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Application of 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 pseudo-profit function and 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 per cent 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. The profit margin of ₦ 11, 120/ha ascertained cotton farming to be a profitable venture in the study area.

Key words : Cotton farmers, Kano state Nigeria, returns to scale, stochastic production function, Technical efficiency

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 per cent to the GDP. The main crops grown are cotton, cocoa, rubber, peanuts, oil palm, maize, rice, sorghum, millet, cassava, yams, timber and livestock. The sector since 1970's has been characterised by declining productivity and increased dependence on import of food and raw materials (Anonymous, 2014).

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. Anonymous (2012a), Agriculture, particularly, cotton, groundnut, cocoa, rubber production were the main stay of the Nigerian economy. The neglect of other sectors of the economy has had its toll on the Nigerian economy, more so as the country runs a federal system of government with all its tiers of government looking up to the federal government for their share of federation accruals to undertake development programmes (Anonymous, 2013a).

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 (Anonymous, 2013b). The main feature of Nigerian cotton cultivation is that 80 per cent of total production is by peasant farmers under rain-fed conditions with simple tools and animal drawn implements. cotton production areas in Nigeria are divided into 3 ecological zones, namely: the northern cotton zone. These states contribute 60-65 per cent of the cotton produced. The eastern cotton zone contributes 30-35 per cent of the total cotton production. The third ecological area known as the southern cotton zone it contributes 5 per cent of the total cotton production (Alam *et al.,* 2013).

According to Anonymous (2013c) cotton production in Nigeria has dropped in the past three years; the country which was known for its high production of cotton with the iconic display of the pyramids to show for it, started witnessing a downward slide in production from late 1970s leading to the total disappearance of the pyramids in 1990s; declined to 120,000 tons/annum, which is less than half of over 300,000 tons/annum once produced in Nigeria. Cotton in Nigeria has strong linkages with the domestic industries which consume up to 50 per cent of the total production. It had a well developed textile industry till 1980's and was one of the finest and most vibrant industries in the world. At its peak in 1980s, the industry provided about 500,000 direct jobs with well over 250 functional factories. The industry started to decline after 2000 followed by closures of the major factories caused by operational difficulties (Anonymous, 2013a).

As Nigeria entered the millennium, a new dimension was added to the practice of the mono – economy. Resource control took center stage with the petroleum producing areas of the country demanding for more allocation of revenue derived from crude oil sales. Petroleum, national development and resource control have been at the front burners and issues of discuss in the nation's print and electronic media, as well as political discuss. In the midst of these, the different regions of the country are beginning to look at ways to bring about regional development based on what the regions can produce to earn revenue and hence add economic value to the country as opposed to undue reliance on Federal Allocations (Anonymous, 2013c). 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 (Anonymous, 2013a). 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 (Anonymous, 2013c)

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, Alam *et al.,* (2013), 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 (Adzawla *et al.,* 2013) 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. The specific objectives are to: (i) Estimate the cost of and return to cotton farming, and (ii) Determine the technical efficiency of resource use in cotton farming.

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. 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. There are two non-parametric measures of efficiency. Several approaches, which fall under the two broad groups of parametric and non-parametric methods, have been used in empirical studies of farm efficiency. These include the production functions, programming techniques and recently, the efficiency frontier. The frontier is concerned with the concept of maximality in which the function sets a limit to the range of possible observations (Amodu *et al.,* 2011). Thus, it is possible to observe points below the production frontier for firms producing less than the maximum possible output but no point can lie above the production frontier, given the technology available. The frontier represents an efficient technology and deviation from the frontier is regarded as inefficient. The literature emphasizes two broad approaches to production frontier estimation and technical efficiency measurement: (a) The non parametric programming approach, and (b) the statistical approach. The programming approach requires the construction of a free disposal convex hull in the input output space from a given sample of observations of inputs and outputs. The convex hull (generated from a subset of the given sample) serves as an estimate of the production frontier, depicting the maximum possible output. Production efficiency of an economic unit is thus measured as the ratio of the actual output to the maximum output possible on the convex hull corresponding to the given set of inputs. The statistical approach of production frontier estimation can be sub divided into two, namely, the neutral shift frontiers and the non neutral shift frontiers. The former approach measures the maximum possible output and then production efficiencies by specifying a composed error formulation to the conventional production function. The non neutral approach uses a varying coefficients production function formulation. The main feature of the stochastic production frontier is that the disturbance term is composed of two parts, a symmetric and a one sided component. The symmetric (normal) component, Vi captures the random effects due to the measurement error, statistical noise and other non symmetric influences outside the control of the firm. It is assumed to have a normal distribution. The one sided (non positive) component, Ui with Ui e” 0, captures technical inefficiency relative to the stochastic frontier. This is the randomness under the control of the firm. Its distribution is assumed to be half normal or exponential. The random errors, Vi are assumed to be independently and identically distributed as N (0, ó^{2}) random variables, independent of Uis. The Uis are also assumed to be independently and identically distributed as, for example, exponential, half normal, truncated normal and gamma.

The stochastic frontier function is typically specified as:

$Yi=f (Xij; ß) + Vi-Ui$ (i = 1, 2, n) .... (1)

Yi = Output of the ith firm;

Xij = Vector of actual jth inputs used by the ith firm;

ß = Vector of production coefficients to be estimated;

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

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

The model is such that the possible production Yi, is bounded above by the stochastic quantity, f (Xi; ß) exp (Vi), that is when Ui = 0 hence, the term stochastic frontier. Given suitable distributional assumptions for the error terms, direct estimates of the parameters can be obtained by either the Maximum Likelihood Method (MLM) or the Corrected Ordinary Least Squares Method (COLS). However, the MLM estimator has been found to be asymptotically more efficient than the COLS, thus, the MLM has been preferred in empirical analysis. In the context of the stochastic frontier production function, the technical efficiency of an individual firm is defined as the ratio of the observed output to the corresponding frontier output, conditional on the levels of inputs used by the firm. Thus, the technical efficiency of firm is:

$Tei = exp (-Ui)$ .... (2)

$Tei = Yi/Yi^*$ .... (3)

$= f (Xi; ß) exp (Vi - Ui) / f (Xi; ß) exp (Vi) exp (-Ui)$.

Tei = Technical efficiency of farmer i;

Yi = observed output; and,

Yi* = frontier output.

The technical efficiency of a firm ranges from 0 to 1. Maximum efficiency in production has a value of 1.0. Lower values represent less than maximum efficiency in production.

Several empirical applications have followed the stochastic frontier specification. These studies are basically based on Cobb-Douglas function and transcendental logarithmic functions that could be specified either as production or cost or profit function.

The use of the stochastic frontier analysis in studies in agriculture was first used in Nigeria in year 2000. Such earlier studies include that of Udoh (2000), Okike (2000) and Amaza (2000). Udoh (2000) used the maximum likelihood estimation of the stochastic production function to examine the land management and resource use efficiency in south eastern Nigeria. The study found a mean output-oriented technical efficiency of 0.77 for the farmers, 0.98 for the most efficient farmers and 0.01 for the least efficient farmers. Okike (2000) study investigated crop livestock interaction and economic efficiency of farmers in the savanna zones of Nigeria. The study found average economic efficiency of farmers was highest in the low population low market domain; northern Guinea and Sudan Savannas ecological zones; and crop based mixed farmers farming system. Available literature indicates that cotton production in Nigeria is yet to benefit significantly from application of the stochastic frontier model. Likewise empirical research effort using neoclassical model is also new. This paper employs the stochastic frontier model in determining technical efficiency in cotton farming.

Study area : This study was based on the farm level data on cotton farmers in Kano State, Nigeria. Kano State is in the North-western part of Nigeria and lies in between longitude $8^0 45^1$ and $12^0 05^1$ east of the Greenwich Meridian and latitude $10^0 30^1$ and $13^0 02^1$ north of the equator .The land area is approximately 20,760 square Kilometre, consisting of 1,754,200 hectares of agricultural land and over 92, 250, 81 hectares of forest vegetation and grazing land with varying physical features like hills, lowland and rivers.

The state have four vegetation zones, namely, Sudano sahelian savanna, Sudan savanna, Open Guinea savanna and protected Guinea savanna, *i.e.* the Dry guinea in the southern fringe and Sudan in the larger part of the region (Adamu *et al.,* 2014). The state is known for its commercial and industrial activities with the state ranking second largest industrial center in Nigeria and the largest in northern Nigeria. The state plays a significant role in tourism (Wikipedia, 2014).

Sampling procedures, size and data collection method : The data for the study was drawn from primary source with the aid of pre tested questionnaire coupled with interview schedule. The questionnaires were administered on 60 cotton famers selected through multistage sampling procedure. Kano state is divided into 3 agricultural zones, namely, Kano north, Kano south and Kano central. The first stage involved the purposive selection of one local government area from each of the 3 Agricultural zones in the state based on their lead in cotton production. The LGAs' are Gwarzo, Kiru and Gaida. Secondly, a sample frame of cotton outgrowers' was obtained from each of the selected local government area offices of KNARD. Thirdly, a scale/ ratio of 10 per cent was used to determine the proportionate respondents sample size for each of the selected LGAs'. Lastly, simple random technique was used to select equivalent of the proportional respondents sample size of from each LGAs', thus giving a total sample size of sixty (60) cotton farmers.

Analytical technique : Pseudo profit function and inferential statistics was used to analyze the data collected. Farm budgeting technique was used to achieve objective (I) and Cob Douglas stochastic production frontier function was used to achieve objective (II).

Model specification

1. Gross margin : Gross margin is the difference between the total value of production and the total variable cost. Gross margin analysis is used to study the performance of an enterprise. It is a very useful tool in a situation where fixed capital is a negligible portion of the farming enterprises as in the case of subsistence agriculture.

The empirical model is specified below

GM = GI – TVC

Where

GM = Gross margin

GFI = Gross farm income

TVC = Total variable cost

The Net farm income (NFI) was computed using the formula below:

NFI= GM –TFC

Where:

NFI = Net farm income

GM = Gross margin

TFC = Total fixed cost

2. The stochastic frontier production function : Following Erhabor and Ahmadu the model was specified as follows:

ln Yi = lnßo + Óßj lnXij + Vi – Ui .... (4)

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 ha); 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 = ä$_0$ + ä$_1$$Z_1$ + ä$_2$$Z_2$ + ……. + änZn …………… (5)

Where, Ui = technical inefficiency effect of the ith farm;
Z_1 = Age (years);
Z_2 = Educational level (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 availability (yes=1, otherwise=0); and,
Z_8 = Cooperative membership (yes=1, otherwise=0).
ä$_0$ = Intercept
ä$_{1-8}$ = variable vector parameters to be estimated.

The ß and ä coefficients are un-known parameters to be estimated along with the variance parameters ó^2 and ã. The ó^2, and ã, 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.

RESULTS AND DISCUSSION

Costs and return estimates in cotton production : The data in Table 1 showed the cost and returns estimates of cotton farmers in the study area. The revenue from cotton output/ha was found to be ₦58, 500. The total cost incurred/ha in cotton production was ₦43, 380, with labour costs having the highest percentage (31.7%) of the total cost of production. The total variable cost accounts for 75.5 per cent of the total cost, while fixed cost accounts for 24.5 per cent of the total cost. The enterprise recorded a gross margin of ₦ 22,700 and net farm income of ₦ 11, 120/ ha, respectively. Furthermore, the result revealed that returns on Naira invested by farmers in the study area was ₦ 0.63, meaning that a farmer gain 63 Kobo on every one naira invested in cotton production. This profit margin should attract financing from the lending institutions, because if cotton farmers is funded with ₦50, 000 at an interest rate of 8 per cent the farmer will return the principal of ₦50,000, interest of ₦4000 and retain ₦4500.0 as profit. This result clearly indicated that cotton production is a profitable venture and so farmers in the study area should be advised to venture into it, because it is a profitable enterprise. This finding is in conformity with the result of Alam *et al.*, (2013) who conducted a research on the economic analysis of cotton production in selected local government areas of Taraba state in Nigeria and came out with a similar result. The rate of return/capital invested (RORCI) is the ratio of profit to total cost of production. It indicates what is earned by the business capital outlay. The results revealed that the RORCI of 22 per cent is greater than the prevailing bank lending rate of 8 per cent, thus, indicating healthy business going concern.

Technical efficiency and associated inefficiency factors : Maximum likelihood estimates of the stochastic frontier production function and the inefficiency are presented in Table 2. 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 per cent. 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 per cent level. 1 per cent increase in fertilizer quantity will make output level to improve by a margin of 0.34 per cent. This finding conforms with the report by Adzawla *et al.*, (2013), 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 per cent level. This result is at variant with the findings of Adzawla *et al.*, (2013) 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 per cent, output level will improve by less than proportionate, by a margin of 0.55 per cent. This implies that there is still scope to increasing output per plot by expanding farmland. The coefficient of family labor was significant at 5 per cent 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 1per cent, output level will decrease by -0.03. This calls for creation

Table 1. Cost and returns analysis/ha

Items	Quantity/ha	Unit price(₦)	Cost (₦)	Total cost (%)
Expenditure (Debit)				
Variable Cost				
Cost labour	30 manday	500	15000	31.7
Cost of fertilizer	65kg	60	3900	8.2
Cost of seed	4kg	200	800	1.7
Cost of pesticides	2	900	1800	3.8
Cost of transportation	1300kg	5	6500	13.7
Cost of harvesting	1300kg	5	6500	13.7
Cost of bagging	1300kg	1	1300	2.7
Total variable cost			**35800**	**75.5**
Fixed cost				
Interest on loan payment (50000@8%)			4000	8.4
Rent on land			5000	10.6
Depreciation on capital equipment			2580	5.5
Total fixed cost			**12580**	**24.5**
Total cost			**47380**	
Income (credit)				
Revenue/Receipts from product sold	1300kg	45	58500	
Total income			**58500**	
Gross margin			**22700**	
Net farm income			**11120**	
Operating ratio			**0.61**	
Gross ratio			**0.81**	
Return on capital invested (RCI)			**0.63**	
Rate of return/unit of capital invested (RORCI)			**0.23**	

Source: Field survey, 2014

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 2, in the sense that technical inefficiency effects are of interest and have important implication. The sources of inefficiency were examined by using the estimate ä 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

Table 2. 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	$â_0$	5.293	0.43	12.33***
Family labour	$â_1$	-0.03	0.012	-2.5**
Hired labour	$â_2$	0.08	0.075	1.06^{NS}
Seeds	$â_3$	0.25	0.11	2.27**
Fertilizer	$â_4$	0.34	0.20	1.7*
Farm size	$â_5$	0.56	0.03	18.67***
Depreciation	$â_6$	0.62	0.59	1.05^{NS}
Inefficiency model				
Constant	$ä_0$	0.21	0.071	2.96***
Age (years)	$ä_1$	0.89	0.41	2.17**
Educational level	$ä_2$	-0.18	0.10	-1.8*
Household size (number)	$ä_3$	-0.32	0.021	-15.24***
Farming experience (years)	$ä_4$	-0.65	0.25	2.6**
Extension contact	$ä_5$	-0.09	0.02	-4.5***
Access to credit	$ä_6$	-0.83	0.11	7.56***
Readily market availability	$ä_7$	-0.73	0.40	-1.83*
Co-operative membership	$ä_8$	-0.08	0.021	—3.81***
Diagnostic statistic				
Sigma-square $ó^2 = ó^2v + ó^2u$		0.35	0.15	2.33**
Gamma $ã = ó^2u/ó^2v + ó^2u$		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

was estimated to be negative and is significant at 10 per cent. This indicates that farmers with formal education tend to be more technically efficient. This agrees with the findings of Amodu *et al.,* (2011); and Adzawla *et al.*, (2013). 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. 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 per cent, 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. 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 1per cent. 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. The coefficient of access to credit carried negative sign and was significant at 1per cent 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. Furthermore, coefficient of farming experience had the expected negative sign and was significant at 5 per cent. 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 Adzawla *et al.,* (2013). The coefficient of readily availability of market was significant at 10 per cent 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 per cent. 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. The variance parameters for ó^{2} and ã are 0.35 and 0.76, respectively, are significant at 5 and 10 per cent level, respectively. The sigma squared ó^{2} indicates the goodness of fit and correctness of the distributional form assumed for the composite error term while the gamma ã indicates that the systematic influences that are unexplained 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 per cent 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 â = 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÷^{2}cal value (82.02) is greater than ÷^{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.

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 3. 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 per cent 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 per cent scores (1– [0.63/1.00*100]) to be on the frontier. However, the most efficient farmer needs a technical efficiency score of 17 per cent (1– [0.83/1.00*100]) to be on the frontier, while the average farmer needs a technical efficiency score of 24.1 per cent (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 per cent (1– [0.25/0.83*100]) to attain the status of the most technical efficient farmer and 75 per cent technical efficiency score (1– [0.0.25/1.00*100]) to be on the frontier. The most frequently occurring efficiency score was 61 per cent. From the results obtained, although farmers were generally relatively efficient, they still have room to increase the efficiency in their farming activities since 37 per cent efficiency gap from the optimum (100%) remains yet to be attained by all farmers.

Table 3. Deciles frequency distribution of technical efficiencies

Efficiency level	Frequency	Relative efficiency (%)
d• 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
e” 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

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