





## PROFIT EFFICIENCY AMONG COTTON FARMERS: A COBB-DOUGLASS STOCHASTIC FRONTIER PRODUCTION FUNCTION ANALYSIS



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### ABSTRACT

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Based on Stochastic Frontier Profit Function that assumed Cobb-Douglass specification form, a multiple regression model was estimated using a cross-sectional data obtained from a sample of 349 cotton farmers by means of a multi-stage and simple random sampling techniques. Maximum likelihood estimates of the specified profit model explained that profit efficiency of the producers varied between 67.1% and 98.1% with mean 91.3% implying that an estimated 18.7% of the profit is lost due to a combination of technical and allocative inefficiencies in cotton farming production. In addition, results from the technical inefficiency model showed that age, education, farming experience, credit access, extension visit and marital status were significant factors influencing profit inefficiency, revealing that profit inefficiency in cotton production could be shortened significantly with improvement in the level of the aforementioned socio-economics characteristics of the sampled farmers. The overtone of these results is that, it would give more insight to policy makers for further improvements in productivity by given more emphasis to exploiting the technical efficiency 'gap' through adaptive research, farmer education and improved input supply.

**Contribution/ Originality:** Independence is the primary issue in Nigerian cotton production. To improve productivity, the best and effective way is to encourage the farmers to utilize their resources efficiently to achieve of higher yield in the end. This paper to study the production efficiency among cotton farmers in Nigeria, employing a stochastic profit Frontier and inefficiency model.

### 1. INTRODUCTION

Cotton farming remains by far the most important natural fiber as it represents 38 percent of the fiber market and is crucially important for income, raw materials and employment provided that its production and processing is adequate. According to Akpan [1] cotton was one of the main sources of foreign exchange and second largest employer of labor after public sector prior to the oil boom. Indeed, the contribution of the crop production sub-sector is one of the indicators of the roles played by agriculture. This is in terms of some cash crops particularly cocoa, cotton, groundnuts and some other staple food-crops contributing to the expansion of the economy of the country, Odedokun, et al. [2]. On the annual basis, the area under cotton cultivation is about 0.2-0.6 million

hectares, largely in the Savannah areas of the country. Production depends on various factors ranging from the vagaries of weather, cotton price, problems of the textile industries, etc. During 2005–2006, about 232,675 hectares were cultivated to produce about 300,000 tons of seed cotton or 110,000 tons of lint (about 607,735 bales of cotton lint). The prospect for 2007/2008 is about 400,000 tons of seed cotton from about 0.3million hectares. Production is mainly in three cotton zones: The Northern zone (60%); Eastern Zone (30%); and the Southern Zone (10%), respectively. Production is dominated by small-scale farmers, with farm sizes ranging from 1-5 hectares all under rainfed ecologies. Seed cotton yield ranges from 0.6 to 1.5 tons per hectare, Sani [3].

As one of the major cash crop, Cotton has played a key role in the economic and social development and remains still today a significant source of income for many agricultural farms in Nigeria. Cotton and textile activities are widespread in the country and its production has dates back to 1903 with the British Cotton Growers Association taking the lead until 1974, when it was disbanded and replaced by the Cotton Marketing Board to develop, gin and market the produce. Following the deregulation of the Nigerian economy in 1986, the Board has abolished vis-à-vis the economic activities rendered by it. The Cotton Consultative Committee (CCC) was set up in an advisory capacity to the public sector, while a cotton revolving fund scheme with a management Committee (CRFMC) was put in place to ensure the sustainable supply of certified cotton seed to farmers. In 2005, the Cotton Development Committee was established which subsumed both the CCC and the CRFMC, to address the cotton economy in a holistic manner, Audu [4].

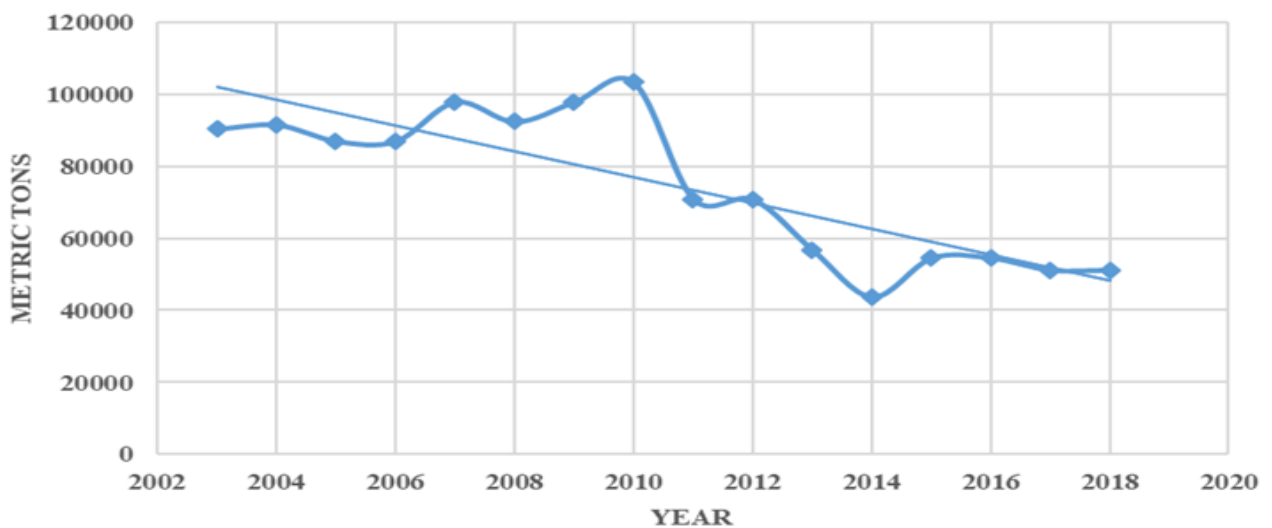


Figure-1. Cotton Production (000 metric tons) in Nigeria, 2001-2018

Source: FAOSTAT [5]

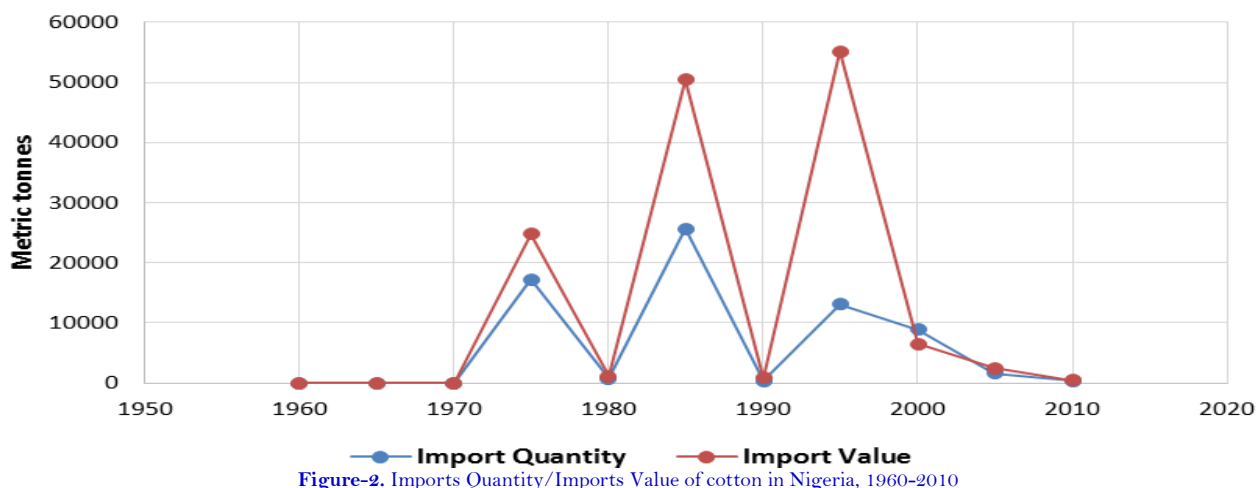
Table-1. Imports Quantity/Imports Value of cotton in Nigeria, 1960-2010

Year	Import Quantity	Import Value (\$1000)
1960	0	0
1965	0	0
1970	0	0
1975	17196	24739
1980	700	1115
1985	25608	50446
1990	336	857
1995	13070	55167
2000	8921	6506
2005	1586	2412
2010	318	446
<b>Total</b>	<b>67735</b>	<b>141688</b>

Source: FAOSTAT [5]

Although the cotton production in Nigeria has been in fluctuation right from independent to date, the fluctuation is marginal and fall within the domestic demand as the country still imports from the international market. However, there is a huge potential to increase production through an increase in area cultivated and the use of improved seedlings and agrochemicals, Karim and Perret [6].

History has shown that Nigerian imports quantity of cotton from 1960-1970 is zero (Table 1.4). From 1975-2010 importation of cotton has been increasing astronomically. This is as a result of a decrease in production that affected the balance of trade of the country, National Bureau of Statistics [7].



Source: FAOSTAT [5]

## 2. MATERIAL AND METHODS

### 2.1. Study Area

The study was conducted in the North-East Zone of Nigeria. The North East (NE) Geopolitical Zone of Nigeria covers close to one-third (280,419km<sup>2</sup>) of Nigeria's land area (909,890km<sup>2</sup>). It comprises 6 states: Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe. Three states (Adamawa, Gombe and Taraba State) were purposively selected for the study. In each state, concentration was given to areas where cotton production is a predominant occupation of the people in that area. In Adamawa state, the study was carry out in cotton growing areas of Numan, Yola south, Lamure, Demsa and Guyuk which constitute Zone three and four of the Adamawa state Agricultural Development Project, hence at least four privately owned ginneries are located within the cotton belt. The presence of these companies has intensified cotton production in the area. Most cotton out-growers are registered with these private ginneries.

Similarly, in Gombe state cotton growing belt, Gombe South and North, Akko, Billiri and Kaltungo are the areas that cotton is being cultivated. In Taraba state, as in other two states, the local governments that cotton are being cultivated are Lau, Gassol and Karim Lamido. As mentioned earlier, these areas are cotton producing areas, therefore, attention was given to them for the purpose of this study. Three hundred and sixty registered cotton out-growers were randomly selected from registered out-growers with the extension officer of the private ginneries in the cotton belt. According to projections for 2011 by the National Bureau of Statistics [7] these States have 13.5% (i.e. 23,558,674) of Nigeria's population which is put at 173,905,439 and has been a major contributor to national net food production, Abiayi, et al. [8].



Figure-3. Map of Nigeria, showing the study area in the northeast

Source: Abiayi, et al. [8]

## 2.2. Data Collection

Primary data was mainly used as the source of data for the study. The data were collected with the aid of structured questionnaire primarily quantitative input-output variables from a sample of 349 households. Information on socio-economic variables such as age, education, farming experience, extension contact, credit access, off farm activities were also collected from the respondents.

## 2.3. Sampling Techniques

The sampled States were Adamawa, Gombe and Taraba State. Adamawa state has twenty-two local governments and five were selected. Gombe State has eleven local governments and four were selected. the list of the cotton farmers was obtained from Afcott out-growers scheme.

A total of thirty-two local governments were selected at the first stage for the study through randomized sampling design out of sixteen local governments in the study area. At the final (second) stage a total of 165 cotton farmers was selected out of 2505 farmers in Adamawa state. While in Gombe State 102 cotton farmers was selected out of 1560, 93 cotton farmers were selected from Taraba State out of 1350 cotton farmers in the area. This gives the total of 360 sampled respondents out of 5465 cotton producers in the study area.

## 2.4. Data Analysis

A multiple regression model based on Stochastic Frontier Profit Function which assumed Cobb-Douglass model specification form and inefficiency function model was employed to determined profit efficiency and determinants of profit inefficiency of cotton farmers using a single stage maximum likelihood function estimation procedure of Frontier version 4.1 [9].

## 2.5. Theoretical Framework

Production inefficiency is usually analyzed by its two components: technical and allocative efficiency. Recent development combined both measures into single system, which enable more efficient estimates to be obtained by simultaneous estimation of the system, Wang, et al. [10]. The profit function approach combines the concepts of technical and allocative efficiency in the profit relationship and any errors in the production decision are assumed to be translated into lower profits or revenue for producer, Ali, et al. [11]. Profit efficiency, therefore, is defined as the

ability of the farm to achieve highest possible profit given the prices variable inputs and levels of fixed factors of that farm. Profit inefficiency in this context is defined as the loss of profit for not operating on the frontier Ali and John [12]. Battese and Coelli [13] extended the stochastic production function model by suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics.

The advantage of this model is that it allows the estimation of farm specific efficiency scores and the factors explaining the efficiency differentials among farmers in a single stage estimation procedure. Following Rahman, et al. [14] this study utilizes the Battese and Coelli [13] model by postulating a profit function, which assumed to behave in a manner consistent with the stochastic frontier concept. The stochastic Profit function is defined as:

$$\pi^* = \frac{\pi}{\rho} = h(q_i, z) \exp(v_i - u_i) \quad (1)$$

Where:  $\pi^*$  = normalized profit of i-th farmer;  $\frac{\pi}{\rho}$  = description of the normalized variable inputs; Z= vector of fixed input(s);  $\rho$  = output price used to normalize variables in the model;  $\pi$  = farmer's profit defined as total revenue minus total cost of production (here cotton revenue consists of return from the sales of cotton output; while total cost is made up of the cost of seed, fertilizer, agrochemicals and labour;  $\exp(v_i - u_i)$  = composite error term.

The profit/economic efficiency (EE) of an individual farmer in the context of stochastic frontier profit function is derived as a ratio of the predict, observed or actual profit ( $\pi_i$ ) to the corresponding predicted maximum ( $\pi_i^*$ ) for the best farm or frontier profit given the price of variable inputs and the level of fixed factor (s) of production of that farmer. Mathematically, it is expressed as following Sunday, et al. [15] as:

$$\text{Profit Efficiency} = \frac{\text{Actual Farm Profit}}{\text{Frontier Profit}} = \frac{\pi_i}{\pi_i^*} = \frac{(q_i z) \exp(v_i - u_i)}{(q_i z) \exp(v_i)} \quad (2)$$

Then,

$$\text{Profit Efficiency} = \frac{\exp(v_i - u_i)}{\exp(v_i)} = \exp(-u_i) \quad (3)$$

The stochastic disturbance term ( $e_i$ ) consists of two independent elements : "v" and "u". The symmetric two sided error term (v) account for random variation in profit attributed to the factors outside the farmer's control (random effects, measurement errors, omitted explanatory variables and statistical noise). The one-sided component (u) is a non-negative error term accounting for the inefficiency of the farm. Thus represents the profit shortfall from its maximum possible value that will be given by the stochastic profit frontier. However, when u= 0, it implies that farm profit lies on the efficiency frontier (i.e. 100% profit efficiency) and  $u < 0$  means that the farm profit lies below the efficiency frontier. Both v and u assumed to be independently and normally distributed with zero mean and constant variance.

## 2.6. Stochastic Profit Model Specification

A multiple regression model based on the stochastic frontier profit function which assumes Cobb-Douglass functional form was employed to determine the profit efficiency of cotton producers in the study area. The frontier model examined following Ifeanyi and Onyenweaku [16]; Nganga, et al. [17] and Sunday, et al. [15] was therefore specified as follows:

$$\ln \pi_i^* = \alpha_0 + \sum_{j=1}^4 \alpha_j \ln X_{ji}^* + \alpha_k \ln X_k + v_i - u_i \quad (4)$$

Where:

$\pi_i^*$  = normalized profit computed for i-th farmer

ln = Natural log

$X_1^*$  = price for seed (\$/Kg) normalized by price of cotton,

$X_2^*$  = price of fertilizer (\$/Kg) normalized by price of cotton,

$X_3^*$  = price of labour (\$/man-day) normalized by price of cotton,

$X_4^*$  = price of agrochemical (\$/lt) normalized by price of cotton,

$X_k^*$  = area of land cultivated (ha),

$\alpha_0, \alpha_1, \dots, \alpha_4$  and  $\alpha_k$  are parameters to be estimated,  $v_i$  represents statistical disturbance term and  $u_i$  represents profit inefficiency effects of i-th farmer.

### 2.7. Profit Inefficiency Function Specification

The determinant of profit inefficiency of profit inefficiency of cotton farmers in line with Ogunniyi [18] were modelled following specific characteristic of farmers in the study area. From equation (4) the  $u_i$  component is specified as follows:

$$\mu_i = \gamma_i + \sum_{r=1}^8 \gamma_r R_i + k \quad (5)$$

Where:

$\mu_i$  = Profit inefficiency of i-th farmer,  $\gamma_0$  and  $\gamma_r$  are parameters to be estimated,  $R_i$  = are variables explaining inefficiency effects,  $r = 1, 2, 3, \dots, n$ ,  $k$  is truncated random variable,  $R_1$  = farmer's age (year),  $R_2$  = Level of education (years),  $R_3$  = marital status (married=1, single=0),  $R_4$  = Household size (number),  $R_5$  = Credit usage (access=1, no access=0),  $R_6$  = Farming experience (year),  $R_7$  = access to extension contact (number),  $R_8$  = Off-farm activities (yes=1, others=0), were jointly estimated by maximizing the likelihood function using computer program Frontier version 4.1 [9].

## 3. EMPIRICAL RESULTS

### 3.1. Estimation Procedure

Maximum likelihood estimates of the parameters in the Cobb-Douglass and trans-log stochastic profit function were obtained using Frontier 4.1. The unknown parameters of the stochastic profit function and inefficiency were

estimated simultaneously. To select the lead functional form for the data, hypothesis test base on the generalized likelihood ratio test (LR) was conducted. The formular  $\lambda = -2 \{ \log [L (H_0) - \text{Log } L (H_a)] \}$  was used to carry out the likelihood ratio test. The first null hypothesis is the statement that Cobb-Douglas profit function is the best fit model for the data. Result indicated that it is fail to reject the first null hypothesis because Lambda ( $\lambda$ ) value ( -161.928) was less than critical value (14.853) at 5% level of significance, meaning that Cobb-Douglas form was the best functional form for the data (table 1). After having Cobb-Douglas profit functional form as the function that suit the data, it was applied to run another generalized likelihood ratio test for the second null hypothesis which states that profit inefficiency is absent.

**Table-2.** Generalized likelihood ratio test for stochastic profit model

Null Decision Hypothesis	Log likelihood of H <sub>0</sub>	Log likelihood of H <sub>a</sub>	Test statistic ( $\lambda$ )	Degree of freedom	Critical value (5%)	Decision
Cobb-Douglas is the best fit	-104.090	23.126	-161.928	8	14.853	Fail to Reject H <sub>0</sub>
No profit Inefficiency	291.945	299.646	15.402	8	14.853	Reject H <sub>0</sub>

Note: Taken from table of Kodde and Palm [19] using 5% levels of significance.

This means that there is no profit inefficiency function of cotton farms and the actual profit which is higher than the estimated profit is caused by uncontrollable factors. The LR test revealed that this second null hypothesis is rejected at 5% level of significance as test statistic value (15.402) is greater than the critical value (14.853).

**Table-3.** Maximum likelihood Estimates of Cobb-Douglas Stochastic Frontier Profit Function

Variable	Parameter	Coefficient	Std. Error	t- Value
Constant	$\alpha_0$	0.1114	0.7778	0.1437
Price of Seed	$\alpha_1$	-0.1012	0.3111	-0.3254
Price of Fertilizer	$\alpha_2$	0.9765	0.5927	0.1647
Price of Agrochemicals	$\alpha_3$	0.8508	0.50027	0.1692
Price of Labour	$\alpha_4$	-0.4692	0.2130	-0.2203
Land Area	$\alpha_5$	0.6218	0.4648	0.1347
Variance Parameters				
Sigma-Squared	$\delta^2$	0.3026	0.9364	0.3232
Gamma	$\gamma$	0.9987	0.6164	0.1620
Log-likelihood		-0.3119		

Source: Field Survey data, 2016.

Table 2 shows the ML estimates of normalized frontier profit function. The estimated value of gamma ( $\gamma$ ) is close to 1 and is significantly different from zero thus ascertaining the fact that a higher level of inefficiencies exists in cotton production. The estimated gamma parameter of 0.9333 is highly significant at 1% level of significance. This revealed that 93.33% of the variation in the actual profit from the maximum profit (frontier) among cotton farmers was mainly due to the differences in farmers' practices rather than random variability. The table indicates that the coefficients of the estimated parameters of the normalized profit function were positive except the price of labour.

This shows that a unit in the price of inputs with positive coefficients will lead to increase in the normalized profit realized from cotton production and vice-versa. Furthermore, the coefficient for price of fertilizer with positive value of 0.9765 was statistically significant at 10% level of significance and this was revealed to be the most

important variable determining the profit efficiency. The means that 10% increase in the price incurred through fertilizer purchase. The profit obtained from cotton production will increase by 97.65%. Oladeebo and Oluwaranti [20] reported similar results. The positively signed and significant coefficient of land (0.6218) at 1% level of significance indicates the fact that cotton farmers were operating at small scale level, therefore increasing their cultivated land area will improve profit other things being equal. Alternatively, a 10% increase in cultivated land area will lead to 6.218% increase in profit obtained from the production of cotton in the study area. A research conducted by Ifeanyi and Onyenweaku [16]; Kaka, et al. [21] and Sunday, et al. [15] reported comparable result.

A farm level profit also has negative relationship (-0.4692) with respect to the price of labour in the model. The result shows that continuous increase in the price incurred through labour purchase will lead to the reduction in farm level profit of cotton farmers in the study area. The result is consistent with the findings of Oladeebo and Oluwaranti [20]; Ogunniyi [18] and Kaka, et al. [21]. The analysis also showed that the sign and the significance of the estimated coefficient of price of agrochemicals (0.8508) have implications on the profit of cotton farmers. In the light of this, the model indicated that as the price increase through the purchase of agrochemicals the profit obtained by the farmers through the production of cotton will increased. This finding is also in conformity with result estimated by Oladeebo and Oluwaranti [20] and Kaka, et al. [21].

### 3.2. Profit Inefficiency Function

The frequently distribution of farm specific efficiency scores for the cotton producers is presented in Table 4. The estimates showed that considerable amount of profit is lost from the cotton production because of existence of profit inefficiency in resource use among cotton farmers in the study area. The findings revealed that cotton farmers achieved on the average 91.3% level of profit efficiency. Also, the had revealed profit inefficiency gap of about 8.7%. This implies that the average farmer in the study area could increase profit by 8.7% through their technical and allocative efficiency.

Table-4. Frequency Distribution of Profit efficiency

Efficiency score	Adamawa		Gombe		Taraba		Overall	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
1.00	0	0.00	0	0.00	0	0.00	0	0.00
> 0.90 < 1	94	56.97	60	59.41	68	81.94	222	63.61
>0.80≤ 0.90	51	30.91	31	30.69	13	15.66	95	27.22
> 0.70≤0.80	16	9.70	10	9.90	1	1.20	27	7.74
>0.60 ≤ 0.70	4	2.42	0	0.00	1	1.20	5	1.43
Total	165	100	101	100	83	100	349	100
Mean	0.882		0.910		0.937		0.913	
Minimum	0.663		0.737		0.692		0.676	
Maximum	0.979		0.999		0.990		0.981	
Std. Dev.	0.072		0.068		0.051		0.062	

Source: Author's computation from field Survey data

The cotton farmers exhibited varied profit efficiencies ranging from 67.6% to 94.8%. However, the least profit efficient cotton farmer needs an efficiency gain of 91.3%  $(1-0.676/0.981)100$  of production if such a farmer is to attain the profit efficiency of the best efficient farmer in the study area. Likewise, for an average profit efficient farmer, he will need an efficiency gain of 8.7%  $(1.0.913/0.981)100$  to attain the most efficient level of Production. Furthermore, the most profit efficient farmer in the study area needs about 0.019% gains in Profit efficiency to be on the frontier efficiency. However, despite the variation in efficiency, it could be seen that about 90.83% of cotton farmers seemed to be skewed towards efficiency level of greater than 70%. On State wise, Taraba is revealed on the average to be the most profit efficient (93.7%) with minimum, maximum and coefficient of variation in the profit of 69.2%, 99% and 5.1% respectively compared to Gombe with average profit efficiency level of 91%, minimum,



maximum and coefficient of variation of 73.7%, 99.9%, and 6.8% and Adamawa with average profit efficiency level of 88.2%, minimum, maximum and coefficient of variation of 66.3%, 97.9% and 7.2% respectively.

#### 4. CONCLUSIONS

Maximum likelihood estimates of the specified Cobb-Douglass stochastic profit function model show that farmer's profit efficiency has not reached the frontier level. The results indicate that cotton farmers profit efficiency could still be increased by 8.7% using the available technology to the farmers. Based on the magnitude of the profit efficiency estimates, the study has found age, education, marital status, credit access, experience and no farm activities as the major determinant of profit efficiency among cotton farmers. Finally, inefficiency in cotton production could be reduced significantly by improving the above mentioned socio-economics packages.

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## APPENDIX

### Frontier-4.1. Result of Cobb-Douglas Stochastic Frontier Profit Function and Profit Inefficiency effects

the final mle estimates are :

Parameter	coefficient	standard-error	t-ratio
beta 0	0.11144144E+02	0.77784509E+00	0.14326945E+02
beta 1	-0.10124499E+00	0.31109641E-01	-0.32544572E+01
beta 2	0.97646801E+00	0.59274576E-01	0.16473640E+02
beta 3	0.85083286E-01	0.50279253E-01	0.16922146E+01
beta 4	-0.46919186E-01	0.21297702E-01	-0.22030163E+01
beta 5	-0.62182166E+00	0.46148468E-01	-0.13474373E+02
delta 1	-0.85312941E-01	0.29927671E-01	-0.28506375E+01
delta 2	-0.77802531E-01	0.34956916E-01	-0.22256692E+01
delta 3	-0.20557643E-01	0.14887981E-01	-0.13808214E+01
delta 4	0.28445881E+00	0.32794195E+00	0.86740599E+00
delta 5	-0.13472563E+00	0.62118238E-01	-0.21688579E+01
delta 6	-0.15609614E+01	0.51672644E+00	-0.30208661E+01
delta 7	-0.78402836E+00	0.27455988E+00	-0.28555824E+01
delta 8	-0.74537909E+00	0.25430050E+00	-0.29310957E+01
sigma-squared	0.30259744E+01	0.93638660E+00	0.32315439E+01
gamma	0.99874298E+00	0.61635400E-03	0.16204048E+04
log likelihood function =	-0.31194946E+01		
LR test of the one-sided error =	0.20194007E+03		

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