Research Article

Comparative Analysis of Bt and Non-Bt Cotton Farmers Technical Efficiency of Core Cotton Zone in Punjab Pakistan

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Abstract | In agrarian economies, agriculture considers a major source of population feeding, employing and coactive partner of industrial growth. The purpose of the study was to analyze technical efficiency of Bt and Non-Bt cotton farmers in two core cotton districts Muzaffargarh and Rahim Yar Khan of Punjab, Pakistan. In this study, the stochastic frontier approach was employed for empirical analysis and multiple stages random sampling technique used for data collection of 400 Bt and Non-Bt cotton farmers for the year of 2012-13. The results of the study have indicated Bt cotton farmers of both districts with higher technical efficiency score as more efficient than Non-Bt cotton farmer. Empirical findings specified a cropped area, seed, labor, fertilizer and irrigation were the significant variable of increasing cotton production of Bt farmers while pesticides, irrigation and extension services more significant in increasing the Non-Bt cotton farmers production. Age of farmers, educational status, credit access and agriculture extension services access have significantly and positively impacted while the shortage of irrigation negatively impacts in both districts Non-Bt and Bt cotton farmers technical efficiency. There is need of proper policy measure for overcome market imperfections regarding prices of cotton output and inputs and provision of adequate formal credit to use advance mechanization to increase cultivated area and rising productivity of the cotton crop. Application of adequate advanced technology and familiarity of expertise in farming practices can overcome inefficiencies in both districts with cultivating varieties of Bt and Non-Bt cottonseed.

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Introduction

No poverty, zero hunger and good health for the well-being in the lives of peoples are some significant goals out of seventeen Sustainable Development Goals (SDGs) of United Nation General Assembly Resolution 70/1 as declared unanimously by all countries of the world on September 25, 2015, (United Nation, 2015). In the current global scenario, almost 700 million peoples with a major share of rural inhabitants extremely poor while 800 million chronically hungry (Food and Agriculture Organization (FAO, 2017). Depletion of soil, scarcity of water resources and emission of green gases are massive deforestations due to traditional resource-intensive farming and high inputs as indicated the major constraints in rising agricultural production and sustainable food security (FAO, 2017). In 2050, the projected world population is 9.73 billion and more than double agricultural production need to increase to meet the demand of estimated population specifically in South Asia (United Nations, 2015; FAO, 2017). Infusion of research base innovative technical and mechanical advances specifically in agriculture inputs and resources is the feasible source for potential growth in agriculture as directly and indirectly associated the wellbeing specifically developing countries inhabitants due to the major source of their livelihood for nutrition and employment (FAO, 2018).

In Pakistan, agriculture plays a prominent role in employing 42.3% labor force and sharing 18.9% in Gross Domestic Product (GDP) of the country (GOP, 2018). This sector provides the food basket to population nutrition needs, raw material to local industry and earns foreign exchange from agricultural exports through various sub-sectors crops, livestock, forestry and fishing Pakistan Bureau of Statistics (PBS, 2018). Cotton is a major cash crop of Pakistan contributing 1% in GDP of the country and sharing 5.5% in value addition of the agriculture (PBS, 2018). Pakistan is 4th major cotton producing with the share of 3rd cotton consuming country of the world and sharing 7.1% of cotton production and 9.2% of cotton consumption of the world Pakistan Central Cotton Committee (PCCC, 2018). Punjab the foremost cotton producing province with the production of 3349.44 (000, Tonnes) and sharing 65.39% of total country cotton production (Agriculture Statistics of Pakistan, 2017). Southern Punjab has formally known the cotton zone of Punjab, a major cotton producing area, sharing almost 94% of total provincial cotton production (Government of Punjab, 2017). Millions of farmer's employment and livelihood are interlinked with cotton cultivation, (PARC, 2013). During a couple of decades, the sequential decline in cotton production was estimated as compared to historical bulk cotton production of 14.62 million bales in 2004-05 due to some significant market imperfections, climatic changes, stormy rains with intensive floods and severe pest attacks (Agriculture Statistics of Pakistan, 2017).

Familiarize advanced mechanization, improved managerial capabilities and more specific use of advanced and economical Bt cottonseeds rather than traditional cotton varieties of Non-Bt seeds are some significant and feasible measures for rising cotton crop production in developing economize like Pakistan. Quality based and preserved side effects Bt cotton seed under the State regulation is prerequisite for overcoming market imperfections as fake Bt seed and other farming economic losses (Bakhsh et al., 2016). It was estimated, almost half millions of cotton farmers used fake seeds and it cost Rs 19 billion rupees, (GOP, 2008). In agriculture, farm efficiency has a significant role in farm production measurement (Hazarika and Subramanian, 1999). In developing agrarian countries, economic stability considerably influenced major crops forecasting regarding cultivation, production and yield, (Ahmad et al., 2017). A limited research work specifically focused cotton crop technical efficiency and productivity about developing and developed countries as Fatima et al. (2016); Helmers and Weiss (2000); Javed et al. (2009) and Woosink and Denaux (2006). Managerial competencies regarding familiarity and application of technical advances and optimal utilization of on-hand resources are prerequisite for potential output, Ahmed et al. (2018). Farming expertise regarding farm intercultural activities have a significant effect on farming productivity Ahmad and Afzal (2018).

In Pakistan, the literature of cotton crop mostly focused on technical efficiency while a limited research work has justified specifically the aspect of Bt and Non-Bt cotton crop. The economic aspect of inputs use (pesticides, fertilizer) and comparing the analysis of Bt and Non-Bt various varieties of cottonseed cultivation of cotton crop mostly focused in studies (Bakhsh et al., 2016; Veettil et al., 2016; Qiao et al., 2016). According to the best knowledge of author only the study of Fatima et al. (2016) focused technical efficiency of cotton production with comparing Bt and Non-Bt cotton farmers in core cotton crop area district Rahim Yar Khan of Punjab province. There is no study as addressed the comparison among core cotton areas technical efficiency of cotton production in Bt and Non-Bt cotton crop cultivation. In finding out this research gap the main objective of this study is a comparative analysis of Bt and Non-Bt cotton farmers technical efficiency in two core cotton producing districts of Rahim Yar Khan and Muzaffargarh in southern Punjab of Pakistan.

Materials and Methods

In this study, among major crops cotton crop is focused due to some global and national significance as the 4th major cotton-producing country of the world with a share of 7.1% of global cotton production (PCCC, 2018). In national level cotton crops sharing 1% of GDP and contributing 5.5% value addition of agriculture and the major source of providing raw material to the local textile industry and employing millions of farmers (GOP, 2018). Multistage simple random sampling approach used for collecting the data of Non-Bt and Bt cotton farmers in this study. In the selection of study area, some significant reason was focused firstly, Punjab province was selected for the study due to contributing 53% of agricultural GDP and producing 65% cotton of the country (GOP, 2017). Secondly, Southern Punjab region was selected in Punjab province the reason for producing 94% cotton of the province (GOP, 2017). Thirdly, Muzaffargarh and Rahim Yar Khan districts were selected for the reason of core cotton producing areas and contributing a significant share of cotton production of southern Punjab region (Government of Punjab, 2017). Two tehsils were randomly selected from each district in the fourth stage of the sampling procedure. In the fifth stage, one union council from each tehsil was randomly selected and two villages from each union council were selected in the sixth stage. In the last, each twenty-five Non-BT and BT cotton farmers from each village were randomly selected. The study consists of the total sample size of 400 Non-Bt and Bt cotton farmers from both districts.

The efficiency measurement ideology was significantly associated with the masterwork of Farrell (1957) indicated technical efficiency as producing capability on frontier isoquant while technical inefficiency as producing divergence from isoquant. Bravo-Ureata and Rieger (1991) represented the perceptions of applied literature as efficiency has valid and substantial consequence regarding resources saving. In literature about empirical work, efficiency is normally estimated with non-parametric and parametric approaches. Empirical estimates regarding find out the finest firms in total population sample non-parametric approach has frequently applied Data Envelopment Analysis (DEA) while technical efficiency score has no outcome variation regarding firm's marginal addition in DEA approach.

In operational function of DEA about empirical estimation could coexist with assumption if data set has zero random shocks while in agricultural farming considerably influenced by natural variation so Stochastic Frontier Analysis (SFA) was significantly control of natural stochastic as proposed for efficiency measurement (Aigner et al., 1977; Coelli, 1995; Ezeh, 2004). The stochastic frontier approach was employed in the study for efficiency measurement with the aim of significantly deal with inefficiency factors effects and stochastic noise effects. Translog specifications and Cobb-Douglas production model mostly used in estimations of stochastic frontier models while due to ease to handle, homogeneity estimation returns to scale and elasticity of coefficients Cobb-Douglas production function preferably applied rather to other approaches (Coelli et al., 1998). In Translog estimation, functional forms of large sample size prerequisite while such limit does not exist in the procedure of Cobb-Douglas production function estimation (Xu and Jeffrey, 1998). In literature parametric approach was mostly used for empirical estimation of agriculture as in the studies of Fatima et al. (2016); Croppenstedt (2005); Basnayake and Gunartne (2002); Hassan (2004); Ahmad and Afzal (2012). In this study, Stochastic Frontier approach employed for empirical estimation as primarily familiarized by Meeusen and Broeck (1977) and Aigner et al. (1977) as Equation (1) indicate Stochastic Frontier approach.

$$Y_i = [\ f(X_i, \beta) e_i\ ] \quad \ldots..(1)$$

The stochastic and deterministic fractions of production frontier indicated Equation (1) with inputs combinations as X_i and output with the sign of Y as the composed error term e_i and estimated parameters of vectors were as indicated with sign β.

$$e_i = f(V_i - U_i) \quad \ldots..(2)$$

In Equation (2) e_i is indicated as composed error term with the combination of V_i and U_i. The normally distributed and symmetrically error term as V_i which is commonly identically distributed and independently error term $N(0, \sigma^2_V)$ as exogenous variables which are confined and not in the farmers' access. When there is $U_i \geq 0$ indicating as random error term non-negative identically and independently distributed $N(0, \sigma^2_u)$ denotes to confine output shortfall due to production frontier.

$$TE = \frac{exp(xi\beta + V_i - U_i)}{exp(xi + V_i)} \quad \ldots.(3)$$

The notion TE indicates technical efficiency as the estimated level of observed output dividing the maximum possible output with specified inputs level as indicated in the Equation (3).

The region of southern Punjab is formally known cotton zone of Punjab province districts Muzaffargarh and Rahim Yar Khan located in this core cotton areas where Non-Bt and Bt cottonseed varieties are generally used for cotton crop. In this study for the empirical estimation, Cobb-Douglas production function was used for each cottonseed variety and district. In Equation (4) Rahim Yar Khan district Non-Bt cottonseed variety production function as given.

$$\log Y_i = \phi_0 + \phi_1 \log(x_{1i}) + \phi_2 \log(x_{2i}) + \phi_3 \log(x_{3i}) + \phi_4 \log(x_{4i}) + \phi_5 \log(x_{5i}) + \phi_6 \log(x_{6i}) + \phi_7 \log(x_{7i}) + U_i \quad \ldots..(4)$$

In the above equation Y_i indicates Non-Bt cotton production of ith farms and ith farm inputs vectors X_i as X_{1i}, X_{2i}, ……X_{7i}. Cropped area of cotton and cottonseed are signified with X_1 andX_2. The notion of X_3 indicates fertilizer usage and X_4 pesticides used in the crop. The X_5 signify farms irrigation and X_6 farms cotton participated labor force. The notion of X_7 denotes tractor used for cultivation. Equation (5) defined below indicates the model of technical inefficiency effect.

$$U_i = \text{§}_0 + \text{§}_1 Z_1 + \text{§}_2 Z_2 + \text{§}_3 Z_3 + \text{§}_4 Z_4 + \text{§}_5 Z_5 + \text{§}_6 Z_6 + \text{§}_7 Z_7 \quad \ldots..(5)$$

The notion of Z_1 denotes farmers age while Z_2 represents schooling years of farmers. Z_3 Signify farm size and Z_4 farmers formal credit access. The notion Z_5 indicates tubewell owned farmer and Z_6 points out the shortage of water. The notion of Z_7 indicates agriculture extension services availed by cotton farmers. Production frontier model of Rahim Yar Khan variety of Bt cotton characterize in Equation (6).

$$\log Y_i = \text{¥}_0 + \text{¥}_1 \log(x_{1i}) + \text{¥}_2 \log(x_{2i}) + \text{¥}_3 \log(x_{3i}) + \text{¥}_4 \log(x_{4i}) + \text{¥}_5 \log(x_{5i}) + \text{¥}_6 \log(x_{6i}) + \text{¥}_7 \log(x_{7i}) + U_i \,.(6)$$

The notion of Y_i denotes Bt cotton output and X_i as vectors of inputs. Equation (6) inputs reports are same as indicated in above given Equation (4). Equation (7) indicates Bt farmers technical inefficiency effect model.

$$U_i = \text{Ᵽ}_0 + \text{Ᵽ}_1 Z_1 + \text{Ᵽ}_2 Z_2 + \text{Ᵽ}_3 Z_3 + \text{Ᵽ}_4 Z_4 + \text{Ᵽ}_5 Z_5 + \text{Ᵽ}_6 Z_6 + \text{Ᵽ}_7 Z_7 \quad \ldots..(7)$$

The notion of U_i denotes Bt cotton farms score of technical inefficiency. Inefficiency variables indicated by Z_i have similar illustration as represented in Equation (5) as given above. Production frontiers of Non-Bt cotton crop of district Muzaffargarh denoted in Equation (8).

$$\log Y_i = \text{ß}_0 + \text{ß}_1 \log(x_{1i}) + \text{ß}_2 \log(x_{2i}) + \text{ß}_3 \log(x_{3i}) + \text{ß}_4 \log(x_{4i}) + \text{ß}_5 \log(x_{5i}) + \text{ß}_6 \log(x_{6i}) + \text{ß}_7 \log(x_{7i}) + U_i \quad (8)$$

The Equation (8) Y_i as notion of Non-Bt output and inputs of ith farm of model variable description is same as in Equation (4) as given above. Muzaffargarh district cotton farmers of Non-Bt technical inefficiency effect model denoted in Equation (9).

$$U_i = \vartheta_0 + \vartheta_1 Z_1 + \vartheta_2 Z_2 + \vartheta_3 Z_3 + \vartheta_4 Z_4 + \vartheta_5 Z_5 + \vartheta_6 Z_6 + \vartheta_7 Z_7 \quad \ldots(9)$$

Cotton farmers of Non-Bt scores of technical inefficiency effect model have indicated by U_i Z_i denotes inefficiency variables and its model report is same as presented Equation (5). In Equation (10) Muzaffargarh production frontier of Bt cotton as given below:

$$\log Y_i = \text{þ}_0 + \text{þ}_1 \log(x_{1i}) + \text{þ}_2 \log(x_{2i}) + \text{þ}_3 \log(x_{3i}) + \text{þ}_4 \log(x_{4i}) + \text{þ}_5 \log(x_{5i}) + \text{þ}_6 \log(x_{6i}) + \text{þ}_7 \log(x_{7i}) + U_i \quad \ldots\ldots(10)$$

Equation (10) Y_i as indicate Bt cotton production output of district Muzaffargarh explanation of inputs combinations are identical as denoted in above given Equation (4). As Equation (11) denotes district Muzaffargarh Bt farmers technical inefficiency effect model.

$$U_i = \text{ɧ}_0 + \text{ɧ}_1 Z_1 + \text{ɧ}_2 Z_2 + \text{ɧ}_3 Z_3 + \text{ɧ}_4 Z_4 + \text{ɧ}_5 Z_5 + \text{ɧ}_6 Z_6 + \text{ɧ}_7 Z_7 \quad \ldots..(11)$$

U_i denote scores of technical inefficiencies model which estimated of district Muzaffargarh of Bt cotton as elaborated in Equation (11). Description of model Equation (11) is identical as indicated in Equation (5) as given above.

Results and Discussion

Empirical estimates of Rahim Yar Khan district Bt and Non-Bt cotton crop have estimated with stochastic frontier production function and inefficiency effect model as indicated in Table 1. Estimated values of gamma Bt cotton 0.76 and Non-Bt 0.98 have specified as statistically significant according to gamma theory.

Bt cotton cropped area with positive and significant coefficient signify as cropped area increase cotton production increase and these findings are alike the studies as Ahmad (2001); Barnes (2008);

Table 1: *Rahim Yar Khan Stochastic Production Frontier empirical estimates.*

	Non-Bt cotton farms estimates			Bt cotton farms estimates		
Variable	Parameters	Coefficient	t-ratio	parameters	Coefficient	t-ratio
Constant	ϕ_0	1.789	8.083***	¥$_0$	0.232	6.40***
ln cropped area	ϕ_1	-0.101	-1.194*	¥$_1$	0.117	24.231***
ln seed	ϕ_2	0.124	0.7443	¥$_2$	0.725	1.947*
ln NPK fertilizer	ϕ_3	0.110	1.181	¥$_3$	0.112	3.412**
ln Pesticide	ϕ_4	0.521	1.954*	¥$_4$	0.112	1.97*
ln irrigation	ϕ_5	0.341	3.063**	¥$_5$	0.728	2.92**
ln labor(no)	ϕ_6	0.120	0.156	¥$_6$	0.139	0.852**
ln cultivation	ϕ_7	0.351	2.129*	¥$_7$	0.569	3.293**
	Inefficiency Effect			Inefficiency Effect		
Constant	§$_0$	1.218	4.006***	þ$_0$	0.420	2.883**
Farmers age	§$_1$	-0.544	-1.222	þ$_1$	-0.203	-0.916
Schooling years	§$_2$	-0.111	-4.730***	þ$_2$	-0.381	-6.052***
Cropped farm size	§$_3$	-0.995	-1.933*	þ$_3$	-0.406	-7.680***
Credit access	§$_4$	-0.657	-1.507*	þ$_4$	-0.166	-2.123*
Tubewell usage	§$_5$	-0.249	-1.936*	þ$_5$	-0.313	-2.696**
Water shortage	§$_6$	0.743	1.791*	þ$_6$	0.127	1.913*
Agriculture-extent	§$_7$	-0.249	-0.336	þ$_7$	-0.828	-2.319**
variance parameters				variance parameters		
σ^2		0.173		σ^2		0.178
gamma γ		0.949		gamma γ		0.736
log likelihood function		-2.993		log likelihood function		115.84

****1percent level of significance **5percent level of significance *10percent level of significance.*

Basnayake and Gunaratne (2002); Ashfaq et al. (2012) and Fatima et al. (2016).

Cropped area variable with negative and significant coefficient in Non-Bt farms indicate as cropped areas rise cotton production declines as these findings are the alike study of Ahmad and Afzal (2012). The positive while insignificant coefficient of seed and fertilizer in Non-Bt cotton farms elaborated as seed and fertilizer increase no effect on production of cotton as results similar the studies of Noonari et al. (2015) and Ahmad and Afzal (2012) while Bt cotton farms seed and fertilizer with positive and significant coefficient as seed and fertilizer use increases cotton production increases and findings are alike studies of Ashfaq et al. (2012); Kavitha et al. (2013); Fatima et al. (2016) and Bakhsh et al. (2016). In Bt and Non-Bt cotton farms the coefficient of pesticide positive and significant denotes farmers use proper pesticides that raises cotton production and findings are consistent with studies of Hassan and Ahmad (2005); Ashfaq et al. (2012); Kavitha et al. (2013); Fatima et al. (2016) and Bakhsh et al. (2016). Irrigation coefficient positive and significant in Bt and Non-Bt cotton farms indicates cotton production increases as irrigation use raised and findings are alike studies of Hassan (2004); Ahmad and Afzal (2012); Bashir et al. (2005); Ashfaq et al. (2012); Bakhsh et al. (2016) and Fatima et al. (2016) in dissimilarity study of Ma et al. (2017). Positive and significant coefficient of labor in Bt cotton farms indicated raises production of cotton as labor increases outcomes are alike the work of Hassan and Ahmad (2005) and Ashfaq et al. (2012), while in Non-Bt cotton farms positive and insignificant coefficient of labor as labor increases no significant effect on cotton production and these findings similarity with studies of Noonari et al. (2015); Ahmad and Afzal (2012) and Bakhsh et al. (2016). In Non-Bt and Bt cotton farms significant and positive coefficient of cultivation mentions cotton production increases with improved land preparation findings are alike the studies of Battese et al. (1993); Ahmad and Afzal (2012); Hassan and Ahmad (2005); Kavitha et al. (2013) and Fatima et al. (2016).

Estimated parameters of district Rahim Yar Khan Bt and Non-Bt technical inefficiency effect models have specified in Table 1. The coefficients of age variable of Bt and Non-Bt cotton farmers is negative and insignificant it is not logical to say as aged farmers less efficient compared to younger and these findings are alike of Hussain (1999); Coelli (1996); Ahmad and Afzal (2012); Hassan and Ahmad (2005) and Bakhsh et al. (2016). In Bt and Non-Bt cotton farms significant and negative coefficient of education indicated as illiterate farmers are more inefficient then literate farmers and results are alike the findings of Ahmad (2001); Ahmad and Afzal (2012); Noonari et al. (2015); Fatima et al. (2016) and Spielman et al. (2017). The farm size of Non-Bt and Bt farms with the value of negative and significant coefficient pointed out as farm size enlarge production raise and results are indifference with outcomes of Ahmad and Afzal (2012); Bakhsh et al. (2016) and alike findings Hassan and Ahmad (2005). In Non-Bt and Bt cotton farms credit coefficient is negative and significant indicated as farmers have no access to formal credit have more inefficiency as compared to farmers access to formal credit less inefficient. These results are consistent studies of Hassan and Ahmad (2005); Hussain (1999) and Ahmad and Afzal (2012). In cotton farms of Non-Bt and Bt tubewell coefficient is negative and significant as tubewell usage denoted cotton farmers less inefficient which have own tubewell and findings are similar with the study of Hassan and Ahmad (2005). The shortage of water positive with significant coefficient in Non-Bt and Bt cotton farms mentioned inefficiency increases as water shortage increases and these results are alike the studies of Ahmad and Afzal (2012); Hassan and Ahmad (2005). Agriculture extension coefficient with negative and significant of Bt and Non-Bt farms indicated farmers use services of agriculture extension less inefficient and findings are alike to study of Ahmad and Afzal (2012) and Spielman et al. (2017).

Table 2 has indicated empirical estimates of maximum likelihood stochastic frontier production function and inefficiency effect model cotton farms of Bt and Non-Bt of district Muzaffargarh. The estimated Bt and Non-Bt cotton farms gamma value as 0.85 and 0.97 which is significant and in the sequential regarding theory.

In Bt and Non-Bt cotton farms coefficient of the cropped area is positive and significant indicated cropped area raise cotton production raise and these findings are alike studies of Fatima et al. (2016), Ahmad and Afzal (2012) and Barnes (2008). The low quality or overuse of seed decrease production of cotton in Non-Bt cotton farms as denoted negative and insignificant value the coefficient of seed coefficient, as findings are alike studies of Bakhsh et al. (2016); Hassan and Ahmad (2005) and Battese and Hassan (1999). In Bt cotton farms cotton production increases with seed usage indicated with seed coefficient of positive and significant and findings are similar regarding results of Fatima et al. (2016). Fertilizer usage increases cotton production in Bt and Non-Bt farms with the positive and significant coefficient and results are alike Kavitha et al. (2013); Battese et al. (1993); Bakhsh et al. (2016); Hussain (1999); Fatima et al. (2016); Hassan and Ahmad (2005) and Ashfaq et al. (2012). Overuse of pesticides reduces cotton production in Non-Bt farms with a negative coefficient of pesticides these results are alike with the study of Ahmad and Afzal (2012) in dissimilarity to Noonari et al. (2015). Proper use of pesticides in Bt farms increase cotton production with the positive and significant coefficient and these findings are alike studies Hassan and Ahmad (2005); Ashfaq et al. (2012); Kavitha et al. (2013); Fatima et al. (2016) and Noonari et al. (2015). In Non-Bt and Bt farms coefficient of irrigation is positive and significant indicated cotton crop production increases with the use of irrigation and findings are alike Hassan (2004); Bakhsh et al. (2016); Fatima et al. (2016) and Bashir et al. (2005) in dissimilarity with the study of Ma et al. (2017). An increase in labor increases cotton production in Bt cotton farms as indicates labor coefficient positive and significant and results are similar with studies Battese et al. (1993); Ashfaq et al. (2012); Hussain (1999); Noonari et al. (2015) and Hassan and Ahmad (2005). The negative and significant coefficient of labor in In Non-Bt cotton farms labor force coefficient is positive and significant cotton production decrease as labor increase and these results are similar the findings of Bakhsh et al. (2016) and Ahmad and Afzal (2012). In Non-Bt and BT cotton farms coefficient of cultivation is positive and significant specified as cotton production increases with improved land preparation and these results are alike the findings of Ahmad and Afzal (2012); Battese et al. (1993); Kavitha et al. (2013) and Fatima et al. (2016).

Empirical estimates of Non-Bt and Bt cotton crop inefficiency model parameters as indicated in Table 2.

Table 2: *Muzaffargarh Stochastic Production Frontier empirical estimates.*

	Non-Bt cotton farms estimates			Bt cotton farms estimates		
Variables	Parameters	Coefficient	t-ratio	Parameters	Coefficient	t-ratio
constant	ß_0	4.163	6.417***	þ_0	3.822	7.764***
ln cropped area	ß_1	0.875	3.249**	þ_1	0.906	3.874**
ln seed	ß_2	-0.252	2.468*	þ_2	0.2456	3.766**
ln NPK fertilizer	ß_3	0.199	1.962*	þ_3	0.5386	7.534***
ln Pesticide	ß_4	-0.495	1.968**	þ_4	0.771	3.881**
ln irrigation	ß_5	0.384	1.723*	þ_5	0.1179	1.917*
ln labor(no)	ß_6	-0.151	2.382**	þ_6	0.2109	4.6288**
ln cultivation	ß_7	0.625	2.798***	þ_7	0.8633	1.7223*
	Inefficiency Effect			Inefficiency Effect		
Constant	ϑ_0	0.7448	4.717	ɧ_1	0.7299	3.0308*
Farmers age	ϑ_1	-0.191	-1.849*	ɧ_1	-0.7417	-1.8345*
Schooling years	ϑ_2	-0.212	-3.942*	ɧ_2	-0.6909	-4.729**
Cropped farm size	ϑ_3	0.396	9.418***	ɧ_3	-0.1218	-1.909***
Credit access	ϑ_4	-0.117	-2.791**	ɧ_4	-0.2202	-3.072*
Tubewell usage	ϑ_5	-0.658	-1.875*	ɧ_5	-0.2204	-5.317***
Water shortage	ϑ_6	0.288	1.771*	ɧ_6	0.6491	2.7355**
Agriculture-extent	ϑ_7	-0.957	-2.894***	ɧ_7	-0.1127	-3.661*
variance parameters				variance parameters		
σ^2			0.362	σ^2		0.5307
gamma γ			0.969	gamma γ		0.8491
log likelihood function			29.22	log likelihood function		56.614

****1percent level of significance **5percent level of significance level *10percent level of significance*

Age consider as the experience of farming which reduces the inefficiency of Bt and Non-Bt cotton farms indicated with age coefficient value of negative and significant. These estimates are alike the results of Coelli (1996); Hassan and Ahmad (2005); Hussain (1999) and Bakhsh et al. (2016). Schooling years in both (Bt and Non-Bt) cotton farms reduces inefficiency and raise production of cotton with negative and significant coefficient and these outcomes are alike findings of Noonari et al. (2015); Battese et al. (1993); Spielman et al. (2017); Bakhsh (2007); Ahmad and Afzal (2012) and Fatima et al. (2016). Farm size raises inefficiency positive and significant coefficient of farm size as these results are consistent the studies of Bakhsh et al. (2016) and Ahmad and Afzal (2012). The negative and significant coefficient of In Bt farm size pointed out the inefficiency reduces as farm size increases due to the positive and significant coefficient of farm size and findings alike results of Khan and Makki (1979) and Hassan and Ahmad (2005) . Credit coefficient indicated as access to formal credit increases, farmer inefficiency reduces reason of negative and significant credit coefficient of Bt and Non-Bt farms and these findings are similar the results of Parikh et al. (1995); Ali and Flinn (1989); Hussain (1999); Ahmad et al. (2018); Hassan and Ahmad (2005). Non-Bt and Bt cotton farms indicated inefficiency decreases as farmers have own tubewell reason of tubewell coefficient negative and significant and results are consistent with findings Ahmad and Afzal (2012) and Hassan and Ahmad (2005). Non-Bt and Bt cotton farms indicated inefficiency raise as water shortage increase due to the significant and positive coefficient of water shortage and results are alike the findings of Ali and Flinn (1989); Ahmad and Afzal (2012); Hassan and Ahmad (2005). Increase in access to agriculture extension reduces farm inefficiency reason for agriculture extension coefficient negative and significant in both Bt and Non-Bt cotton farms. These results are alike findings as Ahmad et al. (2016); Bravo-Ureta and Pinherio (1997); Ahmad and Afzal (2018); Bakhsh (2007); Spielman et al. (2017); Ahmad and Afzal (2012).

Mean technical efficiency of Bt cotton farmer is 0.85

Table 3: *Cotton farmers of Non-Bt and Bt Technical efficiency frequency distribution.*

Efficiency Level	Rahim Yar Khan farmers technical efficiency				Muzaffargarh farmers technical efficiency			
	Non-Bt Farms		Bt Farms		Non-Bt Farms		Bt Farms	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
0 – 0.15	-	-	-	-	-	-	-	-
0.15 – 0.30	1	0.83	-	-	-	-	-	-
0.30 – 0.45	14	11.66	-	-	46	38.33	5	4.16
0.45 – 0.60	41	34.16	8	6.66	53	44.16	20	16.66
0.60 – 0.75	20	16.66	31	25.83	14	11.66	25	20.83
0.75 – 0.90	26	21.66	13	10.83	4	3.33	21	17.5
0.90 – 1.00	18	15	68	56.66	3	2.5	49	40.83
Total	120	100	120	100	120	100	120	100
Mean	0.66		0.85		0.51		0.79	

while it varies from 0.49 to 0.99 and mean efficiency of Non-Bt cotton farmers technical efficiency is 0.66 with ranges of 0.24 to 0.99 in Rahim Yar Khan district. In comparing Bt and Non-Bt cotton farmers mean technical efficiency it signified Bt cotton farmers 19% technically more efficient comparative of Non-Bt cotton farmers. The Bt cotton farmers mean technical efficiency in district Muzaffargarh as 0.79 with the range of 0.38 to 0.98 while Non-Bt cotton farmers mean technical efficiency is 0.51 with the range of 0.34 to 0.95. In Muzaffargarh Bt cotton farmers technically 28% more efficient as compared to Non-Bt cotton farmers. Technical inefficiency prevails in both districts Non-Bt and Bt cotton farmers as indicated with empirical estimates of stochastic frontier technical inefficiency model. In Rahim Yar Khan Bt cotton farmers 15 percent and Non-Bt are 34 percent technically inefficient. Bt cotton farmers are 21percent and Non-Bt cotton farmers are 49 percent are technically inefficient in Muzaffargarh. Technical inefficacy can overcome in Non-Bt and Bt farmers through economize use cotton inputs regarding environmental and crop requirement (Fatima et al., 2016). In comparing the cotton seed varieties Bt cotton farmers in both study areas using advanced Bt cotton seed which has relatively higher resistance against cotton disease, more appropriate regarding climatic environmental changes and relatively more economical in utilizing cotton crop inputs like, fertilizer, pesticides, irrigation, cultivation and labor, as obtaining higher cotton crop production as compared to non-Bt cotton farmers. The lower inefficiency status of Bt cotton farmer in both study areas as compared to non-Bt farmers was estimated due to the adoption of advanced mechanization, higher experienced, more schooling, focusing on the installation of tubewell for water availability, maximum extension service and credit access.

Conclusions and Recommendations

In this study, two core cotton producing districts of Punjab, Rahim Yar Khan and Muzaffargarh stochastic production frontier approach was used for estimating Bt and Non-Bt cotton farmers technical efficiency. Findings of the study have indicated, technically Bt cotton farmers are more efficient comparative to Non-Bt farmers in both districts. In comparing technical estimates of Non-Bt and Bt cotton farmers as indicated Bt farmers are 19% technical more efficient rather Non-Bt cotton farmers in Rahim Yar Khan. In Muzaffargarh Bt farmers technically 28% more efficient compared to Non-Bt cotton farmers. In both districts, technically Rahim Yar Khan relatively more efficient in cotton production rather than Muzaffargarh in Non-Bt and Bt varieties of the cotton crop. The frequency of inefficiency in both cotton producing districts in Non-Bt and Bt cotton farmers was estimated. In the current scenario, the sequential squeezing area for cotton crop and declining cotton production is a burning issue for future cotton crop in Pakistan. There is a need to promote the awareness status among cotton farmers to using Bt cotton seed for higher yield, more familiarity with environmental dynamics and advanced diseases resistance rather than tradition cotton seed varieties. Improving managerial competencies among cotton farmers it is necessary to promote farmers literacy, infusion of extension services through farmers training and application of innovative farming practices and mechanization for promoting cotton crop productivity. Emergency measures are prerequisite for favorable and research-based cotton policies regarding cottonseed, overcoming market imperfections of cotton inputs and output and promoting crop insurance policies to minimizing farmers' risk.

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Author's Contribution

The basic concept of this research, the data collection procedure, introduction, literature, methodology and empirical estimation was the contribution of Dilshad Ahmad. Mohammad Afzal contributed with Dilshad Ahmad in proper guidance of conclusion, suggestion and final revision of this research.

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