Advances in Economics and Business Management (AEBM)
Print ISSN: 2394-1545; Online ISSN: 2394-1553; Volume 2, Number 4; April-June, 2015 pp. 393-397

http://www.krishisanskriti.org/aebm.html

Application of Dual Stochastic Production Function in Estimating Technical Efficiency in Cotton Production in Kano State, Nigeria

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Abstract—*This paper presents empirical study on technical efficiency of cotton production in Kano State of Nigeria. Multi-stage sampling techniques was used to select a total of sixty respondents in the study area through which data were elicited through primary source using pre-tested questionnaires administered on the respondents'. Data were analyzed using stochastic production frontier function. The results shows a relative presence of increasing returns to scale among the farmers considering the size of the farm which is an indication that they operates in stage I of production surface. This result was further collaborated by the mean technical efficiency score of 0.63 obtained from the data analysis which shows that an average farm in the sample area is about 63% below the frontier, indicating that they are relatively efficient in allocating their scarce resources. Furthermore, the result of the analysis indicate presence of technical inefficiency effects in the cotton production as depicted by the significant estimated gamma coefficient of about 0.76 and the generalized likelihood ratio test result obtained from the data analysis.*

Keywords: *Technical efficiency; stochastic production function; returns to scale; cotton farmers; Kano state; Nigeria*

1. INTRODUCTION

Nigeria with a population of over 116 million is the most populous country in Africa; located in West Africa with total land area of 923,768 sq km. Agricultural sector is the largest employer (70%) of its labor force and contributes more than 33% to the GDP. The sector since 1970's has been characterised by declining productivity and increased dependence on import of food and raw materials [12].The discovery of oil changed the equation in the economy as the country gradually began to drift into a mono economy heavily dependent on oil exploration and export since 1990s to the neglect of other sectors including agriculture and solid minerals. For decades cotton production (lint and cotton seed) has been a driving force for economic development in Nigeria. The neglect of the agricultural sector during the oil boom years (1970-80's) had a direct impact on the cotton sector. In the recent years due to poor management and reduced production of both lint and seed, the cotton sector has slackened [8].The main feature of Nigerian cotton cultivation is that 80% of total production is by peasant farmers under rain-fed conditions with simple tools and animal drawn implements.

The new agricultural policy being implemented by the Federal Government is aimed at addressing our failures in the 1970s and to encourage public private partnership so that agriculture becomes a business. In the case of resuscitating cotton production and the ginneries, a value chain is already being created. The 15 ginneries in Gusau, apart from being a ready market for the cotton farmers in the state, it process the cotton to feed Nigeria textile industries, thus creating jobs and reviving the textiles. This should be the case with all the ginneries in the country [8].The Government of Nigeria has given priority to reviving the once flourishing cotton textile industry (Cotton, Textile and Garment Industry Revival Scheme) and also trying to diversify its non-oil economy [13]. The question of efficiency in resource allocation in agriculture is not trivial. It is widely held that efficiency is at the heart of agricultural production. This is because the scope of agricultural production can be expanded and sustained by farmers through efficient use of resources. For these reasons, efficiency has remained an important subject of empirical investigation particularly in developing economies where majority of the farmers are resource-poor. Inspite of increase in agricultural activities, recent literature search in Nigeria reveal that most of the efficiencies studies in cotton production used classical model (OLS), for example, [3], with little or no documentary literature evidence of an empirical studies on efficiency using neoclassical model in Nigeria. Furthermore, recently study on efficiency in cotton production using neoclassical model was conducted in Ghana which is a neighbouring country [2] using neoclassical model. The question therefore is, are Nigerian cotton farmers efficient in the use of resources? This study is an attempt to answer this question with specific emphasis on the technical efficiency in cotton production using the neoclassical model (stochastic frontier function). This research will analyze empirically, the technical efficiency of resource use in cotton farming.

2. THEORETICAL FRAMEWORK

Three types of efficiency are identified in the literature, these are technical efficiency, allocative efficiency and overall or economic efficiency. Technical efficiency is the ability of a firm to produce a given level of output with minimum quantity of inputs under a given technology. Allocative efficiency is a measure of the degree of success in achieving the best combination of different inputs in producing a specific level of output considering the relative prices of these inputs. Economic efficiency is a product of technical and allocative efficiency. In one sense, the efficiency of a firm is its success in producing as large an amount of output as possible from given sets of inputs. Maximum efficiency of a firm is attained when it becomes impossible to reshuffle a given resource combination without decreasing the total output. Since the seminal work of Farrell in 1957, several empirical studies have been conducted on farm efficiency. These studies have employed several measures of efficiency. These measures have been classified broadly into three namely: deterministic parametric estimation, nonparametric mathematical programming and the stochastic parametric estimation.

3. RESEARCH METHODOLOGY

This study was based on the farm level data on cotton farmers in Kano State, Nigeria. Multi stage sampling technique was used to draw sixty (60) respondents with pre-tested questionnaire used to elicit information. Stochastic frontier model as used to elicit information for the study. Stochastic frontier wwas used for the analysis.

3.1 Model specification:

Following Erhabor and Ahmadu the model was specified as follows:

$$\ln Yi = \ln ßo + \Sigma\, ßj \ln Xij + Vi - Ui \ldots \quad .(1)$$

Where,

Yi = Farm output (kg) from farm i;

Xi = Vector of farm inputs used.

X_1 = Family labour (in man days);

X_2 = Hired labour (in man days);

X_3 = Seeds (kg);

X_4 = Fertilizer (kg)

X_5 = Farm size (in hectares); and,

X_6 = Depreciation on capital items (in Naira).

Vi = Random variability in the production that cannot be influenced by the farmer;

Ui= Deviation from maximum potential output attributable to technical inefficiency.

ßo = intercept;

$ß_{1-6}$=vector of production function parameters to be estimated;

i = 1, 2, 3, n farms; and,

j = 1, 2, 3, m inputs.

The inefficiency model is:

$$Ui = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \ldots\ldots + \delta n Zn \ldots. \quad .(2)$$

Where, Ui = technical inefficiency effect of the ith farm;

Z_1 = Age (years);

Z_2=Educational (formal=1, otherwise=0);

Z_3 = Household size (numbers);

Z_4 = Farming experience (years);

Z_5=Extension contact (yes = 1, otherwise =0);

Z_6=Access to credit (yes=1, otherwise=0);

Z_7= readily market (yes=1, otherwise=0); and,

Z_8=Co-operative (yes=1, otherwise=0).

δ_0=Intercept

δ_{1-8}=variable vector parameters to be estimated.

The ß and δ coefficients are un-known parameters to be estimated along with the variance parameters σ^2 and γ. The σ^2, and γ, coefficients are the diagnostic statistics that indicate the correctness of the assumptions made on the distribution form of the error term and the relevance of the use of the stochastic production frontier function.

4. RESULTS AND DISCUSSION

4.1Technical efficiency and associated inefficiency factors.

Maximum Likelihood Estimates of the stochastic frontier production function and the inefficiency are presented in Table 1. All parameters estimate have the expected sign, except family labour, and all are significant with exception of hired labour and depreciation on capital items, meaning that these factors were significantly different from zero and thus were important in cotton production. The coefficient of seed was positive and significantly at 5%. This implies that seeds are important in cotton production in the study area. The production elasticity of output with respect to quantity of fertilizer was 0.34 and statistically significant at 10% level. 1% increase in fertilizer quantity will make output level to improve by a margin of 0.34%. This finding conforms with the report by [2], who reported positive and significant contribution of fertilizer in cotton production in Yendi municipality in Ghana. The coefficient of farm size was found to be positive and highly significant at 1% level. This result is at variant with the findings of [2] study on technical efficiency of cotton farmers in Yendi municipality in northern Ghana which reported farm size to be significant but with negative sign. The result could mean that it is possible to expand farming activity in the study area, given that competition between infrastructural development and crops for land is not yet keen enough to jeopardize the expansion of crop production. Statistically, the magnitude of the coefficient of farm size shows that output is inelastic to farm size. If the farm size is increased by 1%, output level will improve by less than proportionate, by a margin of 0.55%. This implies that there is still scope to increasing output per plot by expanding farmland. The coefficient of family labor was significant at 5% level and carried a negative sign. The negativity of the coefficient of family labour was due to its supply which is readily available in abundance and cheap, given that this kind of labour is contributed freely by members of the farmer's household. This situation is attributed to large household size, small land holding, poverty of the farmers and lack of affordable equipment. This kind of labour is important in virtually all farming activities, particularly in developing countries where mechanization is only common in big commercial farms. Furthermore, it appears that it will continue to play a crucial role in traditional agriculture, affecting its efficiency, until factors constraining mechanization is addressed. If family labour is increased by 1%, output level will decrease by -0.03. This calls for creation of alternative employment opportunities to absorb the excess family labour used in cotton production. The coefficient of the hired labour was positive but non-significant. The non-significance of this variable may be due to the fact that this kind of labour is mostly used on rare conditions. Also the coefficient of depreciation is positive and non-significant. The non-significance of the variable may be as a result that farming in the study area is still at the subsistence level generally, with use of traditional farming implements such as hoe and machete. The estimated return to scale (RTS) was 1.63 suggesting an increasing return to scale. This implied that a unit increase in the quantities of the productive resources would lead to more than proportionate increase in output of cotton, *ceteris paribus.*

The estimated coefficient in the explanatory variables in the model is presented in the lower part of Table 1, in the sense that technical inefficiency effects are of interest and have important implication. The sources of inefficiency were examined by using the estimate δ coefficients associated with the variables. The inefficiency variable specified were those relating to farmer's personal socioeconomic characteristics; level of educational, age, household size, farming experience, access to extension service, access to credit, readily available market and co-operative membership. The co-efficient of all the variables were negative except age. The sign of the estimated coefficient in the model have important implication on the technical efficiency of cotton production. The coefficient of education was estimated to be negative and is significant at 10%. This indicates that farmers with formal education tend to be more technically efficient. This agrees with the findings of [4,1,2]. They reported that formal education is imperative for better understand and adoption of new technology which subsequently make it possible to move close to the frontier. Furthermore, educated farmers are expected to be more receptive to improved farming techniques and therefore have higher level of technical efficiency than farmers with non-formal education [9]. Farmers with non-formal education would be less receptive to improved farming techniques. The predicted coefficient of household size was negative and significant at 10%, implying that this variable decrease technical inefficiency or increase technical efficiency. The negative coefficient agreed with the hypothesized expected sign and implied that as the number of adult farmers in a household increases, efficiency also increases. This conforms to the findings of [6,11]. A possible explanation is that more adult persons in a household means that more quality labour would be available to carry-out farming activities in timely fashion, thus making the production process more efficient. The coefficient of co-operative membership was negative and significant at 1%. This means that this variable decrease technical inefficiency. Membership in Farmers' Cooperatives affords the farmers the opportunity and access to subsidized input supply, marketing of his products and also information sharing on modern cotton practices through interaction with other farmers. This result is in tandem with findings of [5].The coefficient of access to credit carried negative sign and was significant at 1% level. Farmers' access to credit enhances timely acquisition of production inputs that would enhance productivity via efficiency, that is, it loosens the production constraints and hence makes it easier for timely purchase of resources thereby increasing productivity through efficiency. The result is consistent with earlier findings of [10,5]. Furthermore, coefficient of farming experience had the expected negative sign and was significant at 5%. This means being an experienced farmer was important to significantly cause a farmer to attain higher levels of efficiency if he can rearrange his inputs to obtain higher output levels with a given technology. Furthermore, farmers tend to be more active, acquire more skills and training as they spend more years in production which culminates in increase efficiency. This findings was in line with findings of [2,6,11]. The coefficient of readily availability of market was significant at 10% level and carried a negative sign. This implies this variable increases the technical efficiency of the farmer in the production of cotton. The significance of this variable is important given that it is a cash crop and mostly been produced on contract basis with its main consumers being industrial users. Age coefficient was positive and significant at 5%. This implies that technical efficiency decreases as farmer gets older. However, with respect to new ideas and techniques of farming older farmers are less likely to adopt innovations and thus would be less technically efficient than younger farmers. This result is in conformity with the findings of [10]. The variance parameters for σ^2 and γ are 0.35 and 0.76 respectively, are significant at 5 and 10 percent level respectively. The sigma squared σ^2 indicates the goodness of fit and correctness of the distributional form assumed for the composite error term while the gamma γ indicates that the systematic influences that are un-explained by the production function are the dominant sources of random errors. This means that the inefficiency effects make significant contribution to the technical inefficiencies of cotton farmers. The estimated gamma parameter of 0.76 indicates that about 76% of the variation in the value of farm output of cotton farmers was due to their differences in technical efficiencies. However, the result of generalized likelihood ratio test which is defined by the chi-square distribution reveals that the hypothesis which specifies that the inefficiency effects are absent from the model is strongly rejected (coefficient of $\beta = 0$), thereby, proving that traditional response function (OLS) is not an adequate representation of the data. This is because the results revealed that the magnitudes of the explanatory variables incorporated into the inefficiency model are not equal to zero. In other words the null hypothesis which specifies that inefficiency effects in the stochastic frontier production function are not stochastic is rejected, since the χ^2cal value (82.02) is greater than χ^2 critical (18.48) at 0.01 probability level, hence the null hypothesis of no technical inefficiency in cotton production is rejected and the alternative accepted.

Table 1: Maximum-likelihood estimates of parameters of the Cobb-Douglas stochastic production frontier function and technical inefficiency in cotton production in Kano state, Nigeria.

Variable	Parameters	Coefficients	Standard error	t-ratios
General model				
Constant	β0	5.293	0.43	12.33***
Family labour	β1	-0.03	0.012	-2.5**
Hired labour	β2	0.08	0.075	1.06NS
Seeds	β3	0.25	0.11	2.27**
Fertilizer	β4	0.34	0.20	1.7*
Farm size	β5	0.56	0.03	18.67***
Depreciation	β6	0.62	0.59	1.05NS
Inefficiency model				
Constant	δ0	0.21	0.071	2.96***
Age (years)	δ1	0.89	0.41	2.17**
Educational level	δ2	-0.18	0.10	-1.8*
Household size (number)	δ3	-0.32	0.021	-15.24***
Farming experience (years)	δ4	-0.65	0.25	2.6**
Extension contact	δ5	-0.09	0.02	-4.5***
Access to credit	δ6	-0.83	0.11	7.56***
Readily market availability	δ7	-0.73	0.40	-1.83*
Co-operative membership	δ8	-0.08	0.021	--3.81***
Diagnostic statistic				
Sigma-square σ2 = σ2v + σ2u		0.35	0.15	2.33**
Gamma γ = σ2u/σ2v + σ2u		0.76	0.41	1.85*
Log likelihood function (llf)		25.49		
LR test		82.02		

Source: Computer print-out of FRONTIER 4.1
Note: ***, **, * Implies significance at 0.01, 0.05 and 0.10 probability levels respectively.
NS: Non-significant

4.2 Individual farm technical efficiency scores

The frequency distribution of predictive individual farm level technical efficiency score for each respondent was also estimated and was shown in Table 2. The result of the frequency distribution of technical efficiency estimates shows that the estimates ranged from 0.25 to 0.83. The distribution seemed to be skewed toward the frontier. The minimum technical efficiency score was 0.25, which indicated high level inefficiency in resource allocation, while the maximum technical efficiency score was 0.83, implying that the most efficient farmer operated almost on the frontier. Even with the mean of 0.63, 65% of the farmers are frontier farmers since their efficiency scores were above the mean. This implies that average farmer can increase its technical efficiency by 37% scores (1– [0.63/1.00*100]) to be on the frontier. This finding is consistent with the findings of [5,11,6] who reported mean technical efficiency levels of 0.65 and 0.69 for large and small-scale rice farmers, respectively in Imo state of Nigeria, 0.65 for small-scale farmers in Patigi Local Government Area in Kwara state of Nigeria, and 0.61 for small-scale rice farmers in Nigeria, respectively. However, the most efficient farmer needs a technical efficiency score of 17% (1– [0.83/1.00*100]) to be on the frontier, while the average farmer needs a technical efficiency score of 24.1% (1 – [0.63/0.83*100]) to attain the status of the most technical efficient farmer. Furthermore, the least farmer needs a technical efficiency score of 69.9% (1– [0.25/0.83*100]) to attain the status of the most technical efficient farmer and 75% technical efficiency score (1– [0.0.25/1.00*100]) to be on the frontier. The most frequently occurring efficiency score was 61%. From the results obtained, although farmers were generally relatively efficient, they still have room to increase the efficiency in their farming activities since 37% efficiency gap from the optimum (100%) remains yet to be attained by all farmers.

Table 2: Deciles Frequency Distribution of technical Efficiencies

Efficiency level	Frequency	Relative Efficiency (%)
≤ 0.40	3	5
0.41-0.50	6	10
0.51-0.60	12	20
0.1-0.70	15	25
0.71-0.80	20	33.3
≥ 0.81	4	6.7
Total	60	100
Minimum	0.25	
Maximum	0.83	
Mode	0.61	
Mean	0.63	

Source: Computed from MLE Results

5. CONCLUSION AND RECOMMENDATIONS

This empirical study is on technical efficiency in cotton production using stochastic frontier production function. The empirical evidence indicates the existence of increasing returns to scale in the sense that, the computed overall return to scale is slightly above one, which is an indication that the cotton farmers are currently expanding their present level of production, which in the long run will enable them to attain the economic (optimum) production region. Furthermore, the outcome of this analysis shows that about 65% of the farms included in the sample operate close to the frontier level, achieving scores of about 63% in terms of technical difference in relation to the best-practiced technology. However, the level of the observed technical efficiency has been shown to be significantly influenced by all the socio-economic characteristics of the farmers. In conclusion, the relative closeness of an average technical efficiency score of 0.63 from unity, is an indication that even though the farmers are small scale resource poor, they are fairly efficient in the use of their resources, and any expansion in their present production level would increase technical efficiency in production per output. Based on these results, the following recommendations were made:

- To make change in cotton sector a reality, both the farmers and the industrialists need government intervention to boost the production chain.
- The role of the Governments of the cotton producing States and the Federal Government in the production chain is very important. They should provide the enabling environment for the textile industry to become functional.
- The study recommends the use of biotechnology to increase cotton production in other to restore Nigerian textile industry; adding that, field trails in India have shown that Bt cotton hybrids give 80% greater yield than non-biotech hybrids varieties currently grown in Nigeria.
- Farmers should be encouraged to grow organic cotton, adding that it shows potential in Nigeria and it is expected that through rigorous efforts the country will be able to produce 400 tonnes of organic cotton by 2015.

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