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Full Length Research Paper

Technical efficiency of sole cowpea production in Adamawa State, Nigeria: A Cobb-Douglas stochastic frontier function

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The stochastic frontier production model represents an improvement over the traditional average function and the deterministic functions, which use mathematical programming to construct production frontiers. The study was conducted to analyze the technical efficiency of sole cowpea production in the Northern part of Adamawa State using a stochastic frontier model. The result revealed that the variance of parameter (gamma and sigma squared) of the frontier production function was both significant at 10 and 1% levels. Farm size, seeds, agro-chemicals and hired labour were positive and had significant effect on output at 1%. The mean technical efficiency index was 0.89 while the minimum and maximum efficiency values were 0.55 and 0.95 respectively. This implies that the farmers were not fully efficient as the observed output was 11% less than the maximum output.

Key words: Stochastic frontier, efficiency technical, production, sole cowpea.

INTRODUCTION

The concept of efficiency is concerned with the relative performance of the process used in transferring given input into output. The crucial rule of efficiency in increasing agricultural output has been widely recognized by researcher and policy makers. The Nigerian Government in 2003 made a policy on exportation of food crops (Omonona et al., 2010). Therefore, it is necessary to study the efficiency of farmers sequel to the export promotion on one of the major food crops produced in Nigeria. An underlying premise behind this study is that if farmers were not making efficient use of existing technologies, then effort made to improve efficiency will be more cost effective than introducing new technologies as a means of increasing agricultural output (Belbase and Grabouski, 1985; Omonana et al., 2010). The efficiency of a farm/firm refers to its success in producing as large amount of output as possible given as set of inputs. To determine the efficiency of a particular firm, there is need for efficiency measurement through the production factor inputs and processes. This efficiency measurement has received considerable attention from both theoretical and applied economics.

From a theoretical point of view, there has been a spirited exchange about their relative importance of the various components of firm efficiency (Cornanor and Leibenstein, 1969). From an applied perspective measuring efficiency is important because this is the first step in a process that might lead to substantial resource savings. These resource savings have important implications for both policy formulation and firm management (Bravo-Ureta and Reiger, 1991). The measurement of efficiency begins with Farrell (1957) who drew upon the work of Debrew (1951) and Koopmans (1951) to define a simple measure of firm efficiency which could account for multiple inputs. He proposed that the efficiency of a firm consists of two components: technical efficiency (TE), which reflects the ability of a firm to obtain maximal output from a given set of inputs, and allocative efficiency (AE), which reflects the ability of a firm to use the inputs in optimal proportions, given their respective price. These two measures are combined to provide a measure of total

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economic efficiency. Farrell's model which is known as a deterministic nonparametric frontier (Fortuned et al., 1980) attributes any deviation from the frontier to inefficiency and imposes no functional form on the data. Several extensions of Farrell deterministic model have been made by economists such as Afriat (1922), Aigner and Chu (1968), Richmond (1974), Schmidt (1980) and Greene (1980), among others. A deficiency characterizing all deterministic frontier models is their sensitivity to extreme observations. A more recent approach for measuring efficiency, which seeks to ameliorate the extreme observation problem, is the stochastic frontier model developed by Aigner et al. (1977) and by Meeusen and Van deu Broeck (1977). Other models such as data envelope analysis (DEA) is a non parametric data based methodology that provides measures of optimal profit ratio and best practice efficiency. It identifies the best firms on the efficient productivity frontier (efficient firm) and firms that are interior to that frontier (inefficient firms). Many outputs and inputs can be analyzed simultaneously for a number of observations (Zaibet and Dharmapala, 1999).

However, the model is not used in this study because the study was strictly on sole cowpea production in the state. The stochastic frontier model assumes an error term with two additive components, a symmetric component that accounts for pure random factor and a one sided component which captures the effects of inefficiency relative to the stochastic frontier. In general, a firm is technically efficient if its observed production outlay (y^o, xo) exactly satisfies the Cobb-Douglass production equation given as $y^o = f(x^o)$, where f is the production frontier, y^o is the output and x^o is the a vector of input for the firm. The firm is technically inefficient if $y^o < f(x^o)$ that is, the firm operates inside the production frontier. The firm is allocatively efficient, if the ratio of the marginal products, $MP_{(X)}$ between ale input equals to the ratio of the input prices $MP_i/MP_i = P_i/P_i$. Scale efficiency is achieved if the firm produces at a marginal cost, that is, the same as the price of the output. Allocative and scale efficiency is the condition for profit maximization and is labeled price efficiency. This paper contributes to the efficiency literature of agriculture in developing countries by quantifying the level of technical efficiency for sampled cowpea farmers in Adamawa State. The sole objective was to examine the technical efficiency of sole cowpea production in the northern part of Adamawa State. Specifically, the study identified the determinants of sole cowpea production in the study area.

MATERIALS AND METHODS

Multistage and purposive random sampling techniques were adopted for the study. The first stage involved the selection of three notable cowpea producing districts out of the eight districts of the local government area; the second stage was the selection of one ward from each of the selected districts. Thirdly, two villages were randomly selected from each ward, and finally twenty farmers were selected in each village which amount to one hundred and twenty farmers. They and were served with structured questionnaires. However, one hundred and two respondents were eventually used for the study.

ANALYTICAL FRAMEWORK

Stochastic production frontier was employed using the variant of the Stochastic production analysis adopted by Bravo-Ureta and Rieger (1994), Dawson et al. (1991), Son et al. (1993), Coelli and Battese (1996), Amaza and Tashikalma (2003), and Amaza and Maurince (2005). It is assumed that the farm frontier production function can be written as:

$Q = f(X_i; \beta)$……………………………………….i

Where Q is the quantity of cowpea output, X_i is a vector of input quantities, and β is a vector parameters.

The empirical model of the Stochastic production function frontier applied in the analysis of efficiency of the production system of the cowpea production is specified as:-

$$\ln Y = \ln \beta_0 + \beta_1 \ln X_{ij} + \beta_2 \ln X_{2ij} + \beta_3 \ln X_{3ij} + 4\ \beta_4 \ln X_{4ij} + \beta_5 \ln X_{5ij} + V_{ij} - U_{ij}$$

Where,

Y = Output of cowpea (kg)
X_1 = Farm size in hectare (ha)
X_2 = Quantity of seeds (kg)
X_3 = Quantity of agro-chemical used (in liters)
X_4 = Hired labour (man days)
X_5 = Family labour (man days)
V_i = Random noise (white noise)
U_i = Are efficiency effect which are non negative with half normal distribution

Descriptive i and j refer to the ith cowpea produced and the jth input respectively; and $V_{ij} - U_{ij}$ is the composed error term (Aieger et al., 1977; Meeusen and Van deu Broeck, 1977). The two components, V and U are assumed to be independent of each other where V is the systematic (two-sides) component, normally distributed random error (V-N Co, □^{2}v) which captures variations in output due to factors outside the control of the former. This could be fluctuation in input prices and it is the one-sided efficiency component with a half-normal distribution (U□~□/NCO,$_\delta$^{2}U) which is a non negative random variable called technical inefficiency effect. It is associated with the technical efficiency of cowpea production and it captures the variation in output due to age and educational level, farming experience and extension officers' visitation. U_{ij} is equal to zero for any output lying on the frontier while U_{ij} 70 is for any output lying below the frontier. Hence, $\delta^2 = \delta^2 + \delta^2 u$

However, the output variable in the stochastic frontier production function is output in kg.

The measures of technical efficiencies obtained are, of course, the measures of the overall technical efficiencies of the cowpea farmers. It is assumed that the inefficiency effects are independently distributed and U_{ij} arises by truncation (at zero of the normal distribution with U_{ij}) and variance.

The model was used to analyze the effect of certain socio-economic factors on the technical efficiency of the farmers. The model was used because the dependent variable technical efficiency scores are censored, having values ranging between O and 1 (Liewenlyn and Williams, 1996). The model specification is given as:

Table 1. Maximum likelihood estimate of parameters of Cobb-Douglas stochastic frontier production function for sole cowpea famers.

Variable	Parameters	Coefficient	t. Value
Stochastic frontier (production parameters)			
Constant	β_0	2.69***	15.32
Farm size	β_1	0.96***	6.17
Seeds	β_2	0.29***	2.61
Agro-chemical	β_3	0.65***	3.75
Hired labour	β_4	1.18***	4.73
Family labour	β_5	1.10	0.85
Inefficient effects			
Constant	δ_0	4.15	0.74
Age	δ_1	-3.37	-1.18
Education	δ_2	-0.39***	-2.64
Farm experience	δ_3	-8.31*	-1.80
Visit by extension officer	δ_4	-0.08	-0.75
Variance parameters			
Sigma squared	δ_2	082*	1.80
Gamma	γ	0.92***	21.82
Mean TE		0.89	

Source: Field survey (2007). ***Significant at 1%; * significant at 10%.

$$Ui = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4$$

Where,

Z_1 = Age of farmers (years); Z_2 = Education in level; Z_3 = Farming Experience (years); Z_4 = Visit by extension officer (dummy:1 for visit and 0 otherwise); $\delta_0 - \delta_4$ = Unknown parameters to be estimated.

RESULTS AND DISCUSSION

The maximum likelihood estimate (MLE) of the parameters of the stochastic frontier model of cowpea farmers is shown in Table 1. The variance parameters of the frontier production are represented by sigma squared (δ) and gamma (γ). The sigma squared in Table 1 is 0.82 and significantly different from zero to 10%. This indicates a good fit and correctness of the distribution form assumed for the composite error term. Gamma indicates that the systematic influence of the unexplained variables by the production function is the dominant sources of random error. The gamma estimate, which was 0.92, shows the amount of variation in output resulting from the technical inefficiencies of the farmers. This means that 92% of the variation in farmers' output was due to technical efficiency. This implies that the ordinary least square estimate (OLS) will not be adequate to explain the inefficiencies on cowpea farming. Hence, the specification of a stochastic frontier production function is therefore justified. Typical of the Cobb – Douglas production function, the estimated coefficients for the specified function can be explained as the elasticity of the explanatory variables. The mean technical efficiency (TE) of cowpea farmers was 0.89 (89%), implying that the farmers were not fully efficient as the observed output was 11% less than the maximum output. The estimate of the parameters of the stochastic production frontier indicated that the elasticity of output with respect to farm size was positive (0.96) and it is statistically significant at 1%.

This implies that farm size is a positive and significant factor that influences the output of cowpea farmers. An increase of 1% in farm size will result to an increase in output by 0.96%. The production is statistically significant at 1%. The production elasticity of agro-chemical was positive (0.65) and statistically significant at 1%. This implies that positive and statistical significance influences the output of cowpea farmers. An increase of 1% of agro-chemical will result in an increase in output by 0.65%; also the production elasticity of hired labour was positive at 1.18 and it was statistically significant at 1%. This indicates that hired labour was a positive and significant factor that influences the output of cowpea farmers. An increase in 1% of hired labour will result in an increase in output by 1.18%; the coefficient of the variable associated with family labour was 1.10 and was not statistically significant. The implication of this is that family labour was not a critical factor in cowpea production.

Source of disparity in technical inefficiency among sole cowpea farmers

The existence of technical inefficiency paves way to find out the sources of inefficiencies among sole cowpea farmers in the study area. Socio-economic variables were considered and estimated in the model and the result is presented in Table 1. The signs and coefficients in the inefficiency model are interpreted in the opposite way, such that a negative sign means the variable increases efficiency and vice versa. The result of the inefficiency model shows that the coefficients for age and visit by extension officer were not statistically significant. This implies that these characteristics do not contribute to farm inefficiency. Since these variables were not significant, they do not deserve further discussion.

The coefficient for education was estimated to be negative and statistically significant at 1% level. This shows that an increase in education will result in increase in output of farmers. Also, the coefficient for farming experience is estimated to be negative, statistically significant at 10% level. In line with the aforementioned findings, Adebayo (2006) revealed that farming experience in pastoral farming has positive impact and is statistically significant.

Conclusion

The result of the stochastic frontier analysis showed that the entire production coefficient had the expected (*a priori*) positive signs, indicating that increase in any of the variables will lead to increase in output. The technical efficiency of sole cowpea farmers was less than one, indicating that the farmers were not operating on the efficiency frontier. The mean technical efficiency index was 0.89, suggesting that farmer's output can be improved by 11% through improved resource allocation. This will require addressing those factors which are constraints to efficiency, which include shortage of agro-chemicals and other inputs that will bridge the gap between the demand and supply of the important inputs in sole cowpea farming.

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