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# Efficiency and economics in cotton production of Bangladesh

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**Abstract:** Bangladesh is one of the most prominent and promising garments producing and exporting country in the world. At present it uses approximately 6 million bales cotton for its textile and garments industry. But cotton production is much lower than the volume required in the textile and garments industries. The inadequate production of cotton results in poor backward linkage to the ever-flourishing garments sector coupled with high import bill payment. The present study was conducted to determine the technical, allocative, and cost efficiencies of cotton farmers in Bangladesh. Data envelopment analysis was used to determine efficiencies while tobit regression was applied to determine factors affecting efficiencies. Mean CRS TE was 83.6% while VRS TE was estimated at 89.1%. Allocative, cost and scale efficiencies were 78.1%, 69.7% and 93.9% respectively. Seventy five percent cotton farms exhibited increasing returns to scale while only 10 percent and 14 percent respectively displayed evidence of decreasing and constant returns to scale. Experience, number of working adult person, access to credit, extension service and size of cotton cultivated land were the significant factors determining technical efficiencies.

*Keywords: Efficiency, Economics, DEA, Tobit regression, cotton, Bangladesh*

## Introduction

Cotton (*Gossypium sp.*) is the second largest cash crop in Bangladesh followed by jute. The most important source of earning foreign currency is exporting of textile and garments products. Raw cotton is the main raw material of textile industry to produce fabric yarn and textile. Cotton is grown in around 42 thousand hectares of land with a yearly production of nearly 0.15 million bales which is only 3 percent of the total quantity demanded by the textile and garments industries of Bangladesh. About 97% of the total requirements are managed by importing raw cotton from Uzbekistan, India, Pakistan, Turkmenistan and some cotton growing Sub-Saharan (African) countries (Uddin and Mortuza, 2015). It is thus obvious that Bangladesh needs an all out effort to expand the cotton production very rapidly. Devoid of hindering the food crop production in main areas, production of cotton can be raised by extending cotton cultivation in non-conventional areas like tobacco cultivated lands, drought affected non-productive areas as well as in hilly, saline, and char areas.

The United States Department of Agriculture remarked that because of declining cotton cultivation in China who is the top most cotton producer in the world, global cotton production will get down by 5% in every year. They also added that it will reduce approximately 113 million bales in the year of 2015-16. Consumption of cotton in Bangladesh is increasing enormously day by day as more spinning mills are being set up to meet up the ever-growing demand for yarn from rapidly flourishing domestic weaving and knitting industries. Bangladesh Textile Mills Association (BTMA) indicated that, now-a-days the country imports approximately $2 billion worth of cotton every year.

Gul *et al.* (2009) estimated mean technical efficiency at 79% for the cotton farmers in Turkey. Compared to that, Bangladeshi cotton farmers are more technically efficient as the mean technical efficiency is 89.1%. Binici *et al.* (2006) estimated the same (89%) level of technical efficiency in Turkey.

In spite of having high level of technical efficiency, the production of cotton is very insignificant compared to the quantity demanded by textile & garments industries of Bangladesh. As research on cotton production is quite inadequate in Bangladesh, it is reasonably difficult to identify the factors that affect the cotton production in this country. Nevertheless, the authors have tried to determine several grounds for inadequate production of cotton in Bangladesh. One of the main reasons behind inadequate production of cotton is the lack of sufficient initiatives by the government to introduce cotton as an important as well as a profitable cash crop to the farmers. The farmers producing other cash crops are not acquainted with the cotton production techniques, the market demand, marketing or supply chain and its profitability. For this reason, being risk averse, farmers go for growing conventional cash crops like jute, sugarcane and even pernicious stuff, tobacco. Climate, temperature, formation of land and natural calamities are other reasons of inadequate cotton production. Arable lands throughout the country are not suitable for cotton production as it requires a specific type of land and temperature.

Moreover, cotton production is highly sensitive to climate and natural calamities. Cotton is planted in July when huge rainfall and high temperature prevail in Bangladesh. It is surely detrimental to cotton cultivation. On the other hand, cotton is harvested in December when very cool and dry weather with very low temperature prevails in our country which is also a barrier to get good harvest of cotton. Cotton grows sound in temperate and moist climate where summer is extensive with temperature of 24°C. But in July, August & September temperature exists almost above 30°C in Bangladesh which is detrimental for cotton production. Heavy rainfall occurs during those months ranging from 119.4 cm to 344.5 cm which is also injurious as 60-100 cm rainfall is indispensable for cotton growing. Notwithstanding, the area under present production is far below the quantity of lands suitable for cotton cultivation. Therefore, horizontal expansion of cotton area seems to be very difficult in Bangladesh in the short run. Thus, the immediate option is to increase technical efficiency of the cotton producers, and then in the long-run, researchers may go for developing cotton varieties suitable for Bangladesh climatic condition.

This study aims at determining technical efficiency (TE) of cotton producers of Bangladesh by involving data envelopment analysis (DEA), and is expected to answer the extent of possible production enhancement by improving TE. DEA has been very popular to study efficiency in crop and non-crop sectors. For example, Amir Ashkan Mahjoor (2013) applied DEA to estimate allocative efficiency in Iran and Majid Karimzadeh (2012) applied the same technique to estimate technical efficiencies in the banking sector of India. Chavas and Aliber (1993) estimated economic efficiency of agriculture in Wisconsin using a non-parametric approach showing that the small farms experienced economies of scale to some extent whereas larger farms suffer from diseconomies of scale in agricultural sector. Sharma, Leunga and Zaleskib (1999) estimated different efficiencies of swine production in Hawaii using both parametric and non-parametric approach and made a comparison between those two approaches.

Cotton is a unique agricultural product which may become one of the most important impact factors for the socioeconomic betterment of Bangladesh. If the production of cotton can be increased domestically to exploit the entire quantity demanded by the garment sector, it will end with 60-70% instead of currently about 30% domestic value addition resulting in a double jump in net export income from garments products. Moreover, since cotton production is a very labor intensive activity, the unemployment scenario of the country may be relaxed with the expansion of cotton production. The forward linkage industries of cotton are spinning, textile & garments industries which are heavily labor intensive and they are the employers of large number of semi-skilled and unskilled workers. As greater portion of total labor force in our country belong to this group, the expansion of cotton production may become very helpful to alleviate poverty dramatically through reducing unemployed population by engaging them in both production and utilization process of cotton. Furthermore, it will help to reduce import of raw cotton for textile industry which will ultimately improve the balance of payment situation of the country.

Investigation on technical efficiencies of cotton production has never been made earlier in Bangladesh, although there exists a good number of studies on TE, allocative efficiency (AE) and economic efficiencies (EE) or cost efficiency (CE) on crops like rice, wheat, maize, fish etc. Thus, conducting a study on TE of the cotton farmers in Bangladesh appears to be very timely. Secondly, the study is expected to not only add value to the existing literature on economic efficiency but also highlight specific recommendation for the farmers and decision makers so that the farmers can either produce the current level with minimum cost or produce more with the present cost structure which will help reducing import from foreign market.

The rest of the paper is organized into four sections. Methodology section provides the materials and methods and includes a DEA framework for estimating technical, allocative, and cost efficiencies and the tobit model to determine factors affecting TE, AE and CE. Data and variable section presents the data sources and variables. Results and discussion section discusses the results. Finally, last section concludes the study drawing some policy implications.

## Methodology

In general efficiency is measured using either parametric or nonparametric methods. Fare, Grosskopf and Lovell (1985, 1994) discussed the methods of efficiency measurement which is based upon the effort of Farrell (1957); Afriat (1972); Charnes, Cooper and Rhodes (1978) and others. Battese (1992) provided some parametric methods which include deterministic frontier production functions, stochastic frontier methods, and panel data models. On the other hand, Data Envelopment Analysis (DEA) is a nonparametric method which is widely used in efficiency measurement studies.

### *DEA Framework*

In this research DEA was used for estimating efficiency in cotton farming. A wide-ranging introduction to DEA methods is provided in Coelli, Rao and Battese (1998). DEA as used in this study is basically a linear programming technique where the existence of manifold inputs and outputs makes comparisons complicated.

### *Technical Efficiency (TE)*

TE tells the degree to which a farm produces the maximum feasible output from a given bundle of inputs, or uses the minimum possible amount of inputs to produce a specified level of output. These two meanings of TE lead to what are recognized as output oriented and input-oriented efficiency measures correspondingly. These two measures of TE will produce similar results when the technology shows evidence of constant returns to scale (CRS), but are likely to be at variance or else. Input-oriented efficiency measure is used in this study for the reason that they show the way a natural decomposition of CE into its technical and allocative components.

The input-oriented DEA model used for calculation of technical efficiency Coelli, T.J. (1996) is:

$\text{Min}_{\theta\lambda}\theta,$

Subject to

$$-q_i + Q\lambda \geq 0$$

$$\theta r_i - R\lambda \geq 0 \qquad (1)$$

$$N1'\lambda = 1$$

$$\lambda \geq 0,$$

where θ is a scalar and subscript i stands for the i-th farm, N1 is an N×1 vector of constant and N1'λ is a convexity constraint. The acquired value of θ is the technical efficiency score for the i-th farm where the TE score having a value varying from 0 to 1; λ is an N×1 vector of constants (weights) that delineates the linear combination of the peers of the i-th farm; Q is a vector of output quantities and R is a vector of observed inputs. A score of 1 entails that the farm is on the frontier and it is fully efficient.

The first constraint of the above DEA model (1) is with respect to the output (cotton). The term $-q_i$ of the left-hand side of the limit is the vector of observed cotton output of the ith farmer compared with the cotton output vector of the hypothetically efficient farmer (Qλ) i.e., output suggested by the DEA model times weight. If the observed output is equal to model suggested output times weight, the efficiency score turns to be 1. The sum of the constraint value is equal to zero or greater than zero (positive) but can't be negative. Coelli, Rao and Battese (2003) provides detail information on efficiency and productivity measurement.

The second constraint in the above DEA model is concerned with the input. The term Rλ signifies the minimum quantity of input that the hypothetically efficient farm used, particularly for producing the actual level of output by the ith farm. Very clearly the term Rλ implies the minimum amount of input (R) required producing the same level of output which is provided by the model times weight (λ). Left-hand side of the second limit shows that the term $\theta r_i$ characterizes the actual level of inputs used by the i-th farm multiplied by the level of efficiency (θ). The farm uses as possible as small quantity of input for producing the same level of output when the clarification of the programming trouble turns out to be θ equal to 1. If the sum of the second constraint is equal to zero, the efficiency score turns to be 1 which indicates full efficiency of the i-th farm. On the other hand, if the value is greater than zero, the efficiency score appears to be less than 1 which indicates inefficiency of the i-th farm. If the clarification of the trouble turns out to be θ is less than 1, then the level of input utilized by that particular farm can be supplementary reduced to as low as Rλ to turn out the equal level of output. In this situation, technical inefficiency exists for that particular farm.

*Allocative Efficiency and Cost Efficiency*

The cost and allocative efficiencies are acquired by solving the following supplementary cost minimization DEA problem Coelli, T.J. (1996)
Min $\lambda, r_i^* \; w_i' r_i^*$,
Subject to

$$-q_i + Q\lambda \geq 0$$

$$r_i^* - R\lambda \geq 0,$$

$$N1'\lambda = 1,$$

$$\lambda \geq 0$$

where, $w_i$ is a vector of input prices for the i-th farm and $q_i^*$ (which is designed by the model) is the cost-minimizing vector of input quantities for the i-th farm, specified the input prices $w_i$ and the output levels $q_i$. Now we can calculate the total cost efficiency (CE) of the i-th farm as

$$CE = \frac{w_i' q_i^*}{w_i' q_i}$$

So as to, CE is the comparative amount of minimum cost to observed cost designed for the i-th farm. Thereafter the allocative efficiency (AE) is measured residually by

$$AE = \frac{CE}{TE}$$

*Scale Efficiency (SE)*

The above models are concerned with variable returns to scale (VRS) DEA which allows the constructed production frontier to have (local) increasing, constant or decreasing returns to scale properties. By removing the convexity constraint ($N1'\lambda=1$), one can enforce constant returns to scale (CRS) upon the DEA problem in equation (1). This allows estimating the scale efficiency (SE) measure. SE, calculated by carrying out both a CRS and a VRS DEA, can be decomposed into two components, one due to scale inefficiency and one due to 'pure' technical inefficiencies. SE can be calculated as Coelli, T.J. (1996) :

$$SE = \frac{TE_i CRS}{TE_i VRS}$$

where SE close to 1 implies SE operate at CRS and SE<1 indicates scale inefficiency which operate at VRS.

*Tobit regression explaining determinants of efficiency*

After attaining efficiency scores from DEA approach, the variation in efficiency scores have been regressed on the targeted farmers' characteristics using a Tobit regression, in order to assess the impact of different socio-economic variables. Coelli*et al.* (2002) used the DEA approach and Tobit regression for estimating efficiency scores and factors affecting efficiencies in Bangladeshi rice farmers. Similarly, Tobit regression was used by other researchers as well: Brázdik (2006) in rice farms of Indonesia, Tolga Tipi et. al (2009) in rice farms of Turkey, Shao and Lin (2002) in Information technology, Gul (2009) in cotton farms of Pakistan, and Tingley et al (2014) in English Channel fisheries. A Tobit model is suitable for estimating factors affecting efficiencies of the targeted samples as the efficiency scores vary from zero to unity by setting upper limit at one.

The Tobit regression gets the following form:

$$EFF=\beta_0 + \beta_1 EXP + \beta_2 EDU + \beta_3 TRANG + \beta_4 CRE\ AC+ \beta_5 TEN + \beta_6 WA + \beta_7 AGE + \beta_8 EXT\ SER + \beta_9 NON\text{-}INC + \beta_{10} LC + e$$

where EFF are the efficiency scores (ranging from 0 to 1) of the farms obtained from the DEA, EXP is the cotton production experience of the farmer measured in years, EDU is the level of education of cotton farmers measured in years of schooling, TRANG is the training dummy (training = 1, otherwise = 0), CRE AC is the credit access dummy (credit access = 1, otherwise = 0), TEN in the land tenure dummy ( land ownership = 1, otherwise = 0), WA is the number of working adult persons of the cotton farmers' family, AGE is the age of the cotton farmer measured in years, EXT SER is the extension service dummy ( extension service received = 1, otherwise = 0), NON-INC is the non farm income of the cotton farmers measured in USD and LC is the cultivated land measured in decimal.

STATA is used to estimate the Tobit regression and SPSS has also been used to find out correlation between different variables.

## Data and variables

For carrying out the targeted research, primary data were collected from cotton farmers of a northern district of Bangladesh, Lalmonirhat through a farm level survey. Lalmonirhat is one of the important cotton growing districts in Bangladesh. A random sampling technique was employed in the current study for selecting the targeted respondents. The above district was selected for the study because of existence of relatively better cotton production condition. The study was conducted in four villages of two upazilas (lower stratum of the administrative district) of that district during July to August 2014. A total of 49 farm households from these four villages were selected from the list of cotton producers collected from the office of Cotton Development Board situated in Lalmonirhat.

Here, data includes mainly the quantity of input and output and their related prices. Output is measured in kilogram while in case of inputs different measurement units are used for different variables like seed, family and hired labour, insecticides, organic and inorganic fertilizer. The aforementioned variables are the foremost inputs employed in cotton production in the context of Bangladesh. The supplementary variables that could be considered like irrigation and cultivable land of cotton were not included for a variety of reasons. Irrigation was not integrated because only the value of that variable was provided by the respondents. Land used for cotton cultivation was not included as it was quite difficult to measure the value of land for a crop season.

The authors also tried to make clear the differences among efficiency levels of the targeted farms using farm specific variables viz, familiarity with cotton farming, credit access of cotton producers, age of household head, functioning adults in the respondents' household, year of schooling of the cotton growers, total land cultivated, land tenure among cotton farms, the share of non-agricultural income, frequency of contacts with extension service and the agricultural training of household head.

Coelli (1996) built up software named as DEAP version 2.1 which was applied to find out DEA efficiency scores. The targeted efficiency scores were calculated using both CRS and VRS assumptions, whereas Tobit regression model was employed for determining causes of inefficiencies.

## Results and discussion

### *Summary descriptive statistics*

Table 1 illustrates the summary statistics of output, input and other farm specific variables. The table shows that the farms are quite small with an average size of 83.53 decimals (0.34 hectare). The mean output (yield) is 2239.47 kg per hectare while the maximum and minimum yields are 2975.227 and 1580.800 kg per hectare respectively. The average seed requirement per hectare is 16.19 kg ranging from 11.227 to 23.952. Besides, average use of some organic and inorganic fertilizers like urea, triple super phosphate (TSP), muriate of potash (MP), and zipsum is also made to the extent of 1046.05 kg per hectare ranging from 823.333 to 1321.450 kg per hectare. In terms of price of input variables, the prices of all inputs are almost similar throughout the season**.**

The above Table 1 also provides the summary of farm-specific variables which are the socio-economic characteristics of the cotton growers. Average levels of education and age were 7 years of schooling and 43 years respectively. Twenty two percent of income comes from off-farm sources. About 65% of farms are tenant; 94% farmers did get contact of extension officers throughout the past year; about 49% did have credit access for cotton production; and 78% did receive training during the past fifteen years for production of cotton.

*Table1 - Summary statistics of different inputs and factors in cotton production*

| VARIABLES<br>OUTPUT AND INPUTS | MEAN | STANDARD DEVIATION | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| Cotton output (kg/ha) | 2239.47 | 303.366 | 1580.800 | 2975.227 |
| Cotton seed (kg/ha) | 16.19 | 2.25 | 11.227 | 23.952 |
| Organic fertilizer (kg/ha) | 7124.80 | 2438.204 | 3742.424 | 18712.12 |
| Inorganic fertilizer (kg/ha) | 1046.05 | 93.123 | 823.333 | 1321.450 |
| Insecticides (mg/ha) | 3622.00 | 1187.921 | 411.667 | 6175.000 |
| Labour (no/ha) | 137.30 | 17.348 | 93.561 | 172.152 |
| Seed price (US$/kg)* | 0.25 | 0.000 | 0.25 | 0.25 |
| Organic fertilizer price (US$/kg)* | 0.007525 | 0.000628 | 0.00625 | 0.008375 |
| Inorganic fertilizer price (US$/kg)* | 0.185125 | 0.005463 | 0.159375 | 0.1875 |
| Insecticides price (US$/mg)* | 0.051213 | 0.001115 | 0.046875 | 0.053125 |
| Labour price (US$/no)* | 1.8775 | 0.082638 | 1.75 | 2.125 |
| Farm specific variables | | | | |
| Experience in cotton production (years) | 6.350 | 3.376 | 1.000 | 15.000 |
| Distance from market (km) | 3.755 | 4.135 | .500 | 15.000 |
| Age of cotton farmers | 42.690 | 9.478 | 25.000 | 62.000 |
| Education level (year of schooling) | 6.84 | 4.313 | 0.000 | 15.000 |
| Training receipt** | .78.0 | .422 | 0.000 | 1.000 |
| Extension service** | .940 | .242 | 0.000 | 1.000 |
| Cultivable land (decimal) | 83.530 | 37.618 | 27.000 | 198.000 |
| Tenancy** | 0.653 | 0.354 | 0.000 | 1.000 |
| Credit access** | 0.489 | 0.503 | 0.000 | 1.000 |
| Off-farm income (share of total income) | 0.221 | 0.205 | 0.000 | 0.600 |
| Working adult | 1.776 | 0.985 | 1.000 | 4.000 |

* *US$ 1 equalled approximately Bangladesh Taka 80.00 in the year of 2015*

***Dummy: 1 = farmers having training/extension service/credit access, 0 = otherwise*

## Costs, returns and profitability

Table 2 presents per hectare cost and returns of cotton farming. The total variable cost accounts for almost 72 percent whereas the fixed cost encompasses about 28%. Labour cost comprises 28.60% of the total cost of cotton production which is the most important cost in cotton production. The cost and returns analysis designates that the cost of organic and inorganic fertilizer, labour, insecticides and seed accounted for respectively 5.91%, 23.08%, 28.60%, 11.56% and 0.46% of the total variable cost of production. The total cost of production per hectare is US$ 901.49 while the total revenue is US$ 2239.47. Alam *et al.* (2013) in Nigeria found that the total variable 5% cost per hectare of cotton production constituted 95% while fixed cost comprises just

*Table 2 - Per hectare cost and return analysis of cotton farming*

| INPUT ITEMS | QUANTITY USED | PRICE (IN US$) | COST (US$/ha) | % OF TOTAL COST |
|---|---|---|---|---|
| (A) Variable cost | | | | |
| 1. Human labour | 137.30man-day | 1.8775man-day$^{-}$ | 257.8635 | 28.60 |
| 2. Seed | 16.18996 kg | 0.25 kg$^{-1}$ | 4.130125 | 0.46 |
| 3. Compost | 7124.803 kg | 0.0075 kg$^{-1}$ | 53.2665 | 5.91 |
| 4. Inorganic fertilizer | | | | |
| a) Urea | 221.2031 kg | 0.198 kg$^{-1}$ | 43.79513 | 4.86 |
| b) TSP | 296.6639 kg | 0.273 kg$^{-1}$ | 80.81338 | 8.96 |
| c) MP | 385.9962 kg | 0.186 kg$^{-1}$ | 71.064 | 7.88 |
| d) Zipsum | 142.1844 kg | 0.08375 kg$^{-1}$ | 12.4205 | 1.38 |
| 5. Insecticides | | | | |
| a) insecticides 1 | 420.7329 gm | 0.08075 gm$^{-1}$ | 34.15388 | 3.79 |
| b) insecticides 2 | 3201.273 ml | 0.0215 ml$^{-1}$ | 70.02788 | 7.77 |
| Others | | | 22.45688 | 2.49 |
| *Total variable cost (TVC)* | | | 649.9918 | 72.10 |
| (B) Fixed cost | | | | |
| a) Interest on operating capital | | | 24.37475 | 2.70 |
| b) Land use cost | | | 227.1281 | 25.19 |
| *Total fixed cost(TFC)* | | | 251.5029 | 27.90 |
| *Total cost TC(TVC+TFC)* | | | 901.4946 | 100.00 |
| *Returns* | | | | |
| Gross income (US$ha$^{-1}$) | 2239.472kg | 1 kg$^{-1}$ | 2239.47 | |
| Gross margin(US$ha$^{-1}$)= GI- TVC | | | 1589.478 | |
| Net farm income(US$ha$^{-1}$)=GI-TC | | | 1337.975 | |
| Net returns to land | | | 1110.847 | |
| Net returns to labour | | | 1080.112 | |
| Break-even price per kg | | | 0.402625 | |
| Production Efficiency= GI/TC | | | 2.48 | |
| Percent Profit | | | 148.42 | |
| Operating ratio(TVC/GI) | | | 0.29 | |
| Gross ratio(TC/GI) | | | 0.41 | |
| Price received by farmers per kg | | | 1.00 | |
| Break even yield (kgha$^{-1}$) | | | 901.49 | |
| Actual yield (kgha$^{-1}$) | | | 2239.47 | |

Note: US$ 1 equalled approximately Bangladesh Taka 80.00 in the year of 2015, 247 decimals equal to 1 hectare . Interest on operating capital has been calculated @ 7.5% for 6 month period. Break even yield (kgha$^{-1}$) is total cost divided by average price received. Actual yield (kgha$^{-1}$) is gross income divided by average price received

5% of the total cost where labor cost has the uppermost percentage (21%) of the total cost of production. Thus, in this study labor cost appears to be the single highest cost among other variable and fixed costs and this result is similar to the findings of other studies.

It is found that cotton production is profitable as indicated by the average net income per hectare is US$ 1337.97, and gross margin is projected at US$ 1589.478. In addition, net returns to land and labour were US$ 1110.847 and US$ 1080.112 respectively. With the per hectare production achieved, the break-even price stands at US$ 0.403 $kg^{-1}$, whereas the actual farm gate price received by the producers is US$ 1.00 $kg^{-1}$ . The breakeven yield came out to be approximately 901 kg $ha^{-1}$ but their actual yield is more than double that of the break-even level. The gross ratio of 0.41 along with the operating ratio of 0.29 gives a picture that cotton production in the study area is cost-effective. Additionally, the production efficiency index (2.48) per farmer designates that returns go above cost by just about 148% which adjudged the effectiveness of the enterprise in the study area. This result is consistent with the findings of Ogaji (2010), who confirmed that the superior the profitability of the farm enterprise, the minor the gross and operating ratios and vice versa. Given the degree of these ratios, it can be decided that cotton production at farm level is a cost-effective project in the study region.

**Technical, allocative, cost and scale efficiency estimates**

A measure of technical efficiency under CRS assumption is known as a measure overall technical efficiency (OTE, equivalent to CRS TE). The OTE measures represent combined inefficiency due to both VRS TIE (also known as pure technical inefficiency, PTIEs) and inefficiency that is due to inappropriate cotton farm size i.e., scale inefficiency (SIE). However, in contrast to OTE measure, the pure technical efficiency (PTE) measure derived under assumption of VRS devoid the scale effects. Thus, the PTIE scores indicates that all the inefficiencies directly result from managerial inefficiency in organizing the cotton producing inputs without scale efficiency Thus, PTE measure has been used as an index to capture managerial performance. The ratio of OTE to PTE provides SE measure.

The OTE measures indicate that it contains 11% managerial inefficiency and 6% scale inefficiency. The mean VRS (PTE) score for cotton production was 0.891 indicates that the cotton production inefficiency to the extent of about 11% is entirely due to managerial inefficiency. The allocative efficiency score was 0.781 indicating that about 22% reduction of cost could be saved yet by producing the same level of input. The VRS TE implies that farmers could maintain the existing level of cotton production by using 11% less inputs. Thus the farmers/managers need to be very judicious in allocating input quantities in their production. The mean cost efficiency (AE times TE) score is 0.697.

The mean scale efficiency (SE) score is 0.939. The measure of SE provides the ability of the management to choose the optimum size of resources. Inappropriate size of a farm (too large or too small) may sometimes be a cause of technical inefficiency. This is referred as scale inefficiency and takes two forms: decreasing returns-to scale (DRS) and increasing returns-to-scale (IRS). Decreasing returns-to-scale (also known as diseconomies of scale) operation was noticed for 10% cotton farms implying that these farms are too large to take full advantage of scale and has supra-optimum scale size. In contrast, farms experiencing increasing returns-to-scale (also known as economies of scale) constituted 76% of the cotton farms who appear to be too small for its scale of operations and, thus, operates at sub-optimum scale size. About 14% farms are found to be scale efficient as they operated at constant returns-to-scale (CRS). In this particular case, some 6% sale inefficiency exists.

Frequency distribution of farms according to levels of efficiency and major communicative statistics of technical, allocative, cost and scale efficiencies are reported in Table 3. Agricultural crop sector follows law of variable proportions which is dissimilar with industry. For that reason an input-oriented model is run because the input weight is the key alarming factor of the farmers as buying material inputs is constrained due to financial insolvencies of many small farmers. The justification for using a VRS input-oriented model to determine efficiencies thus appears appropriate. Gul et al (2009) also made use of an input-oriented VRS DEA model to estimate efficiency of cotton farmers of Turkey.

From table 3 it was also observed that the highest percentage (about 52%) of VRS TE farmers operate within 0.91 to 1 efficiency level while 45% allocatively efficient farmers fall under 0.71 to 0.80 efficient level. For cost efficiency, only 18% operate at the same range of efficiency level. About 43% cost efficient farms fall within 61-70% efficiency level.

The results indicate that in case of technical efficiency, most cotton growers of Lalmonirhat became the users of sophisticated technologies as 25 out of 49 farmers

*Table 3 - Frequency distribution of Technical, Scale, Allocative, Cost Efficiency*

| Efficiency Level(%) | $TE_{CRS}$ | | $TE\ V_{RS}$ | | SE | | AE | | CE | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of farms | % of total farms | No. of farms | % of total farms | No. of farms | % of total farms | No. of farms | % of total farms | No. of farms | % of total farms |
| 0.51≤.60 | 1 | 2.040 | 1 | 2.041 | 0 | 0 | 1 | 2.041 | 10 | 20.408 |
| 0.61≤.70 | 6 | 12.244 | 3 | 6.122 | 2 | 4.08 | 10 | 20.408 | 21 | 42.857 |
| 0.71≤.80 | 9 | 18.367 | 4 | 8.163 | 2 | 4.08 | 22 | 44.898 | 9 | 18.367 |
| 0.81≤.90 | 21 | 42.857 | 16 | 32.653 | 3 | 6.12 | 10 | 20.408 | 4 | 8.163 |
| 0.91≤1.0 | 12 | 24.489 | 25 | 51.020 | 42 | 85.71 | 6 | 12.245 | 5 | 10.204 |
| Mean | 0.836 | | 0.891 | | 0.939 | | 0.781 | | 0.697 | |
| Std. dev | 0.111 | | 0.104 | | 0.076 | | 0.101 | | 0.129 | |
| Minimum | 0.532 | | 0.560 | | 0.653 | | 0.608 | | 0.521 | |
| Maximum | 1.000 | | 1.000 | | 1.000 | | 1.000 | | 1.000 | |
| IRS(%) | | | | | 75.51 | | | | | |
| DRS(%) | | | | | 10.20 | | | | | |
| CRS(%) | | | | | 14.29 | | | | | |

(51.02%) fall in the group of achieving 91% to 100% efficiency level. Next 16 farmers appears to be in the group of securing 81% to 90% efficiency level which is 32.65 % of total sample. Thus, 83.67% (a total of 41 out of 49) farmers in the present sample have technical efficiency level of at least 81% which is a very significant finding of this study.

While the sample shows a significant level of technical efficiency, at the same time it was showing a comparative inclination in case of allocative efficiency among cotton growers. Compared to 83.67% (a total of 25 out 49) farmers in case of technical efficiency, here only 12.25% (6 out of 49) farmers are at the highest (91%-100%) level of allocative efficiency followed by 20.41% at the level 80 to 90% efficiency. The highest 44.90% (22 out of 49) cotton farmers were observed to have allocative efficiency at the level of 71 to 80% who are neither very efficient nor can be treated as inefficient. The rest of the 11 farmers are of efficiency level of below 70%. Thus, the median sample has the allocative efficiency level of around 75%.

The most depressing outcome was observed in the event of cost efficiency compared to technical or allocative efficiency in the study. Mahjoor (2013) found the same results for boiler farming where about 88% farms were technically efficient and approximately 72 and 6% farms were allocative and cost efficient respectively. Among the sample of 49% cotton growers only 10.20% appeared to be as cost efficient at 91 to 100% level of efficiency whereas 10 farmers have fallen in the 51 to 60% efficiency level. In brief, it can be noticed from the result that, 40 cotton growers (63.26%) are lagging behind with comparatively lower level of cost efficiency (below 80%), on the contrary only 9 growers belongs to the higher level efficiency group, i.e., 91 to 100%. The whole situation/ observation depicts the scenario that our sample is at large less efficient in terms of cost efficiency. It indicates that there exists huge scope of reducing the costs of production of cotton at farm level without reducing existing output.

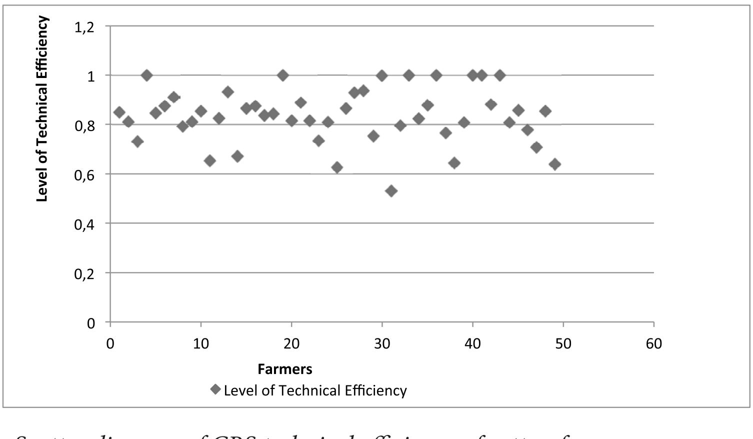


*Figure 1 - Scatter diagram of CRS technical efficiency of cotton farmers*

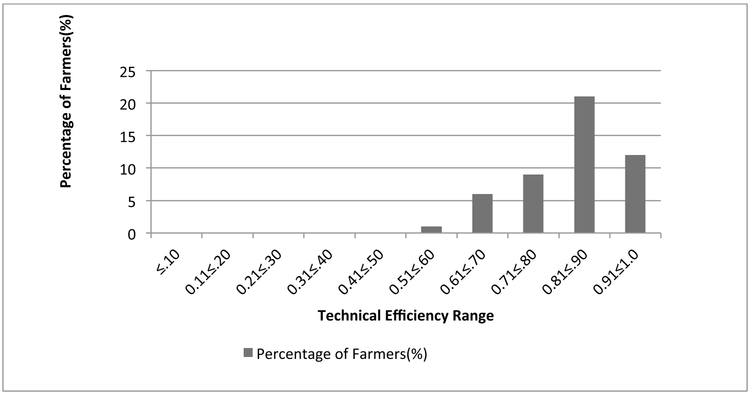


*Figure 2 - Distribution of CRS technical efficiency of cotton farmers*

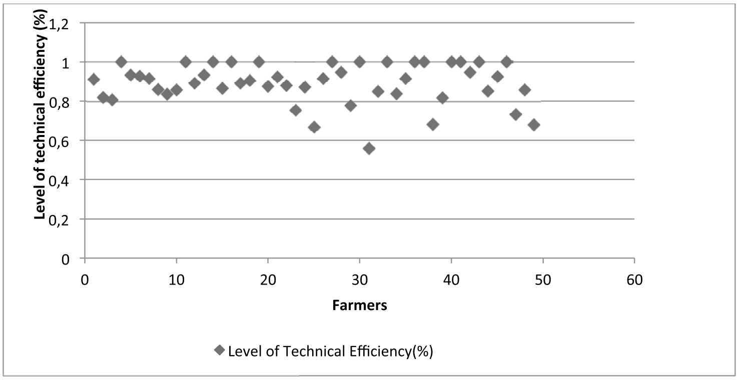


*Figure 3 - Scatter diagram of VRS technical efficiency of cotton farmers*

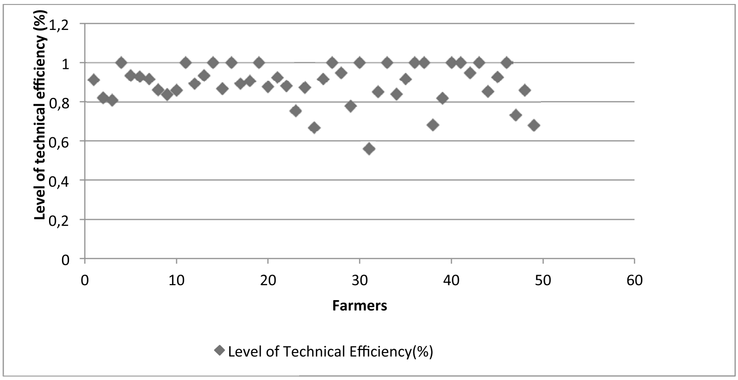


*Figure 4 - Distribution of VRS technical efficiency of cotton farmers*

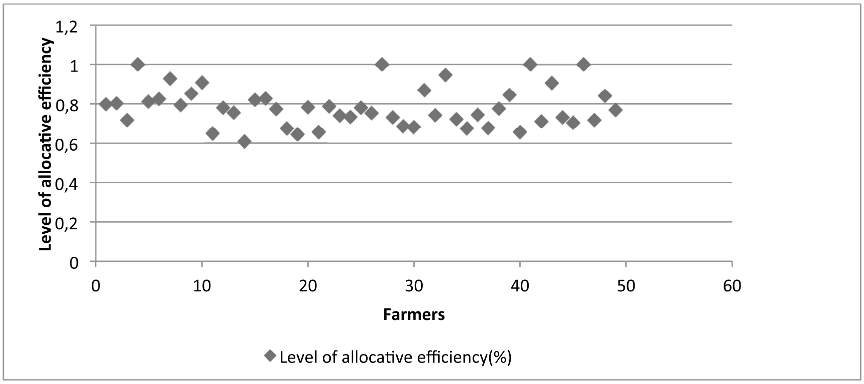


*Figure 5 - Scatter diagram of allocative efficiency of cotton farmers*

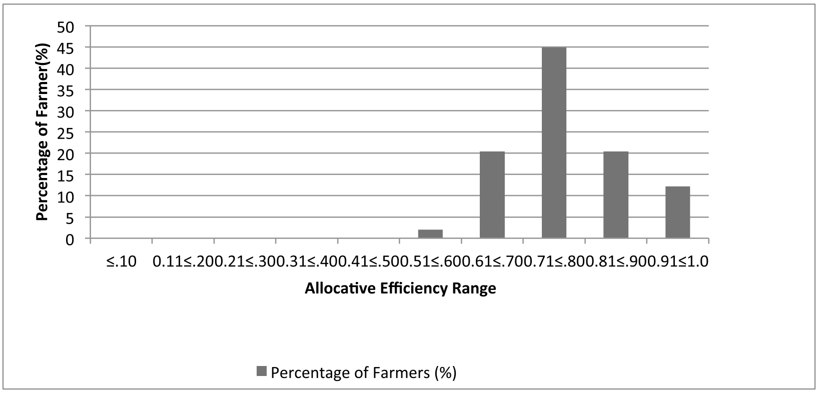


*Figure 6 - Distribution of allocative efficiency of cotton farmers*

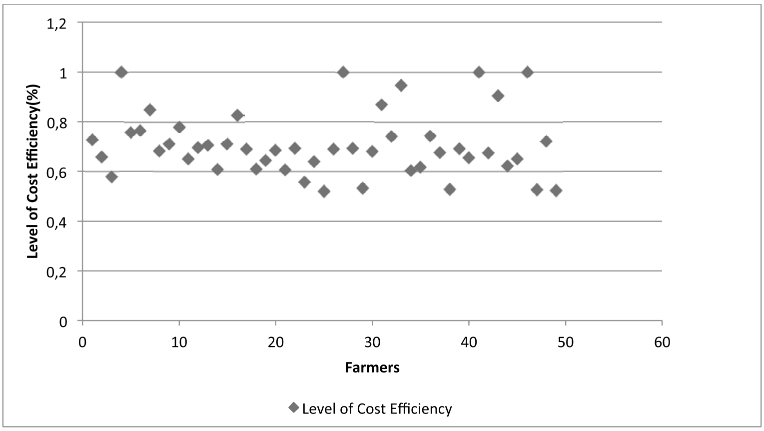


*Figure 7 - Scatter diagram cost efficiency of cotton farmers*

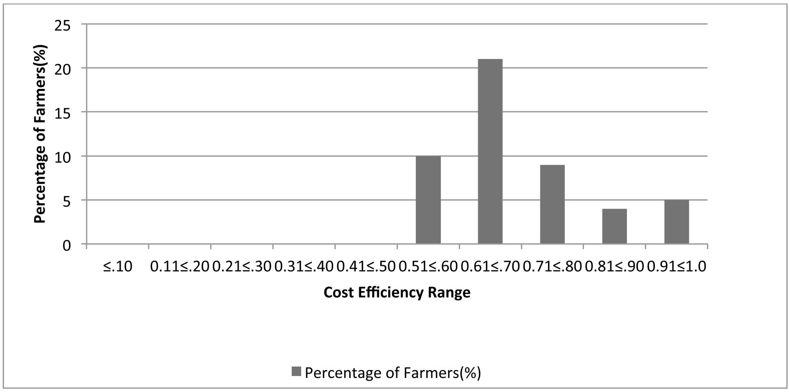


*Figure 8 - Distribution of cost efficiency of cotton farmers*

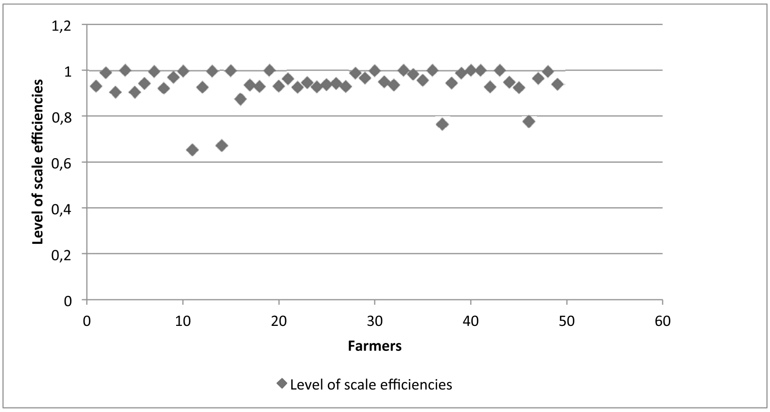


*Figure 9 - Scatter diagram of scale efficiency of cotton farmers*

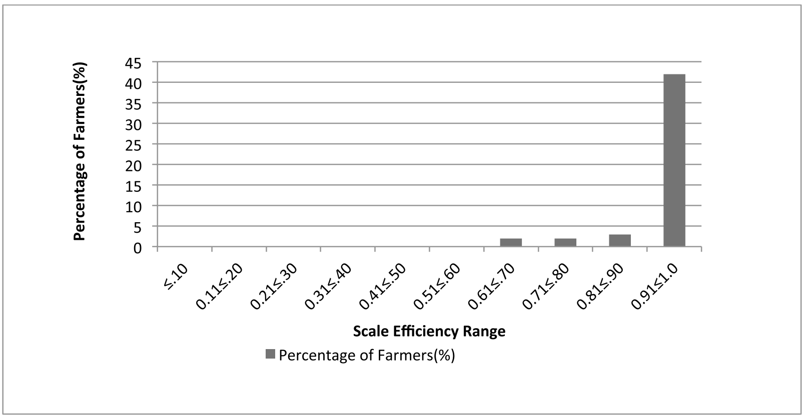


*Figure 10 - Distribution of scale efficiency of cotton farmers*

The above figures also reveal the scatter diagram and distribution of different efficiencies according to the percentage of farms. The distribution of all efficiencies is twisted to the right which is quite clear from the above figure. This has happened basically for two reasons: (i) that 50% of the farms run within right tail, and (ii) no farms run below 50% efficiency level. The distribution of scale efficiency is more skewed towards right compared to other efficiencies which shows that about 86 percent farms have scale efficiency in the distribution level of 0.91 to 1. Furthermore, Table 3 lists the percentages of farms with IRR (increasing returns to scale), constant returns to scale (CRS) and decreasing returns to scale (DRS) constituted 75.51%, 14.29% and 10.20% respectively. The IRR operating farms are too small to be scale efficient and thus operate at sub optimal levels. They are scale inefficient. This implies that there is very limited scope for economics of scale.

**Relationship between efficiency and farm size**

Table 4 shows that mean technical, allocative and cost efficiencies for all farm sizes are 87.3%, 83.8% and 75.1% while scale efficiency is found to be 93.6%.

The table reveals that 78% of the total cotton farmers cultivated less than 1.00 acre of cotton land. Farm sizes do not appear to be positively correlated with the VRS TE, but they are significantly positively correlated with the SE, AE and CE indicating that as the cotton cultivated area increase SE, AE and CE increases. However, the correlation coefficient indicates that small farms are more efficient. The mean SE is quite high (0.936), which points out that farm size plays much less vital role relative to the amount of technical and allocative inefficiencies. It is only the lower most farm sizes that have somewhat lesser SE (0.814), and farm size matters most for these clusters is imperative as some opportunities of economies of scale be present for them.

*Table 4 - Distribution of farms and mean efficiencies according to farm size*

| Size of farms (decimal) | Mean efficiency scores | | | | | |
|---|---|---|---|---|---|---|
| | No. of farmers | % of Farms | TE (VRS) | SE | AE | CE |
| ≤33 | 5 | 10.20 | 1.000 | 0.814 | 0.830 | 0.692 |
| 34≤66 | 22 | 44.90 | 0.736 | 0.932 | 0.736 | 0.681 |
| 67≤99 | 11 | 22.45 | 0.760 | 0.964 | 0.760 | 0.617 |
| k100≤132 | 6 | 12.24 | 0.889 | 0.996 | 0.889 | 0.822 |
| 133≤165 | 4 | 8.16 | 0.853 | 0.978 | 0.810 | 0.691 |
| 166 & above | 1 | 2.04 | 1.000 | 0.930 | 1.000 | 1.000 |
| All farm size | 49 | 100 | 0.873 | 0.936 | 0.838 | 0.751 |
| Correlation | | | -0.159 | 0.439 | 0.343 | 0.158 |

## Factors affecting efficiencies

Table 5 demonstrates the marginal effect of the explanatory variables used to explain factors affecting efficiencies (outcome of tobit regression are presented in appendix table 2). Different types of efficiency estimates such as technical, allocative, and cost resulting from the DEA model were regressed on socioeconomic variables that explain difference in efficiency across farm households using Tobit regression model.

Table 5 shows that access to credit is a significant variable in determining TE, AE and CE among the cotton producers in Bangladesh. The positive and significant impact of credit in this study entails that credit availability enables the respondents to make judiciously use of inputs that they cannot make available using their own capital. Furthermore, farmers with credit access were more technically and economically efficient than farmers who had no access to credit. This finding is consistent with the result of Dolisca and Curtis (2008). This is also true for AE.

The impact of working adult on technical, allocative and economic efficiencies had a significant and positive sign, as anticipated that working adult is a key factor to influence the level of efficiency in the production of cotton. That is to say, farmers having more working adult family members are more efficient. As cotton is a labour intensive crop, larger families having more working adults played a major role for ascertaining higher production.

*Table 5 - Estimates Marginal Effect after Tobit regression*

| Variables | TECRS | TEVRS | AE | CE |
|---|---|---|---|---|
| | Marginal effect | Marginal effect | Marginal effect | Marginal effect |
| Experience | .0035 | .0085*** | .0050 | .0112** |
| Education | -.0024 | -.0024 | .0040 | -.0011 |
| Training | .0257 | .0006 | .0029 | .0100 |
| Credit access* | .0741*** | .0383** | .0425** | .0876*** |
| Tenancy* | .0145 | -.0020 | .0028 | .0229 |
| Working adult | .0303** | .0420*** | .0563*** | .0663*** |
| Age | -.0017 | .0012 | -.0001 | .0013 |
| Extension service* | .0847** | .1152*** | -.0209 | .0292 |
| Non-farm income | .0744 | -.0231 | -.0014 | -.0351 |
| Land cultivated | -.0000 | -.0013*** | .0003 | -.0006* |

(*) dy/dx is for discrete change of dummy variable from 0 to 1

*** significant at 1 percent level ($p<0.01$)

** significant at 5 percent level ($p<0.05$)

*significant at 10 percent level ($p<0.10$)

Surprisingly, the consequence of training was not found significant for any type of efficiencies. It may be the fact that training provided to the cotton growers might not have been effective or adequate to make any contribution in the efficiency achievement. The positive and significant impact of Extension Services is as expected one. The Extension Services provided by govt., semi govt. and non-govt. agencies came to be very effective for attaining efficiency. Age and education could not explain the variation in TE, AE and CE indicating that age is not an important factor (neither opportunity nor barrier) for achieving TE, AE or CE in the event of cotton farming. Likewise, education also seemed to have no significant impact upon increase or decrease in efficiency level because experiences and extension services play more important role than education in cotton farming. Mekonnen*et al.* (2015) found similar outcomes. Like age and education, tenancy status and off-farm income of cotton farmers showed insignificant impact as well. Technical efficiency (VRS) and cost efficiency is influenced positively by farm size. In the same way cost efficiency increases with the parallel increase in the lands cultivated. Experience influences TE very positively. This result is consistent with the result obtained by Adeoti (2004) and Areerat *et al.* (2012).

## Conclusions and policy implications

The Garments Industry is singly the largest sector from where Bangladesh acquires almost 80% of its export earnings. Unfortunately, value addition in this industry is still below 30% as more than 90% of the key raw materials, cotton & yarn are still being imported. So, mass initiatives of increasing domestic production of cotton should be taken gradually to facilitate the existing and to-be-established spinning mills for supporting the textile industry in order to facilitate the garments industry.

The results of this study indicate that the mean technical, allocative, scale and cost efficiencies are about 89%, 78%, 94% and 70% respectively which can be treated as significant level of efficiencies. The degree of marginal effects of the factors also support the reality that appropriate supervision practices such as using more efficient irrigation systems, specific type of seeds, timely use of pesticides along with taking initiatives to control environmental effect and more government involvement will significantly increase the efficiency of cotton production resulting in more efficient grouping of inputs by lowering input costs. To expedite the expansion of cotton acreage, govt. should provide some kind of incentive so that the farmers take the crop favourably in their acreage portfolio.

**Abbreviation:**
AE = Allocative Efficiency
BTMA = Bangladesh Textile Mills Association
CE = Cost Efficiency

CRS = Constant Returns to Scale
CDB = Cotton Development Board
DRS = Decreasing Returns-to Scale
DEA = Data Envelopment Analysis
EE = Economic Efficiency
IRS = Increasing Returns-to-Scale
MP = Muriate of Potash
OTE = Overall Technical Efficiency
PTIEs = Pure Technical Inefficiency,
PTE = Pure Technical Efficiency
SIE = Scale Inefficiency
TSP = Triple Super Phosphate
US$ = US Dollar
VRS = Variable Returns to Scale

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## Appendix

*Table 1 - Measurement techniques of the output, input and explanatory variables used to measure technical efficiency and factors affecting efficiencies*

| VARIABLES | MEASUREMENT /DEFINITION |
|---|---|
| OUTPUT | Kilograms of cotton harvested |
| INPUTS: THE INPUT VARIABLES ARE DEFINED AS FOLLOWS: | |
| Seed | Quantity of seed (kg) used |
| Labor | Sum of both family and hired labour (person-days) used. |
| Inorganic fertiliser | Sum of fertiliser (kg) of all four kinds (Urea, Triple Super Phosphate, Muriate of Potash and Zipsum) practiced to the cotton production. |
| Organic fertilizer | Quantity of cow dung in kg used in cotton production |
| Pesticide | Quantity of pesticides in mg/ml used in the crop practice |
| Seed price | Price of seed (Taka/kg) used for cotton cultivation |
| Fertilizer price | Weighted average of the prices of organic fertilizer (Taka/kg) and four types of inorganic fertilizer (Taka/kg). |
| Wage | Wage (Taka/day) paid to agricultural labour (imputed for family supplied labour). |
| FARM-SPECIFIC VARIABLES: | |
| Experience | Years of farming experience |
| Working adults | Number of working family members in the farm household. This variable, and the one above, are used to pick up possible disguised unemployment |
| Education | Years of schooling completed by the household head |
| Land cultivated | Total area of land cultivated by the farm household |
| Tenancy | Dummy variable for tenure status. The value is 1 if the farmer is an owner operator, and 0 otherwise. |
| Non-agriculture income share | Proportion of total household income obtained from off-farm sources |
| Extension contact | Dummy variable to measure the influence of agricultural extension on efficiency. Value is 1 if the farmer has had contact with an Agricultural Extension Officer in the past year, and 0 otherwise |
| Training | Dummy variable to measure the influence of agricultural training on efficiency. Value is 1 if the farmer had any training on agriculture in the past seven years, and 0 otherwise. |
| Credit access | Dummy: 1 = farmers with access to formal credit facilities, 0 = otherwise |

*Table 2 - Determinants of efficiencies among cotton farmers by tobit regression*

| Variables | $TE_{CRS}$ | | $TE_{VRS}$ | | AE | | CE | |
|---|---|---|---|---|---|---|---|---|
| | Coefficient | t-ratio | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value |
| kConstant | .6884 | 7.80*** | .6776 | 7.50*** | .5928 | 7.87*** | .4396 | 5.41*** |
| Experience | .0041 | 0.83 | .0139 | 2.85*** | .0051 | 1.25 | .0112 | 2.53** |
| Education | -.0029 | -0.87 | -.0039 | -1.20 | .0041 | 1.49 | -.0011 | -0.37 |
| Training | .0302 | 0.90 | .0009 | 0.03 | .0029 | 0.10 | .0100 | 0.33 |
| Credit access | .0881 | 3.32*** | .0629 | 2.28** | .0432 | 1.96** | .0879 | 3.67*** |
| Tenancy | .0169 | 0.45 | -.0032 | -0.08 | .0028 | 0.09 | .0229 | 0.68 |
| Working adult | .0356 | 2.20** | .0687 | 2.88*** | .0571 | 4.26*** | .0664 | 4.52*** |
| Age | -.0020 | -1.35 | .0020 | 1.26 | -.0000 | -0.07 | .0013 | 0.90 |
| Extension service | .0928 | 2.09** | .1481 | 3.39*** | -.0213 | -0.57 | .0293 | 0.72 |
| Non-farm income | .0874 | 1.14 | -.0377 | -0.47 | -.0014 | -0.02 | -.0352 | -0.52 |
| Land cultivated | -.0000 | -0.12 | -.0021 | -3.93*** | .0003 | 1.05 | -.0006 | -1.69* |
| Log-likelihood | 37.747 | | 30.702 | | 50.527 | | 46.695 | |

*** = significant at 1 percent level (p<0.01), ** = significant at 5 percent level (p<0.05),
* = significant at 10 percent level (p<0.10)