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Application of Stochastic Production Frontier in the Estimation of Technical Efficiency of Cassava Based Farms in Akwa Ibom State, Nigeria

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Abstract: The technical efficiency of cassava farms in Akwa Ibom State was investigated using a stochastic frontier production function which incorporates a model for the technical inefficiency effects. Farm-level data from 180 cassava farmers were obtained using well structured questionnaire. Variables included in the model for the inefficiency effects are extension contact, years of experience, age and level of educational attainment of the farmers. The parameters of the stochastic frontier production were estimated simultaneously with those in the model of inefficiency effects. Findings reveal that none of the cassava farms in the study area reached the frontier threshold. Except for capital (β5), all other efficiency variables were significant. Results further show a mean technical efficiency index of 0.74.

Key words: Stochastic, production, frontier, efficiency, Nigeria

INTRODUCTION

Over five hundred million people live on cassava throughout the world, eating its roots or tubers due to their high energy content and its leaves that are an abundant source of protein and vitamins A and B (Tchabana, 2002; Kormawa *et al.*, 2001). Cassava is an important staple food in tropical Africa and had the potential to become a cash crop in many African countries (Oirschot *et al.*, 2004). Cassava is Africa's second most important food staple, after maize in terms of calories consumed. In the early 1960s, Africa accounted for 42% of world cassava production. Thirty years later, in the early 1990s, Africa produced half of world cassava output; primarily because Nigeria and Ghana increased their production four fold. In the process, Nigeria replaced Brazil as the world's leading cassava producer (Nweke, 2004). In Nigeria, traditionally, cassava is produced on small-scale family farms. As noted by Nweke (2004) the roots are processed and prepared as a subsistence crop for home consumption and for sale in village markets and transported to urban centers. In Congo, Madagascar, Sierra Leone, Tanzania and Zambia, Cassava leaves are consumed as vegetable (Jones, 1959; Fresco, 1986; Dostie *et al.*, 1999; Haggblade and Zulu, 2003). In Nigeria, cassava is primarily a food crop. In the year 2000, 90 % of total production in Nigeria was used as food and the balance as livestock feed (Nweke, 2004).

In the past few decades, this tuber has quietly taken over thousands of hectares and become the staple food of over 200 million Africans, or more than one quarter of the continent's population. Africa produced 103 mt of cassava tubers on 18 million ha of land in 2004. According to Spore, output varies greatly between regions, ranging from 1.8 t ha^{-1} in Sudan to an average of 10.6t ha^{-1} in Nigeria. However, the average yield recorded in Africa still falls way behind the yields achieved in the Caribbean, which is 16.6t ha^{-1} in Barbados. The same can be said to be the situation in Akwa Ibom State. It therefore, becomes imperative for cassava farmers to manage resources optimally for increased yield and sustainable cassava production. As noted by Udoh and Akintola (2001) and Etim *et al.* (2005) farming in general, has to use available inputs as efficiently as possible to achieve optimum production. Inefficiency of resource use and utilization can seriously jeopardize and hamper food production, availability and security. This study therefore, aims at measuring farm level technical and examining the effects of socio-economic characteristics of households on farmers' technical efficiency.

The term efficiency of a firm can be defined as its ability to provide the largest possible amount of output from a given set of inputs. The modern theory of efficiency dates back to the pioneering work of Farrell (1957) who proposed that the efficiency of a firm consist of technical and allocative components and the

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combination of these two components provide a measure of total economic efficiency (overall efficiency). As noted by Farrell (1957) technical efficiency, which is the main focus of this study, is the ability to produce a given level of output with a minimum quantity of inputs and can be measured either as input conserving oriented technical efficiency or output-expanding oriented technical efficiency. Output-expanding oriented technical efficiency is the ratio of observed to maximum feasible output, conditional on technical and observed input usage (Jondrow *et al*., 1982; Ali, 1996). This study aims at using output-expanding orientation to measure technical efficiency effects.

The term frontier involves the concept of maximality in which the function sets a limit to the range of possible observations (Forsund *et al*., 1980). It is therefore, possible to observe points below the production frontier for firms producing below the maximum possible output, but there cannot be any point above the production frontier, given the available technology. Deviations from the frontier are attributed to inefficiency. The need to measure inefficiency effects is the major motivation for the study of frontiers. Frontier studies are classified according to the method of estimation. Kalaitzandonakes *et al*. (1992) grouped these methods into two broad categories-parametric and non-parametric methods. For the parametric methods, it can be deterministic, programming and stochastic depending on how the frontier model is specified. Many researchers, including Schmidt (1976) have argued that efficiency measures from deterministic models are affected by statistical noise. This however, led to the alternative methodology involving the use of the stochastic production frontier models. Aigner *et al*. (1977) and Meeusen and Vander Broek (1977) independently proposed the idea of stochastic measurement.

The major feature of the stochastic production frontier is that the disturbance term is a composite error consisting of two components, one symmetric and the other one-sided. The symmetric component, V_i, captures the random effects due to measurement error, statistical noise and other influences outside the control of the firm and it is assumed to be normally distributed. The one-sided component U_i, captures randomness under the control of the firm. It gives the derivation from the frontier attributed to inefficiency. It is assumed to be half-normally distributed or exponential. The major weakness of the stochastic frontier model is its failure to provide an explicit distribution assumption for the inefficiency term (Sharma *et al*., 1999).

By definition, stochastic frontier production function is

$$Y_i = F(X_i; \beta) \exp(V_i - U_i) \quad i = 1,2,\ldots\ldots\ldots\ldots,N \quad (1)$$

Where Y_i is the output of the ith farm; X_i is the corresponding (MX2) vector of conventional physical inputs; β is a vector of unknown parameter to be estimated; F(.) denotes an appropriate functional form, V_i is the symmetric error component that accounts for random effects and exogenous shock; while, $U_i<0$ is a one sided error component that measures technical inefficiency.

In recent times, econometric modeling of stochastic frontier methodology associated with efficiency estimation has been important aspect of economics research. Both time varying and cross-sectional data have been used in studies based mostly on Cobb-Douglas function and transcendental logarithmic functions that are specified either as production function or cost function to estimate individual firm efficiency (Bagi and Hunag, 1983; Bagi 1984; Ali 1996; Apeziteguia and Garate, 1997; Yao and Liu, 1998; Udoh and Akintola, 200la, b; Udoh, 2005; Etim *et al*., 2005; Udoh and Etim, 2006).However, this study uses a Cobb-Douglas production function to estimate technical efficiency effect at farm levels by assuming a stochastic nature of production.

MATERIALS AND METHODS

The study area, sampling and data collection procedure: The study was conducted in Uyo Local Government Area, the capital city of Akwa Ibom State, Nigeria. Uyo is situated 55 km inland from the coastal plain of South-East Nigeria. It has an estimated population of 234, 615 (NPC, 1991; FOS, 1999). The area lies within the humid tropical rainforest zone with two distinct seasons dry and wet season. The area is located between latitude 5°17[1] and 5°27[1]N and longitude 7°27[1]N and 7°58[1]E. Uyo covers an area approximately 35Km^2. The occupation of the inhabitants reflects the economic activity of the residents. The settlement comprises mainly Ibibios but has settlers from other ethnic groups. The settlement pattern in Uyo is nucleated and being an administrative headquarters, majority of civil and public servants and political office holders reside there. These people engage in part-time farming activities and other commercial ventures within and around their homes as a way of augmenting and supplementing family income and food supplies (Etim *et al*., 2006).

Data used for this study are mainly primary and were obtained from the farmers using structured questionnaire during 2004/2005 cropping season. Specifically, 180 cassava-based farmers were randomly selected from

Mbiabong Etoi, *Afaha Oku* and *Nsukara* rural areas. Baseline information on socio-economic characteristics, input use and output levels were collected and analyzed.

The empirical model: The study utilized stochastic production frontier, which builds hypothesized efficiency determinants into the inefficiency error components (Coelli and Battese, 1996). Assuming we specified a Cobb-Douglas functional form as;

$$\text{Ln(Qty)} = \beta o + \beta_i \text{Ln(Land)} + \beta_2 \text{Ln (Labour)} + \beta_3\text{Ln (Inorganic fertilizer)} + \beta_4\text{Ln (Planting materials)} + \beta_5\text{Ln (Capital)} + Vi - Ui \quad (2)$$

Where, Qty is the grain equivalent measured in Kg; Land is the farm size measured in hectares; Labour is the labour employed in farm operations measured in mandays; inorganic fertilizer is fertilizer applied on the soil measured in kg; value of planting materials measured in Naira; capital is the depreciation value of farm tools measured in Naira.

With $V_i \sim N(O, \sigma v^2)$ and

$$e^{-u}_i = \alpha_o + \alpha_1(\text{Ext}) + \alpha_2(\text{Exp}) + \alpha_3(\text{Age}) + \alpha_4(\text{Edu}) + Z_i \quad (3)$$

Where, Ext is access to extension contact (dummy), Exp is farming experience in years; Age is the age of the farmer (years); Edu is the level of educational attainment of the farmer in years; Zi is an error term assumed to be randomly and normally distributed. The value of the unknown coefficients in Eq. 2 and 3 are jointly estimated by maximizing the likelihood function (Yao and Liu, 1998; Udoh and Akintola, 2001b).

RESULTS AND DISCUSSION

Maximum likelihood estimates result: The model specified was estimated by the Maximum Likelihood (ML) method using a Frontier 4.1 software developed by Coelli (1995). The ML estimates and inefficiency determinants of the specified frontier are presented in Table 1. The sigma square (0.0318) is statistically significant and different from zero at α=0.01. This indicates a good fit and the correctness of the specified distribution assumption of the composite error term. The variance ratio defined as $\lambda = \sigma u^2/(\sigma u^2 + \sigma v^2)$ is estimated to be 68.24%. The result suggests systematic influences that are unexplained by the production function as the dominant source of random errors. Putting differently, the presence of technical inefficiency among cassava-based farmers explains about 68.24% variation in the output level of the cassava cultivated. The presence of one-sided error component in the specified model is thus confirmed implying that the ordinary least square estimation would be inadequate representation of the data. The generalized likelihood ratio test (λ^2 = 8.9264) is highly significant. This implies the presence of one-sided error component. The results of the diagnosis statistics therefore, confirm the relevance of stochastic parametric production function and maximum likelihood estimation.

Table 1: ML estimates and inefficiency function

Variables	Coefficients	Asymptotic T-value
Production function		
Constant term βo	2.5832	3.1472 ***
Land (β_1)	0.1496	2.6842 ***
Labour(β_2)	0.2531`	2.5716 **
Inorganic fertilizer(β_3)	0.1239	2.9384 ***
Planting materials(β_4)	0.1127	1.9830 **
Capital (β_5)	-0.0254	-1.0358
Inefficiency function		
Interceptαo	1.0242	1.6843 *
Extension contact (α_1)	0.0421	1.0023
Experience (α_2)	-0.1753	-1.7658 *
Age (α_3)	0.4381	1.0224
Education (α_4)	-0.0784	2.1543 **
Diagnosis statistics		
Sigma-square (δs^2)	0.0318	3.2114 **
Gamma (λ)	0.6824	4.2165 ***
Ln(likelihood)	24.2061	
LR test	8.9264	
Quasi-function	1.2007	
Number of observations	180	

Source: Computer print out of Frontier 4.1, Note: All explanatory variables are in natural logarithms. A negative sign of the parameters in the inefficiency function implies that the associated variables have a positive effect on technical efficiency and a positive sign indicates the reverse is true. Asterisk indicate significance ***1, **5, *10%

Table 2: Mean values of output and explanatory variables

Description	Unit	Mean value	Min. value	Max value
Output	kg	20140	1540	54000
Land	Hectares	1.46	0.2	2.1
Labour	Mandays	19	12	47
Inorganic fertilizer	kg	10.5	2	50
Planting materials	Naira	1200.00	5000.00	2380.00
Capital	Naira	824.58	362.34	1650.00
Experience	Years	8	4	30
Age Years	46	23	62	
Education	Years	7	3	14

Source: Field survey, 2005

The relative importance of resource inputs is revealed in the production function estimates. Except for capital, the coefficients of other factors have the expected signs and magnitudes. Labour appears to be the most important factor of production with an elasticity of 0.2531. This result explains the labour intensive nature of cropping system in the study area. Land is the second most important factor with an elasticity of 0.1496, followed by planting materials with an elasticity of 0.1127. The insignificance of capital resource coefficient explains the labour intensive nature of small-scale cassava production in the study area.

Table 3: Farm specific technical efficiency

Efficiency class	Frequency	Percentage
0.01-0.10	6	3.33
0.11-0.20	3	1.67
0.21-0.30	5	2.78
0.31-0.40	8	4.44
0.41-0.50	11	6.11
0.51-0.60	9	5.00
0.61-0.70	19	10.56
0.71-0.80	28	15.56
0.81-0.90	40	22.22
0.91-1.00	51	28.33
Total	180	100

Mean efficiency = 0.74, Minimum =0.01, Maximum = 0.98

Table 2 shows the descriptive statistics with regards to the sample characteristics of the variables.

The estimated coefficients of the inefficiency function explain the technical efficiency levels among individual cassava farms. Except for the Age and extension Contact, the coefficients of other inefficiency variables were highly significant. This implies that educational attainment and experience of the cassava-based farmers positively affect the farm level technical efficiency effect. Findings are veracious as higher educational attainment motivates farmers to acquire and utilize innovations more effectively; and the development of a particular area of knowledge or specialization is by experience, which eventually leads to improvement in production technique and higher technical efficiency level. Results are synonymous with findings by Haffman (1977), Ram (1980), Parikh *et al*. (1995) Udoh (2005) and Udoh and Etim (2006).

Resource-use efficiency distribution: A very important characteristic of the stochastic production frontier is its ability to estimate individual, farm-specific technical, allocative and economic efficiencies. Table 3 shows farm specific resource use efficiency indices.

Results on Table 3 shows considerable variation of efficiency index across the cassava farms. The fact that the technical efficiencies of all sampled cassava farms are less than one implies that no farm reached the frontier of production. This means that the cassava-based farms have the potentials to increase efficiency. With a mean technical efficiency index of 0.74, there is still scope for increasing farm output.

CONCLUSION

The study estimated the farm level technical efficiency and its determinants using stochastic parametric estimation methods. The parameters of the ML estimates and inefficiency determinants were asymptotically efficient, unbiased and consistent and were obtained using Cobb-Douglas production function estimated by maximum likelihood estimation technique. Farmers have a mean age of 46 years and are active and productive. The important factor inputs that increase farm outputs are land, labour, inorganic fertilizer and planting materials. The farm specific technical efficiency distribution reveals that none of the farms reached the frontier threshold. Thus within the context of efficient agricultural production, production can still be increased by 26% using available inputs and technology.

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