASTIC FRONTIER PRODUCTION FUNCTION TO THE MEASUREMENT OF TECHNICAL EFFICIENCY IN FOOD CROP PRODUCTION IN IMO STATE, NIGERIA

C. E. Onyenweaku and J. C. Nwaru
Department of Agricultural Economics,
Michael Okpara University of Agriculture Umudike,
Abia State, Nigeria

ABSTRACT

This study was designed to measure the level of technical efficiency and its determinants in food crop production in Imo State of Nigeria using a stochastic frontier production function. A multi-stage random sampling technique was used to select 187 food crop farmers from the three Agricultural Zones of the State using the cost route approach. The estimated farm level technical efficiency ranges from 31.05 percent to 95.12 percent with a mean of 57.14 percent. The wide variation in the level of technical efficiency indicates that ample opportunities exist for the farmers to increase their productivity and income through improvements in technical efficiency. Credit, education, farming experience, farm size and membership of farmers associations/cooperative societies were found to be positively and significantly related to technical efficiency while age and household size were negatively but significantly related to technical efficiency. The study found no relationship between gender and technical efficiency.

Key words: Technical efficiency, frontier production function.

INTRODUCTION

Despite the dominance of the petroleum sector, Agriculture is still the mainstay of Nigeria's economy. Agriculture is the largest non oil export earner and the largest employer of labour accounting for 88 percent of the non oil foreign exchange earnings and 70 percent of the active labour force of the population (FGN, 2001).

However, over the years, the growth rate of agricultural production has either stagnated or failed to keep pace with the country's rapid population growth rate resulting in perennial food shortages, soaring food prices and massive importation of food by Government. The poor performance of the country's agriculture is traceable to the system of production characterized by: (i) Small uneconomic production units; (ii) Predominance of primitive techniques of agricultural production: (iii) Excessive fragmentation of holdings and consequently little mechanization

of farm operations; (iv) Limited use of chemical and biological technology; (v) High dependence on rudimentary.

storage and marketing facilities; (vi) Inadequate supply of credit and (Vii) Low capital investment with its attendant low productivity and income.

The objective of this study is to measure technical efficiency and its determinant in food crop production in Imo State of Nigeria using the stochastic frontier production function. Technical efficiency here refers to the ability to produce the highest level of output with a given bundle of resources, (ability to produce on the production frontier). Previous studies by Olayide (1973), Ogunfowora, Essang and Olayide (1975), Onyenweaku (1988), Ditoh (1991) Olagoke (1991), Obasi, Onyenweaku and Njoku (1994), Onyenweaku (1991 and 1994), Onyenweaku and Awuja (1991), Onyenweaku and Fabiyi (1991), Onyenweaku, Agu and Obasi (2000), Ohajianya and Onyenweaku (2001 and 2002) have pointed to the low resource productivity and efficiency in Nigerian agriculture. However, none of these studies provided numerical measures of technical efficiency, the gap the present study is designed to fill.

MATERIALS AND METHODS

Theoretical Model A Stochastic frontier production function is defined by:

$Y_i = f(X_i;B_i)\exp(V_i-U_i), i=1,2 \quad n \quad (1)$

where: Yi is output of the $_i$-th farm, X_i is the vector of input quantities used by the $_i$-th farm, B_i is a vector of unknown parameters to be estimated, f(.) represents an appropriate function (eg Cobb Douglas, Translog, etc). The term V_i is a symmetric error, which accounts for random variations in output due to factors beyond the control of the farmer e.g weather, disease outbreaks, measurement errors etc, while the term U_i is a non negative random variable representing inefficiency in production relative to the stochastic frontier. The random error Vi is assumed to be independently and identically distributed as $N(0, ó_v^2)$ random variables independent of the U_is which are assumed to be non-negative truncations of the $N(0, ó_u^2)$ distribution (ie half-normal distribution) or have exponential distribution.

The stochastic frontier model was independently proposed by Aigner, Lovell, and Schmidt (1977) and Meeusen and Van den Broeck (1977). The 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^*

$= f(X_i;B) \exp(Vi-U_i) / f(X_i;B) \exp(Vi)$

$=Exp.(-U_i)$ (2)

Where Y_i is the observed output and Y_i^* is the frontier output. The parameters of the stochastic frontier production function are estimated using the maximum likelihood method.

The Empirical Model For this study, the production technology of farmers in Imo State, Nigeria was specified by the Cobb Douglas frontier production function defined as follows.

$$InY = b_o + b_1InX_1 + b_2InX_2 + b_3InX_3 + b_4InX_4 + b_5InX_5 + b_6InX_6 + V_i\ U_i \quad (3)$$

where: Y_i is food crop output in naira, X_1 is farm size in hectares, X_2 is cost of planting materials in naira, X_3 is hired labour input in mandays, X_4 is family labour input in mandays, X_5 is fertilizer input in kilogram, X_6 is capital input in naira in terms of depreciation of farm tools and equipment, interest on borrowed capital, repair and operating expenses of implements, b_0, b_1, b_2, b_3, b_4, b_5, b_6 are the regression parameters to be estimated while V_i and U_i are as defined earlier. In addition, U_i is assumed to follow a half normal distribution.

Determinants of Technical Efficiency In order to determine the factors contributing to the observed technical efficiency the following model was formulated and estimated jointly with the stochastic frontier model in a single stage maximum likelihood estimation procedure using the computer software Frontier Version 4.1 (Coelli, 1996).

$$TE_i: = a_0+a_1Z_1+a_2Z_2+ a_3Z_3+a_4Z_4+a_5Z_5 + a_6Z_6+a_7Z_7+a_8Z_8 \quad (4)$$

Where TE_i is the technical efficiency of the i-th farmer, Z_1 is credit access, a dummy variable which takes the value of unity if the farmer has access to credit and zero otherwise, Z_2 is farmer's age in years, Z_3 is farmers level of education in years, Z_4 is farmer's farming experience in years, Z_5 is farmers household size, Z_6 is farm size in hectares, Z_7 is membership of farmers associations/cooperative societies, a dummy variable which takes the value of unity for members and zero otherwise, and Z_8 is gender of the farmer, a dummy variable that takes the value of unity for female farmers and zero otherwise. The coefficient of gender is expected to be negative and those for the other variables positive.

Study Area Imo State located in the South Eastern Zone of Nigeria is one of the 36 States in Nigeria. It had a population of about 2.485 million people in 1991. The State is divided into 27 administrative units called Local Government Areas (LGAs), which are grouped into 3 agricultural zones of Owerri, Okigwe and Orlu. Agriculture is the major occupation of the people. Almost all the families farm either as primary or secondary occupation. The ecological zone of the State favours the growing of tree crops, roots and tubers, cereals, vegetables and nuts. These crops are grown in smallholder plots usually in mixtures of at least two

simultaneous crops. The main cash crop grown in the State is oil palm while the major food crops are cassava, yam, maize and vegetables.

The Data A multi stage sampling technique was used in data collection. The State was stratified into the three agricultural zones of Owerri, Orlu and Okigwe. From each zone, two Local Government Areas were chosen at random and from each Local Government Area two villages/communities were randomly selected. In each village, sixteen farmers were randomly selected for detailed study. This gave a total sample size of 192 farmers. Information was collected by means of structured questionnaires on the socio-economic characteristics of the farmers and production activities in terms of inputs, outputs and their prices using the cost route approach from January to October 2003. However, only 187 copies of the questionnaire were retrieved and used in the analysis.

RESULTS AND DISCUSSION

Average Statistics of Farmers: The average statistics of the sampled farmers are presented in Table 1. On the average, a typical farmer is 54.78 years old, with 10.53 years of education, 26.51 years of farming experience and an average household size of about 10 persons. The average farmer cultivated 2.78 hectares of land, spent about N14,414.51 on planting materials, N2312.37 on capital inputs, employed 97.46 mandays of hired labour, 88.87 mandays of family labour, 201.22 kg of fertilizer and Produced an output of N70,672.21.Table 1: Average statistics of

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VARIABLE	MEAN VALUE
Farm size	2.78 hectares
Hired labour	98.46 mandays
Family labour	89.87 mandays
Planting materials	N14,414.51
Fertilizer	201.22 kg
Capital	N2131.37
Age	54.78 years
Education	10.53 years
Farming Experience	26.51 years
Household size	9.86 people
Output	N70672.21

Source: Field Survey, 2003

Estimated Production Functions The Ordinary Least Square (OLS) and the Maximum Likelihood (ML) estimates of the production function parameters for food crops in Imo State, Nigeria are presented in Table 2. The OLS function provides estimates of the "average" production function while the ML model yields estimates of the stochastic production frontier. A comparison of the functions shows that the stochastic production function has a higher intercept term than the average production function. Besides, the slope parameters are different in both functions. This suggests that the

stochastic frontier function represents a non-neutral upward shift of the average production function. These results are consistent with those of Shenggen Wailes and Young (1997) for rice in Egypt, and contrast from the neutral upward shift obtained by Ehirim and Onyeka (2002) in Oyo State, Nigeria, Bravo-Ureta and Evenson (1994) in Eastern Paraguay and Bravo-Ureta and Pinheiro (1997) in Domnican Republic. The coefficients of the estimated parameters have the desired signs in both functions except for capital, which is negative in the frontier function. However, the coefficients of the estimated parameters are all statistically significant in the frontier function while in the average function, the coefficients of hired labour (X_3) and fertilizer (X_5) are not significant. The ratio of the standard error of U (óu) to that of V (óv) called lambda () is estimated at 3.149 in the frontier function and is statistically significant

Table 2 Estimated Production Functions for Food Crop farmers in Imo State

VARIABLE	PARAMETER	AVERAGE Function (OLS)	FRONTIER Function (MLE)
Constant term	b_o	0.921 (2.458)**	0.942 (4.561)***
Farm Size (X_1)	b_1	0.032 (2.658)**	0.222 (3.122)***
Planting Materials (X_2)	b_2	0.072 (2.412)**	0.186 (3.199)***
Hired Labour (X_3)	b_3	0.106 (1.602)	0.66 (2.963)***
Family Labour (X_4)	b_4	0.032 (1.848)*	0.094 (3.141)***
Fertilizer (X_5)	b_5	0.190 (1.105)	0.543 (1.852)*
Capital (X_6)	b_6	0.471 (2.296)**	-0.013 (-3.252)***
R^2		0.711	
F- ratio		30.180***	
Log. Likelihood function		-	-727.608
Sigma (ó)			2.111 (3.611)***
Lambda (λ)			3.149 (2.148)**
Gamma (Y)			0.848
$ó_u^2$			0.861
$ó_v^2$			0.133
Sample size (n)		187	187

Source: Field survey data, 2003.

Figures in parentheses are t ratios

* = Significant at 10%, ** = Significant at 5%, *** = Significant at 1%

The coefficients of the estimated parameters have the desired signs in both functions except for capital, which is negative in the frontier function. However, the coefficients of the estimated parameters are all statistically significant in the frontier function while in the average function, the coefficients

As (^{2}/1+^{2}) is equal to 0.848. This implies that 84.8% of the total variation in food crop output is due to technical inefficiency of hired labour (X_3) and fertilizer (X_5) are not significant. The ratio of the standard error of U (ou) to that of V (ov) called lambda ( ) is estimated at 3.149 in the frontier function and is statistically significant at 5 percent. Gamma derived as (^{2}/1+ ^{2}) is equal to 0.848. This implies that 84.8% of the total variation in food crop output is due to technical inefficiency.

Table 3. Frequency Distribution of Technical Efficiency in Food Crop Production

Technical Efficiency Range (%)	Frequency	Relative Frequency
31 – 40	19	16
41 – 50	57	48
51 – 60	25	13.37
61 – 70	48	25.67
71 – 80	13	6.95
81 – 90	10	8.56
91 – 100	9	4.81
Total	**187**	**100**
Mean technical efficiency		57.14%
Minimum technical efficiency		31.05%
Maximum technical efficiency		95.12%

Source: Field Survey 2003

The frequency distribution of technical efficiency of farmers in food crop production is presented in Table 2. Individual technical efficiency indices range between 31.05 percent and 95.12 percent with a mean of 57.14 percent. About 59.36 percent of the farmers had a technical efficiency index of above 50 percent. The mean technical efficiency of 57.14 percent indicates inefficiency in resource utilization and suggests that opportunities exist for increasing productivity and income through increased efficiency in resource utilization by food crop farmers in the State.

Sources of Technical Efficiency The determinants of technical efficiency in food crop production in Imo State, Nigeria are presented in Table 4. The coefficient of credit is positive and

Statistically significant at 1 percent indicating a direct relationship between credit and technical efficiency. This result is consistent with those of Bravo-Ureta and Evenson (1994) in Eastern Paraguay and Lingard, Castillo and Jayasuriya (1983) in Philippines. It however differs from that of Okike (2000), who found a negative relationship between credit and technical efficiency in Northern Nigeria.

The coefficient of farmers' age is negative and statistically significant at 1 percent indicating inverse relationship between age and technical efficiency. This result is consistent with those of Okike (2000) and Onu, Amaza and Okunmadewa (2000) both in Nigeria. However, it differs from those of Kalirajan and Flinn (1983) in Philippines, Kalirajan and Shand (1985) in Malaysia, Belbase and Grabowski (1985) in Nepal; and Bravo-Ureta and Pinheiro (1997) in Dominican Republic whose results showed positive and significant relationship between age and technical efficiency.

The coefficient of education is positive and statistically significant at 5 percent indicating that education is directly related to technical efficiency. This result agrees with *a priori* expectations that education increases productivity and enhances farmers' ability to understand and evaluate new production techniques, and is consistent with the results of Onu, Amaza and Okunmadewa (2000), Belbase and Grabowski (1985), Kalirajan and Shand (1986), Philips and Marble (1986) and Bravo-Ureta and Pinheiro (1993 and 1997).

The coefficient of farming experience is positive and statistically significant at 5 percent. This result indicates that farming experience is directly related to technical efficiency and is in consonance with *a priori* expectations that farmers with more years of farming experience are more technically efficient, and agrees with those of Kalirajan (1981) in India and Kalirajan and Flinn (1983) in Philippines. However, this result differs from that of Onu, Amaza and Okunmadewa (2000) whose result showed a negative relationship between farming experience and technical efficiency in cotton production in Nigeria.

The coefficient of household size is negative and statistically significant at 1 percent indicating that household size is negatively related to technical efficiency. This result is contrary to *a priori* expectations that large household size eases labour constraints thereby leading to increases in productivity and income but is consistent with that of Bravo-Ureta and Pinheiro (1997) in Dominican Republic and suggests that larger households might utilize family labour beyond the point where the marginal value product of labour is equal to the wage rate.

Table 4: Estimated Determinants of Technical Efficiency in Food Crop Production

Variable	Parameter	Estimate
Constant Term	a_0	0.693
		(2.230)*
Credit (Z_1)	a_1	0.066
		(2.998)***
Age (Z_2)	a_2	-(0.214
		(-3.252)***
Education (Z_3)	a_3	0.054
		(2.345)**
Farming Experience (Z_4)	a_4	0.094
		(2.603)**
Household size (Z_5)	a_5	-0.013
		(-3.253)***
Farm size (Z_6)	a_6	0.190
		(2.956)***
Membership of farmers associations/Cooperative societies (Z_7)	a_7	0.073 (2.647)***
Gender (Z_8)	a_8	-0.086
		(-1.169)

Source: Field Survey 2003

Figures in parentheses are t-ratios,

* = Significant at 10%, ** = Significant at 5%. *** = significant at 1%

The coefficient of farm size is positive and statistically significant at 1 percent showing that farm size is directly related to technical efficiency. This result is in consonance with *a priori* expectations that larger farmers are technical efficient than smaller ones. This result contrasts from those of Kalirajan and Flinn (1993), Huang and Bagi (1984), Belbase and Grabowski (1985), Lingard, Castillo and Jayasuriya (1983), Bravo Ureta and Evenson (1994) and Bravo-Ureta and Pinheiro (1997), which found no significant relationship between farm size and technical efficiency.

The coefficient of membership of farmers associations/cooperative societies is positive and statistically significant at 1 percent indicating direct relationship and is consistent with the result of Okike (2000) in Northern Nigeria and a *priori* expectations that members have more access to agricultural information, credit and other production inputs as well as more enhanced ability to adopt innovations,

Finally, the coefficient of gender is negative but statistically insignificant even at 10 percent indicating no relationship between gender and technical efficiency.

CONCLUSIONS

The results of this study show that technical efficiency in food crop production in Imo State, Nigeria ranges from 31.05 percent to 95.12 percent with a mean of 57.14 percent, suggesting that there are substantial opportunities to increase productivity and income in the study area through more efficient utilization of productive resources.

Important factors directly related to technical efficiency are access to credit, education, farming experience; farm size and membership of farmers association/cooperative societies while age and household size were found to be indirectly related to technical efficiency. Policies aimed at improving farmers' access to credit and education will be useful in increasing their technical efficiency. This would involve the establishment of sustainable micro credit schemes and greater investments in formal and informal education. Policies directed at consolidating farmers holdings through the formation of farmers cooperatives, and reducing household size and/or increasing the efficiency with which farmers utilize family labour coupled with appropriate targeting of relevant policies at experienced farmers will be fundamental to increasing the technical efficiency and income of farmers in the study area.

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