Identification of Factors Influencing the Technical Efficiency and Productivity of Wheat crop in Pakistan:

(A Case Study of Rahim Yar Khan)

By

Hina Fatima

Registration #

181-FE/MS (ECO)/F08

Supervisor:

Dr.Zafar Altaf

Co.Supervisor

Dr. M.Azeem Khan

International Institute of Islamic Economics
International Islamic University, Islamabad

December, 2010

Table of Contents

List of Tables

List of Figures

List of Abbreviations

C-D	Cobb Douglas
BT	Bacillus Thuringiensis
DEA	Data Envelopment Analysis
FYM	Farm Yard Manure
NP	Nitrogen and Phosphors Fertilizer
MLE	Maximum Likelihood Estimation
NWFP	North West Frontier Province
OLS	Ordinary Least Square
PARC	Pakistan Agricultural Research Council
SFA	Stochastic Frontier Analysis
SPSS	Special Package for Social Sciences
US	United States

Abstract

The study aspires to investigate the factors influencing the productivity and technical efficiency of wheat crop in Pakistan. A formal survey of wheat crop was conducted in district Rahim Yar Khan in the 2009-10 crop season. The sample size was 430 wheat farmers. A Cobb-Douglas frontier production function model was used. The major objective of this survey was to identify factors of variation and special problems of planting of wheat after Non-BT and BT-cotton that limiting the wheat productivity. The average technical efficiency of wheat farmers on aggregate level was 0.76. The mean technical efficiency of wheat after Non BT and BT-cotton was 0.78 and 0.74 respectively. The result reveals that those farmers cultivate wheat after Non-BT cotton was technically more efficient as compared to farmers who cultivate wheat after BT-cotton. The major factors found to be responsible for increased wheat production were area under wheat crop, wheat after Non-BT or BT cotton, weedicide cost, number of ploughing, optimum sowing, NP ratio, land preparation day, number of irrigation, tractors and tubwells ownership, tenancy status, farmer's education and experience. There is a potential in farmers of study area to increase wheat production from existing cultivating areas using available resources if the farmers can manage at the maximum obtainable yield level. However there is need that wheat farmers of study area use their managerial ability, knowledge, and technical skills.

INTRODUCTION

Farming sector is very important for Pakistan which plays an influential role in the development of the economy of the country. Pakistan's temperature, climate and fertile soil have supported almost every kind of farming across different regions. Agriculture growth needs to be fostered, in order to stand against the competitive pressure. According to economic survey of Pakistan 2009-10 agriculture sector had continuously played a significant role in Pakistan's economy. The sector contributes about 21 percent GDP and employs 45 percent of workforce in country.

Wheat is main staple food item of the country's population and largest grain crop. It is a winter crop sown in October - November, and harvested in April - May. Wheat is most widely grown crop of Pakistan. According to economic survey of Pakistan 2009-10 wheat contributes about 14.4 percent of sector value added in agriculture and 3.1 percent to GDP. The wheat crop area sown was 9042 thousand hectares showing decrease of 0.04 percent as compared to last year's area of 9046 thousands hectares. The size of wheat crop was 23864 million tons against the target of 25 million tons and also indicates 0.7 percent declines than last year crop[1].

According to USAID, wheat fulfills 70 to 80 percent Nutrition needs of Pakistani People. There has been a fluctuating trend in wheat production over the last decade, which threatens household food security and income sources (Khan, 2009). The recent food scarcity and rising prices have affected majority of people in whole part of the world as well as Pakistan and this food crisis is an apprehension for the policy makers and agricultural scientists in Pakistan (Javed et al 2010). According to Ahmad (2003) farm sector in Pakistan are generally plays an essential role in the

[1] Last year wheat production was 24033 million ton

abolition of poverty. Forty countries facing food price crises at the time and Pakistan also listed among them. During the last cropping season, 30 percent significant increase in wheat prices was noted. This rapidly increase prices could lead to push a growing sector of the population below the poverty line (Ashfaq, 2008). Pakistan has comparative advantage in wheat production, but these factors together made Pakistan to import wheat for avoiding food shortages. Pakistan, for most part of its history has been a net importer of wheat (Khan, 2009). Wheat is a principal crop though; Pakistan is 9^{th} largest wheat producing country in the world, while this crop is grown in almost every crop rotation of the country. (Farooq et al, 2009). " Throughout the history of Pakistan supply of wheat remained short of demand and as a result imports has been the only option to fill the supply and demand gap" (Ahmad et al 2002). Pakistan spends huge foreign exchange for wheat import to meet food requirement of growing population. (Akhter, 2006). (Farooq and Iqbal ,2000) also pointed out that Pakistan import wheat quite regularly as its domestic production has remained short of demand.

Production Trends of Major Crops (1950 –2008)[2] Table.1

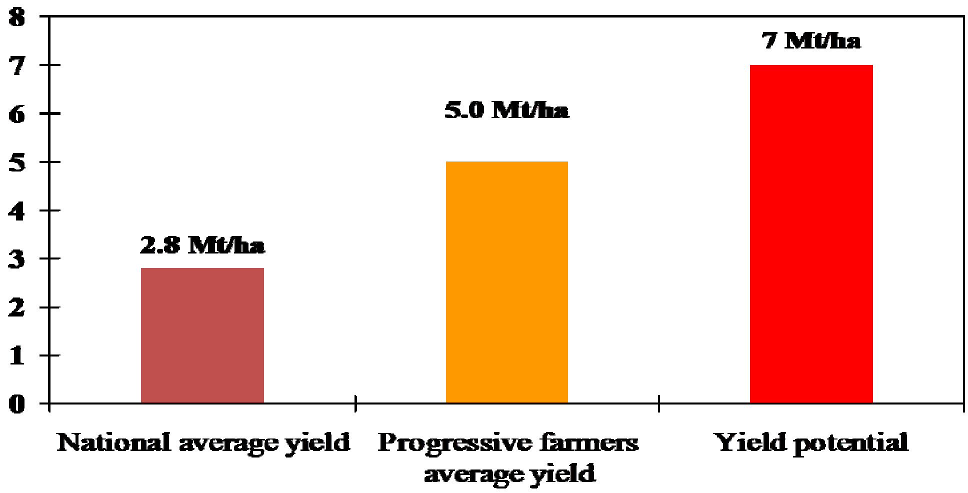
Crops	1950	2007-08	2008
	Production (million tonnes)		Increase in production (in times)
Wheat	3.9	21.8	6
Rice	0.8	5.6	7
Maize	0.4	3.3	8

[2] Source Pakistan Agricultural Research Council

Sugarcane	7.8	63.9	8
Cotton (m bales)	1.3	11.6	9

There is around 4.2 million ton/ha yield gap in wheat production in Pakistan[3]. (Khan, 2009). According to Ahmad et al (2002), main reasons for low wheat in productivity in Pakistan are due to management and socio-economic factors.

Figure 1: Yield Gap Analysis



The major factors for low productivity and instability of wheat crop in Pakistan includes: subsequent late planting of wheat due to double cropping of cotton-wheat rotations emerged leading to significant expansion in wheat area but it leads to late planting of wheat crop. (Randhawa (1979); Hobbs (1997); and Ahamd et al (2004) argued that wheat yield found declined by 30-40 kg/ha for each day delay after 15 November.

[3] According to PARC, in Pakistan approximately 2.8-7 million ton/ ha yield gap present.

On the other hand shortage of water imposes negative effect on wheat yield, especially at critical stage of wheat crop (Bashir et al. 2006). According to (Intizar et al. 2003), timely and good quality ground water leads to higher wheat yield. (Khan, 2009). According to (Ahmad et al 2002) management factors leads to variations in productivity or in other words inefficiency gaps. (Johnston and Cowine 1969) emphasis on experience, knowledge and technical skill of the farmers, because output not only depends on the levels of source use, other than on the ways and means in which it is used. (Coady 1995) explains that availability of knowledge and credit also increases the wheat productivity.

To observed the technical efficiency and productivity of wheat crop a range of studies have been carry out by using wheat crop data on various countries like [Battese, Malik and Broca (1993); Hassan (2004); Croppenstedt (2005); Kamruzzaman and Islam, (2008); Ahmad and Ahmad (1998); Javed et al, (2010)] to study the factors that responsible for inefficiency in wheat production.

(Javed et al, 2010) pointed out that estimation of technical efficiency in developed and developing country still an area of research. It is very important especially in case of developing country like Pakistan where potential to increase the production through increase area under cultivation and adoption of original expertise is limited.

Research Question:

The focal purpose of present study is to identify the factors which influence the technical efficiency and productivity of wheat crop in Pakistan. In recent years, new emerging problem arises in Pakistan is the implication of BT and Non BT Cotton on wheat Yield. Furthermore, with the importance of wheat cultivation in Pakistan, why Pakistani farmers are not able to acquire the maximum level of wheat produced per unit of land.

Objectives:

The core objectives of the study are***:***

- To examine the system implications of emerging cotton-wheat management systems
- To identify factors influencing wheat productivity.
- To validate robustness of technical efficiency of wheat production through using Stochastic Frontier Analysis.

***Structure of the Study*:**

The organization of the whole study includes following parts. Section I following introduction that contains brief discussion on the overview of Wheat crop. In Section II outlines literature review of previous studies. Section III based on data methodology discussion. Descriptive and empirical results presented in section IV. Finally, in Section V concludes the study with some policy recommendations.

II.

Factors Influencing the Productivity and Technical Efficiency of Wheat Crop: Evidence from Literature

Introduction:

Farm efficiency and the question of how to measure it, is an essential subject in, agriculture" (Hazarika and Subramanian, 1999). "Measuring farms efficiency is important insofar as this could be the first logical step in a process that leads to substantial resources savings. Technical efficiency in production is defined as the ability of the farmer to produce at the maximum output, given quantities of inputs and production technology. The technical efficiency indices are of great importance in examining farm performance, a determination of the factors influencing those indices is equally important"(Amaza and Maurice, 2005). This part presents review of some previous studies related to the factors influencing the productivity and technical efficiency of wheat crop. This part is divided into three sections, Section II-1 is about production and efficiency Studies, Section II-2 consists on literature from developed and developing countries, Section II-3 based on studies on Pakistan.

*II-1. **Productivity and Efficiency***

"Productivity and efficiency analysis is frequently applied in the field of agricultural economics to estimate the total factor productivity growth at the sector and farm levels, to decompose the productivity changes to components of technological progress. To achieve productivity growth, either technological innovation or we can say that the more efficient use of production technologies, or some combination of both, is required. In case of developing countries most new agricultural technologies have only been partially successful in improving productivity (Xu and Jeffrey 1998)".

Therefore, there is a potential of increasing wheat production from existing cultivating areas using available resources if the farmers can manage at the maximum obtainable yield level. Maximum obtainable yield level can be determined through estimation of frontier production function. Some farmers may produce maximum obtainable wheat yield and some farmers may not produce maximum obtainable yield level due to some inefficiency factors. Therefore, the stochastic frontier production function used to estimate the level of technical efficiency of wheat production and factors affecting inefficiency (Manos et al. 2006).

II-2. Literature from Developed and Developing Countries:

Bakhshoodeh and Thomson (2001) estimated technical efficiencies of wheat production, Iran. The Cobb-Douglas frontier production function used for that study .The respective average efficiencies were 0.93% and 0.91% respectively, showed that there was limited level of element to increase the profitability of Iranian wheat production either increasing or decreasing the input levels, for wheat production.

Croppenstedt (2005) examined technical efficiency of 800 wheat farmers in Egypt in 1998. The Cobb-Douglas frontier production function was used for analysis. The estimated mean level technical efficiency of wheat farmers was 81. It was ascertain that technical efficiency of 82% farms between 70 and 94 percent. The end results of study indicate that in Egypt by farm size there was no differences in technical efficiency.

Goyal and Suhag (2003) estimated the technical inefficiency of wheat farmers in India. According to the authors parametric approach is better than the non parametric approach in agriculture due to the uncertainty aspect in agriculture sector. The Cobb-Douglus frontier production frontier is used for panel data from 1996 to 1999 year. Results of the study demonstrate that the average technical efficiency is 0.92. The results reveal that a range of farm specific and socio-economic factors were found responsible for technical inefficiency in wheat production in India.

Ghaderxadeh and Rahimi (2008) estimated the wheat farmer's technical efficiency in Kurdistan province, Iran. The data were collected from rainfed and irrigated areas in 2003-2004. The sample size was 210 farmers. A Cobb-Douglas frontier production function model was used in which the variables such as seed rate, plant protection chemicals were positive and significant and nitrogen fertilizer, area situation were negative and significant. The mean technical efficiency of rainfed farms and irrigated farms was 0.65 and 0.67 respectively. The result reveals that the irrigated wheat farmers were technically more efficient as compare to raindfed area farmers.

(Kamruzzaman and Islam, 2008) estimated the technical efficiency of wheat grower in Bangladesh. The data were collected in 2004 and sample size was 60 wheat farms. It was found that farmer's education and those farmers frequently contacted with extension workers were found technically sound and more efficient. The end results of the study was that the optimum sowing and harvesting, high level of farming experience and education are important factors for obtaining high wheat yield.

(Sharma et al 2010) examined the technical efficiency of wheat crop in dryland and irrigated conditions in J&K state in Jammu. The technical efficiency on average of dryland farms was

0.84 and in irrigated condition, it was found 0.88. Thus an average farmer in dryland and under irrigated farming system was producing 16 and 12 percent less than the achievable potential. The outcome reveal that the technical efficiency of study area can be improved by the balanced and proper use of technology.

(Tozer 2010) estimated the efficiency of wheat production of western Australian growers. Sample size is 50 farms of four continuous years from 2004-207. The major factors found to be responsible for increased wheat production were effective rainfall, balanced fertilizer application rates. Inefficiency levels of wheat farms ranges 18 to 31 percent. The inefficient results indicate that wheat farmers suffering from reduced profit over the four year study period. Thus, this inefficiency leads to less competitiveness of Australian wheat farmer.

II-3. Studies on Pakistan:

The estimation of frontier function and efficiency can be completed either in one stage or in two stages. Parikh and Shah (1996) presented a review of the various approaches to efficiency measurement and conducted empirical analyses of cross-sectional data from 397 sample farmers in the NWFP of Pakistan. A two-stage stochastic frontier approach was used. For the first stage of analysis a Cobb-Douglas stochastic frontier production function was estimated. Factors found to be responsible for agricultural output per acre were farm yard manure, fertilizers cost, labor wages, animal labor cost and tractor costs. Estimated technical efficiencies for the second-stage of the analysis were regressed on various socio-economic and farmer-specific variables, which were considered suitable in explaining variations in technical efficiencies in agriculture output of Pakistan.

Hassan (2004) examined that technical efficiency of wheat farmers of the Punjab, Pakistan by using stochastic frontier production function incorporating technical inefficiency effect model.

The mean expected technical efficiency was about 94 percent. Factors found to be responsible for increased wheat production were area under wheat crop, number of cultivation and fertilizer, while the results depicted that the technical inefficiency could be reduced by optimum sowing of wheat crop, farmer's education, and availability of credit to the farmers, However, shortage of canal water especially in time was found increasing technical inefficiency in Pakistan.

Chaudary et al, (2002) articulated wheat productivity, efficiency and sustainability of provinces of Pakistan, namely NWFP, Punjab and Sindh. The study used data from a Fertilizer Use Survey 1997-1998. The sample size was 2368 respondents. The results shows that the mean technical efficiency of wheat farmers is around 68 percent, so an average farmer 32 percent below from their achievable potential output the comparative analysis of provinces also disclose that the wheat farmers of Punjab more efficient then Sindh and the NWFP. The results reveals that the grounds for this dissimilarity were that the farmers in Punjab are more educated and have better irrigation facilities.

Hassan et al. (2007) study that wheat production although increased from last decade, but due to technical inefficiency overall yield does not go beyond of its optimum level.

Bashir et al (2004) examine a comparison of wheat production practices in Pakistan. From public perspective, government wishes to keep wheat prices low under the argument of poverty and malnutrition. On the other hand, lower wheat prices have direct implications on wheat production environment especially in the scenario of rising inputs prices. Timely planting of wheat, increase in support price, relatively more use of fertilizer and weedicide and timely availability of credit are the main factors that contribute to higher yield. Regarding allocation of farm area to wheat crop, the average wheat area was less than the previous year. According to farmers' perceptions, decline in farm area, increase in area under fodder crops, low prices of wheat during last year and water shortage were the main reasons for decline in wheat area.

Azhar (1993) articulated that stagnation of food grain production in Pakistan based on many factors. The common crop rotations for wheat production are cotton-wheat, wheat-rice. This invariably results in late sowing of wheat, which is important cause of low and declining productivity of wheat. due to high profitability in cotton farmers promoting late sowing of wheat because even the last cotton picking done in December or early January is reported to yield better net return then early sown wheat. Higher prices of fertilizers are result in slowdown of fertilizer use. This may have adversely affected the wheat output.

(Ahmad and Ahmad, 1998) articulated the technical efficiency of wheat farmers of barani Punjab. The districts level data used for analysis. The results demonstrated that the average technical efficiency of districts Attock, Rawalpindi, Jehlum, and Chakwal were 0.89, 0.84, 0.88, and 0.88 percent respectively. Moreover, the results reveal positive effects of inputs, like higher used of fertilizer and favorable rains. On the other hand there is dismal requirement to increase water use efficiency because the performance of farming depends on seasonal rains.

Bashir and Khan (2005) estimated the allocative efficiency of wheat cultivators in the NWFP Province of Pakistan by using a translog frontier production function. The data were collected from districts of Peshawar. The result shows that the average allocative efficiency of wheat growers in NWFP was about 72 %. The range of allocative efficiency varies from 51 to 88 Percent. Farm size, experience, access to credit and farm to market distance had a positive impact on profit efficiency of wheat farmers of Pakistan.

Azhar (1991) The paper was employed Cobb Douglas frontier production approach to find out the link between technical efficiency and education in irrigated areas of Pakistan during Green Revolution. Results of study reveals that farmer's education had a positive relationship with technical efficiency. It was found that the education ahead of the basic level of education led about 20% raise in wheat productivity. Therefore the education is an important factor for obtaining maximum achievable yield.

Battese, *et al.* (1996) investigated the technical inefficiency of wheat farmers of Pakistan. Four districts were selected, Fasialabad and Attack from Punjab, Badin from Sindh and Dir from NWFP. Four year panel data was collected from wheat farmers. A Cobb-Douglas frontier production model was used to examine the factors of technical inefficiency of wheat farmers. It was found that Faisalbad was exceedingly efficient by high intensive use of inputs like labor, fertilizer, seed and tractor, and high wheat yield. On the other had Badin is lowest among the four districts and lowest intensity of use of other inputs. Attock and Dir were generally in middle with regard to these inputs.

In this chapter, total studies were reviewed were specifically discussed the efficiency and productivity of wheat crop. In most of studies factors found to be responsible for increased wheat production were area under wheat crop, weedicide cost, number of ploughing, seed rate, optimum sowing, and access to extension, access to market, fertilizer, agrochemicals, tractors tenancy, farmer's age, education and experience. However there is need that farmers use their managerial ability, knowledge, and technical skill. Previous studies reveal that the major factors under lying technical inefficiency were socio-economic and poor managerial abilities of wheat farmers.

III.

Wheat Productivity and Technical Efficiency: Material and Methods

Introduction:

The yields of wheat crop in Pakistan are comparatively lower than those of agriculturally advanced countries. The future gains in wheat productivity very much depends on improvement in efficiency on agricultural based resources (chuadhary et al, 2002). The Cotton – wheat area constitutes the most important cropping system in Pakistan in which wheat is grown. Area allocation to wheat during 2009-10 seasons was almost identical to last year. In 2009-10 cotton - wheat area by zones is approximately 3165 hectares. A significant decline in wheat yield was estimated in 2009-10. Almost two million tones reduction in wheat production for this year is estimated[4]. This part of the study is divided into different sections. Section III-1, contains cotton-Wheat System in Study Area, Section III-2,based on data and sampling procedure, Section III-3 includes efficiency, Section III-4, grasps Stochastic Frontier Analysis.

III-1. Cotton-Wheat System in Study Area:

A formal survey of wheat crop was conducted in district Rahim Yar Khan in the 2009-10 crop season. The major objective of this survey was to identify factors of variation and special problems of planting of wheat after Non-BT and Bt-cotton that limiting the wheat productivity. Wheat after cotton is a major crop rotation in study area. About 100 percent of wheat fields were

[4] According to the report of PARC in 2010

planted after cotton in the study area. In recent years, new emerging problem arises in Pakistan is the implication of Non-BT and BT cotton on wheat yield. The prolonged harvesting of cotton especially in case of BT- cotton is the major conflict in the cotton- wheat system, resulting late planting of wheat. In cotton wheat cropping pattern growers often have difficulty in maintaining good yield of wheat due to late planting. It has been investigated that early stand establishment is an important factor for increasing grain yield (Lindstorm *et al*. 1976). Byerlee *et al.* (1984) observed that late planting increased the risk of hot weather in vital time of grain filling which eventually reduced the grain yield. (Khan and Salim, 1986) reported that early seeded crop resulted in higher yields as compared with late seeding. (Ansari ,2000) explained that early planting wheat resulted in higher yields as compared with late planting in cotton-wheat cropping pattern.

In study area farmer grow Non-BT and BT cotton varieties. As compare to Non-BT cotton, BT cotton acquire more time, BT cotton has the characteristics of early sowing and late harvesting, to obtain high BT cotton yield the farmers appear to rationally weigh up the benefits of additional cotton with the loss from late wheat planting.

III-2. Data and Sampling Procedure:

This study is a primary research. Cross-sectional data has been used. The instrument used is the "questionnaire". A pre-tested questionnaire was used to gather the information from the farm respondents. Battese (1998), explained that a questionnaire is an ordered list of questions for a survey. In building up the questionnaire the main focus was confined to wheat and cotton crop. The data were collected for the crop year 2009-10 (*Rabi* 2010 and *Kharif* 2009). The respondents of the study were those farmers that cultivate wheat after Non-BT and BT cotton. The population of this research encompasses the area of Rahim Yar Khan. Where 430 farmers were selected and it was purposive sampling technique. Data is collected from those fields where wheat was planted after cotton, a number of questions were asked about key practices in the production of cotton in that field in the previous cycle (e.g. variety, planted data and number of pickings) in order to analyze interactions between cotton and wheat. Data was also gathered on wheat-cotton production and their prices, inputs for wheat, farm size and socio-economic and other farm specific characteristics which are considered vital for empirical analysis via a questionnaire. The reason for selection of wheat and cotton for the analysis is that these are most important crops in Pakistan and also the major crops of the study area of Rahim Yar Khan. The two crops are popular with both the smallholder and large-scale commercial farming sectors of Pakistan. Wheat is the staple food and cotton is the most popular cash crop in Pakistan. As far as farmers are concerned cotton is their best cash crop. Farmers in this study area receive marginal rains, cotton which is a drought resistant crop and does well in hot conditions, has given the farmers a feasible substitute to the rice crop in the study area. During the data collection author has faced some difficulties because the sample size is large and focuses only those farmers that cultivate cotton and wheat. It was difficult task to meet 430 farmers and collect information. The author also used the *Punjabi* and *Sarike* language for those farmers that were illiterate and not able to understand the *Urdu* language, as a result they feel ease while giving the information. Present study is based on sample responses.

*III-3. **Efficiency:***

According to Farrell (1957), "efficiency is defined as the actual productivity of a firm relative to its maximal productivity and Maximal productivity is defined by the production frontier" (Lissitsa *et al*. 2005). According to (Bravo and Rieger 1991) measuring efficiency is important from an applied perspective because this is the first step in a process that might lead to considerable resource savings. These resource savings have fundamental implications for both policy formulation and firm management because efficient farms are capable to make higher incomes and therefore set a better possibility of surviving and prospering.

*III-3.i. **Economic Efficiency:***

According to Farrell (1957) "economic efficiency of a firm consists of two components: technical efficiency and allocative efficiency. Thus, in order to be economically efficient, a firm must be both technically and allocatively efficient". In microeconomics of production, technical efficiency which is the main focus of present study is defined as "the maximum attainable level of output for a given level of inputs, given the current range of alternative technologies available to the farmer" (Ellis, 1993). Therefore, technical efficiency represents the ability of a firm to produce on the production frontier. Russell and Young (1983) argued that technical inefficiency arises when less than maximum output is obtained from a given bundle of factors. "Technical efficiency can be analyzed using two approaches. These are the output-oriented and input-oriented approaches. The first one has output augmenting orientation, whereas the second one is targeted to preserve inputs" (Koopmans, 1951).

Allocative efficiency depicts the ability of a firm to utilize the cost minimizing input ratios or revenue-maximizing output ratios. Thus, a firm is allocatively efficient if it uses the optimal combination of inputs with respect to their prices and allocative inefficiency arises when factors are used in proportions that do not lead to profit maximization (Lovell 1993).

On the other hand scale efficiency is used to determine how close an observed firm is to the most productive scale size.

If a+b>1, there are increasing returns to scale.

a+b = 1 indicates constant returns to scale.

a+b<1 indicates diminishing returns to scale.

III-3.ii. ***<u>Approaches to Efficiency Measurement:</u>***

Usually two approaches used for technical efficiency analysis either parametric technique or non-parametric techniques. Non-parametric methods, as originally conceived by Farell, used the unit input output space to create a frontier isoquant within the production possibility set". "The frontier was determined by a single or a convex combination of efficient units which were then compared against inefficient units to calculate the extent of inefficiency. This method was later applied to the multiple input output case" (Murillo and Zamorano, 2004). DEA has been used to judge performance of non-profit organizations, hospitals, courts, school, colleges, universities, public sector, agriculture,(Coelli, 1996). However, now a day's researcher also applied it to examine the performance of profit organizations.

Coelli *et al* (1998) mentioned a number of limitations on DEA method. Measurement error and other noise may influence the shape and the position of the frontier. On the other hand the efficiency scores obtained from DEA are only relative to the best firms in the sample. TE scores remain the same in the addition of an extra firm in DEA analysis.

“developed stochastic frontier models developed by Aigner and Chu (1968), which allow the influence of random errors and data noise ”. Substantial research has been conducted using the stochastic production frontier (Battese and Broca, 1977; Tadesse and Krishnamoorthy, 1997; Amaza *et al*., 2001; Kebede 2001; Pinheiro 1992; Ahmad, *et al.* 2002; Battese and Hassan 1999; Tran *et al.*, 1993; Croppenstedt 2005, Tchale and Sauer 2007; Ojo and Imoudu, 2000 and Basnayake and Gunaratne 2002).

According to (Ezeh, 2004; Coelli, 1995) the stochastic frontier approach is selected for assessing efficiency in agriculture because of the natural stochasticity involved .stochastic frontier technique assumes that deviations from the production frontier is not completely under the control of farmers (Aigner, Lovell and Schmidt, 1977). Stochastic frontier analysis also allows hypothesis testing.

III-4. Stochastic Frontier Analysis (SFA):

Though, it is well documented that the DEA approach works under the assumption of absence of random shocks in the data set. Since farmers always operate under uncertainty, the present study employs a stochastic production frontier approach introduced by Aigner *et al.* (1977); Meeusen and van den Broeck (1977).

The stochastic frontier method assumes that the production function includes the double random error, is written as:

$$Y = f(x_i, B)\ exp\ (V - U) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

“Where, $Y = f(x_i, B)$ represent the deterministic part and $exp\ (V - U)$ represents the stochastic part of the production frontier respectively. β is a vector of parameters to be estimated, Where, V

is the symmetric error component, which is assumed to be independently and identically distributed as $vi \sim N(0, \sigma^2)$. It accounts for the random variations in output due to factors outside the control of the farmer such as weather, disease, measurement error etc. On the other hand, ***U*** represents the technical inefficiency relative to the stochastic frontier and assumes only positive values." Its distribution is assumed to be half normal being identically and independently distributed as N $(0, \sigma^2)$" (Neff *et al*, 1993).

"Let σ_u^2 and σ_v^2 be the variances of the parameters symmetric (v) and one-sided (u) error terms. It then follows that,"

$$\sigma^2 = \sigma^2_v + \sigma^2_u \text{ ....(2)}$$

"According to Battese and Corra (1977), the variance ratio parameter which relates the variability of u_i to total variability can be calculated in the following manner";

$$\gamma = \sigma^2_{u\,/}\sigma^2_v{}^+\,\sigma^2_u \text{ ....(3)}$$

So that $0 <= \gamma <= 1$

"This means that if the value of γ equals zero, the difference between yields (outputs) of farms is entirely due to statistical noise. On the other hand, a value of one would indicate that the difference is attributed to technical inefficiency" (Battese and Corra, 1977; Coelli, 1995).

$$U_i = \delta_0 + \delta_i Z_j + W_i \text{ ………………………………………….. } (5)$$

Technical inefficiency effects are defined as:

"*Zi* is the vector of explanatory variables, associated with technical inefficiency effects. ***δ*** is a vector of unknown parameters to be estimated. W_i represents unobservable random variables, which are assumed to be independently and identically distributed".

$$TE_i = exp(-U_i) = Y_i/Y_i^* \text{………………………}(6)$$

Or

$$TE = exp\ (X_i\beta + v_i - u_i)\ /\ exp\ (X_i\beta + v_i)$$

$$TE = exp\ (-u_i)$$

TE refers the technical efficiency of the ith farm, Y_i is observed output and Y_i^* is maximum possible output using the given level of input.

III-4.i ***Functional Form for Frontier Production:***

There are basically two common functional forms used for stochastic frontier production functions, namely Cobb-Douglas and Translog functional form. The Cobb-Douglas functional form has been commonly used in the estimation of frontier models. "According to (Koop and smith, 1980) functional form has an evident but rather small impact on estimated efficiency". Xu and Jeffrey (1997) "argued that functional form has a limited effect on empirical efficiency measurement". "(Ahamd and Bravo-Uretra, 1996) rejected functional form in favor of a simplified translog form, however concluded that technical efficiency measure do not appear to be affected by the choice of functional form". They also added that coefficients provide more appropriate results in Cobb-Douglas as compare to translog form. According to (Bakhsh et al 2006) the Cobb-Douglas (CD) functional form is used as its coefficients directly represent the elasticity of production. "In addition, its simplicity and widespread use in agricultural economics outweigh its drawbacks".

On the other hand Cobb-Douglas stochastic frontier is widely applied in farm productivity analysis mainly in case of developing countries (Haq and Arshad, 2010). It is simple to use and less liable to multicolinearity as compared to flexible translog production function (Rahman, 2002). However, large sample size is needed for Translog functional form. Several studies used this approach that helps present study to compare the results with findings of other related studies, for example Tesfay *et al*. 2005; Ahmed *et al*., 2002; Hassan *et al*. 2005; Bakhshoodeh and Thomson 2001; Parikh and Shah 1996; Hassan 2004; Chaudary et al, 2002; Javed et al. 2009; Ahmad and Ahmad, 1998; Croppenstedt 2005; Goyal and Suhag 2003; Ghaderxadeh and Rahimi2008; Kamruzzaman and Islam, 2008 and Manjeet 2010.

The Cobb-Douglas type functional form is used in the present study to specify the stochastic production frontier. A production function is the maximum output attainable from given level of inputs and given technology (Beattie and Taylor 1985). A stochastic frontier production function, of the C-D type, proposed by Batttese and Coelli (1995) is used for the estimation for wheat crop of Pakistan.

The model, which is proposed for the analysis of wheat yields, engages stochastic frontier production functions, in which the parameters of the production functions are specified to be a function of the variables associated with the production of the wheat crop. The model is presented in terms of a Cobb- Douglas production function. For purposes of exposition, the Cobb-Douglas model is given in terms of wheat involving nine input variables and seven explanatory variables for the inefficiency effects in the stochastic frontier. The general model for this study relating production, Y, to a given set of resources X, given as follows:

Taking natural log of wheat production frontier is written as:

$$\ln y_i = \ln \beta_0 + \sum_{j=1}^{9} \beta_j \ln x_{ij} + v_i - u_i \text{ ....} (7)$$

Where

Y_i represents the wheat yield per unit of the ith farm.

X_i represents the input vector of $x_{1i}, x_{2i}, \ldots\ldots x_{9i}$ inputs of the ith farm.

X_{1i} represents the Dummy variable showing value of BT area = 1 if the farmer is cultivate wheat crop on BT cotton field, and zero if farmer cultivating wheat crop on Non BT cotton area.

X_{2i} represents the area under wheat crop

X_{3i} represents sowing week of wheat crop.

X_{4i} represents the land preparation days of wheat crop.

X_{5i} represents the weedicide cost on wheat crop per acre

X_{6i}. represents number of irrigation per acre

X_{7i} NP ratio per acre.

X_{8i} represents seed rate (Kg) per acre.

X_{9i} number of ploughing per acre

III-4.ii. The Technical Inefficiency Effects of U_i:

The focus of present study is to provide an empirical analysis of the factors of productivity and inefficiency gaps among wheat farmers in Pakistan. The inefficiency function can be written as:

$$U_i = \delta_0 + \delta_1 edu + \delta_2 \, exp + \delta_3 age + \delta_4 crop.s + \delta_5 tube + \delta_6 trac + \delta_7 ten + \delta_8 own\text{-}cum + \delta_9 owner + W_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where

Educ = Education of the farmer in years

Age = Age of the farmer in years;

EXP= Experience of the farmer in years

Crop Sale = Dummy variable showing value of village =1 if the crop sale in village and zero if crop sale in market

Tractor = Dummy variable showing value of tubewell = 1 if the tractor on rent and zero if tractor is owned.

Tractor = Dummy variable showing value of Tractor = 1 if the tractor on rent and zero if tractor is owned.

Tenant =Dummy variable showing value of Tenant = 1 if the farmer is tenant, otherwise zero;

OwnTen= Dummy variable showing value of OwnTen =1 if the farmer is owner-cum tenant, otherwise zero;

Owner **=** Dummy variable showing value of owner = 1 if the farmer is owner, otherwise zero;

III-4.iii. Test of the Model Specification:

Two hypotheses have been tested with regard to the model specification. These tests are performed using generalized likelihood-ratio statistics, *LR*, The generalized likelihood-ratio is measured for testing the null hypothesis, that the inefficiency effects are not stochastic or that they do not depend on the firm-specific variables (Battses and Colie 1992 and 1995).

Which are defined as:

$$LR = -2 \ln [L (H0) / L (H1)]$$

$$Ho: \gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \ldots\ldots\ldots\ldots\ldots. = \delta_9 = 0$$

1. $Ho: \delta_1 = \delta_2 = \delta_3 = \ldots\ldots\ldots\ldots\ldots. = \delta_9 = 0$

The first null hypothesis that we will tested is **Ho: δ0 =** $\boldsymbol{\gamma = \delta_1 = \delta_2 = \delta_3 = \ldots\ldots\ldots\ldots\ldots = \delta_9 = 0}$ which specify that the farm level technical inefficiencies are not present in the model.

The second null hypothesis which will be tested is **H0: $\delta_1 = \ldots = \delta_9 = 0$**, whether the socio economic and farm management factors considered in inefficiency model, have a significant influence upon the degree of technical inefficiency associated with the wheat farmers.

IV.

Factors Influencing the Productivity and Technical Efficiency of Wheat Crop: Discussion of Results

Introduction:

Pakistan has made significant progress in wheat crop, overtime. But despite all of this increase in the productivity per unit of area has been very low in Pakistan. On all counts, Pakistan potentially can do much better than it does now, by improvement in technical efficiency of inputs of wheat crop. On the other hand, a large share of future yield increase will have to come from improved crop management (Ahmad 2000). This chapter devoted to presentation and discussion of descriptive and empirical analysis. Section IV-1 is about descriptive analysis; Section IV-2 includes empirical analysis.

IV-1. Descriptive Statistics of Sample Farms:

After the data collection, the next major step is to feed the data and its descriptive analysis, for which Special Package for Social Sciences (SPSS 16) has been used. Descriptive analysis gives all the information on the variables in questionnaire. This analysis helps to understand the percentages and mean, standard deviation and significance of various variables that are resulting from the information of the 430 questionnaire. Each variable is explained one by one.

Table 2. Farm size at sample farms

Characteristics	**<5 ac**	**5-12.5 acre**	**12.5-25 acre**	**> 25 acres**	**Prob.**
Average Farm size (ac)	3.67	8.74	17.00	60.93	
Number of farms	40	107	41	27	
Percent farms	19	50	19	13	.000

The area under cultivation is included in the instrument**.** The above table shows that 19% of the people cultivate the area of less than 5 acre and 50% and 19% of the people cultivate the area of 5-12.5 acre and 12.5-25 acre respectively. While only 13% of the farmers cultivate the area above 25 acre. These result showed that a large segment of the farmers are cultivating the area of 5-12.5 acre.

Table 3. Tenancy status by farm size categories

Tenancy	**<5 ac**	**5-12.5 acre**	**12.5-25 acre**	**> 25 acres**	**Over All**	**Prob.**
	Percentage					
Owner	43	36	37	41	38	
Tenant	47	51	27	4	40	
Owner-cum Tenant	11	13	37	56	22	.000

The instrument also takes the point the tenancy situation of farmers, like farmer is owner, tenant or owner cum tenant. The sample result explains that out of 430 farmers, the most common form of land tenure is tenancy that is 40 percent. Although owner operation is also common in the area in third cluster, 22 percent of farmers are owner cum tenant. Hence, greater numbers of farmers are tenant in the study area.

Table 4. Characteristics of sample farm

Characteristics	<5 ac	5-12.5 acre	12.5-25 acre	> 25 acres	Over All	Prob.
Farm Manger education (years)	7	6	7	7	6	0.70
Farm Manger age (years)	38	42	40	42	41	0.26
Farm manager experience (years)	17	21	18	20	19	0.21
Distance of farm from market (kms)	15	16	15	14	15	0.17
Family size (no)	8	8	9	15	9	0.00

"The characteristics of sample farms relate to an individual's management skills or entrepreneurial capability" (Feder et al., 1985) "and consist of characteristic such as the level of education, farming experience, age, distance from market and family size. They imitate a farmer's skill to understand farm technologies and their effect on farming as farmers do vary in their management skills" (Feder et al., 1985; Belknap and Saupe, 1988).

In this study, author has taken the information about the education level of the farm manager in years. Average education of the farm manger is six year of education. Average age of the farmer is (41) year and average experience of the farmers is (19) years. Average distance from main market is (15) kilometer and average family size of the farm manager is (9).

Table 5. Ownership patterns

Characteristics	<5 ac		5-12.5 ac		12.5-25 ac		> 25 ac		Total	Prob.
	Owned	Hired	Owned	Hired	Owned	Hired	Owned	Hired		
Tractor ownership(#)	6	74	62	152	58	24	44	10		
(%)	7.5	92.5	28.9	71.1	70.7	29.3	81	18.5	430	
Tubewell ownership(#)	8	72	60	154	46	36	44	10		
(%)	10	90	28.04	71.9	56.09	43.9	81	18.5	430	.000

Farm power is statistically significant to farm size. The use of tractors and tubewells is mainly confined to larger farms. Most of the small farmers used hired tractors and tubewells. Only 7.5 percent of farmers with less than 5 acres owned a tractor compared to 81 percent of the farmers with over 25 acre of farm size. In case of tubewell, only 8 percent of farmers with less than 5 acres owned a tubewell compared with over 25 acres of farm size. Most of small farmers hired tractor and tubewell for land preparation to avoid delays in planting and irrigation respectively.

Table 6. Source of irrigation

Group Operational Holding	<5 ac	5-12.5 acre	12.5-25 acre	> 25 acres	Over All	Prob.
Canal (#)	36	114	28	12	190	
(%)	18.9	60	14.7	6.3	44.2	
Tubewell (#)	0	4	0	0	4	
(%)	0	0.93	0	0	0.93	
Canal + tubewell (#)	44	96	54	42	236	
(%)	18.6	40.7	22.9	17.8	54.9	
Total (#)	80	214	82	54	430	
(%)	18.6	49.8	19.1	12.5	100	.000

Table 6 is the representation of the sources of irrigation of sampled farmers during Rabi cycle, it is clear that on the whole tubewell and canal both are the essential in supplying water to study area. Canals were the main source of irrigation water for 44.2% area. Merely 0.93% of farmers dependent on tubewell water only. Nearly 55% of the farmers relined on tubewell plus canal sources of irrigation. Sources of irrigation are statistically significant with size of operational holding.

Table 7. Cropping systems on different farm size categories

Particulars		<5 ac	5-12.5 ac	12.5-25 ac	> 25 ac	Over All	Prob.
		Area in acres					
Total Cotton area in acres (2009)	Mean	3.50	7.49	13.96	44.78	12.53	.000
Farm area allocated to cotton (%)		95	86	82	73	80	
Non-BT cotton (ac)	Mean (%)	1.79 (50%)	3.99 (53%)	7.39 (53%)	25.39 (57%)	6.84 (55%)	.000
- Bt-cotton area (ac)	Mean (%)	1.78 (50%)	3.49 (47%)	6.57 (47%)	19.39 (43%)	5.70 (45%)	.000
Wheat area 2009-10 (ac)	Mean	3.50	7.46	13.84	44.78	12.50	.000
Farm area allocated to wheat (%)		95	86	82	73	80	
Wheat area after Non-BT cotton (ac)	Mean (%)	1.7 (50%)	3.9 (53%)	7.4 (53%)	25.4 (57%)	6.8 (55%)	.000
Wheat area after Bt-Cotton (ac)	Mean (%)	1.7 (50%)	3.4 (47%)	6.5 (47%)	19.4 (43%)	5.7 (45%)	.000

Wheat and cotton are the major crops of the Rahim Yar Khan district; farmers were allocating around 80% to cotton crop in Kharif in the study area. Two varieties of cotton are grown in fields where wheat follows cotton. Non-BT cotton varieties had been rapidly replaced with BT-cotton varieties. Survey results shows that currently 55% area was planted under Non-BT cotton and 45% of area under BT-cotton (see table 7). According to PARC report in 2010, during last one year conventional cotton has been replaced further with BT-cotton on 15-20%. In Rabi farmers were allocating 80% area to wheat crop too. Wheat cultivated on Non-BT cotton area was 55% and 45% after BT-cotton.

Table 8. Cropping systems on different farm size categories

Particulars	**Non-BT Cotton Field**	**BT-cotton fields**	**All**	**Prob.**
Cotton sowing Month	May	April	May	.000
Cotton sowing Week	3rd week	2nd week	1st week	.000
Total number of cotton picking (no)	3	3	3	.75
Cotton last picking Month	October	November	November	.000
Cotton last picking week	4th week	3rd week	2nd week	.000
Total cotton crop duration (days)	191	221	206	.000
Wheat area planted before 15 November	0	0	0	-
Avg. Wheat area planted between 15-30 November	6.8 (100)	0	3.41	.000
Wheat area planted after 30 November		5.7 (100)	2.86	.000
Wheat crop duration(including sowing and harvesting time	144	126	135	.000
Land preparation days for wheat (days)	14	10	12	.000

The major conflict in the cotton-wheat cropping system is the prolonged harvesting of cotton resulting in late planting of wheat. The optimum planting period for wheat is in Rahim Yar Khan is in the first two weeks of November. This allows wheat to controls during the cool winter months and reduces the risk of exposure to hot weather in the critical period of early grain filling. Wheat after Non-BT cotton was planted on average 15 days later than wheat after other *kharif* crop or fallow. Wheat was planted after BT-cotton on average 30 days later. As mention earlier that BT-cotton has the characteristics of early sowing and late harvesting as compare to Non-BT cotton. Non-BT cotton sowing approximately begins in May 3rd week, on the other hand BT-cotton sowing was initiated in 2nd week of April, on average cotton sowing of both crop starts in 1st week of May. Non-BT cotton last picking on average started in 4th week of October, and BT cotton last picking begins in November 3rd week. Length of Non-BT and BT-cotton is 191 and 221 days respectively in the study area that clearly shows the one month differentiation in Non-BT and BT- cotton length of crop.

In the study area zero percent area planted before 15 November on Non-BT and BT-cotton field. Average wheat area planted in between 15 to 30 November is 100% on Non-BT cotton area and 0% on BT-cotton field. Wheat area planted after 30 November was 100% on BT-cotton area and 0% on Non-BT cotton area. These results demonstrated the obvious delay of 15 and 30 days in case of Non-BT and BT-cotton respectively, from optimum wheat planting date.

One the other hand cropping pattern determines the land preparation days for wheat. Farm mangers had 14 days on average for land preparation, when wheat planted on Non-BT cotton area and 10 days wheat area planted after BT-cotton.

Table 9. Cotton sowing dates spread at sample farms

Sowing Dates Spread	**Non-BT Cotton Field**	**BT-cotton fields**	**Prob.**
Percent Growers			
Before April 20	0	9	
April 20 to 30	0	33	
May 1 to 10	6	54	
MAY 11 TO 20	88	3	
Above May 20	6	0	.000

The above table specifically shows the cotton sowing dates spread at Non-BT and BT-cotton fields. The results shows that most commonly 88% of conventionally cotton planted in between 11th to 20th May. On the other hand BT cotton mainly planted from April 20 to 10th May.

Table 10. Cotton harvesting dates spread at sample farms

Harvesting Dates Spread	Non-BT Cotton Field	BT-cotton fields	Prob.
	Percent Growers		
Before 10 November	23	0	
10 to 20th November	60	1	
November 20 to 30	16	66	
Above 1st December	0	32	.000

The above table shows the harvesting spread of cotton in Non-BT and BT-cotton fields. The 60% of Non-BT cotton area was commonly picked in between 10th to 30th November. 23% and 16% area picked before 10th and in between 20th to 30th November respectively. In case of BT- cotton, 41% area was commonly picked in between 20th to 30th November. Around 31% and 16% area harvested after 1st December respectively. Only 12% BT-cotton area harvested before 10th November. Hence table 9 and 10 clearly shows the early sowing and late harvesting characteristics of BT- cotton as compared to Non-BT cotton varieties.

Table 11. Wheat varieties used after different cotton types

Particulars	Non-BT Cotton Field	BT-cotton fields	All	Prob.
Sahar	69	20	44	
Bahkar	23	53	38	
Abdul sattar	4	16	10	
Sahfaq	2	6	4	
Wattan	0	0	0	
Inqlab	2	6	4	.000

The survey recoded 6 varieties of wheat planted in the area. Many farmers use more than one variety to accommodate diverse planting dates after different cotton types. *Sahar* on Non-BT and *Bahkar* on BT cotton varieties were planted on 69% and 53% area of all farmers respectively. *Sahar* and *Bahkar* variety was also grown by the farmers for both normal and late planting. About 23% of farmers used *Bahkar* on Non-BT cotton fields and 20 % used *Sahar* on BT-cotton fields. Then the third main variety in the study area was the Abdul Sattar that was planted 4% on Non-BT cotton fields and 16% on Bt-cotton fields. *Shafaq, Watan* and *Inqlab* varieties were slightly used in study area. The problem of slow uptake of new varieties in the area is serious, especially in case of Bahkar variety. Only a few farmers recognized the names of new recommended varieties.

Table 12. Seed rate and sowing methods on sample farms

Particulars	**Non-BT Cotton Field**	**BT-cotton fields**	**Prob.**
Seed Rate (kg/ac)	51 (3.2)	60 Kg (4.4)	.000
Sowing method (%)			
Drill	10	8	
Broadcast	90	92	.569

The seed rate applied was 51 kg/acre on wheat after Non-BT cotton fields. As compare to Non-BT cotton, farmers planted wheat late on BT-cotton field, used 9 kg more seed to compensate delayed planting. Broadcasting of wheat is the usual method of wheat planting in the study area. Around 90% farmers used the method of broadcasting when wheat planted after Non-BT and 92% on BT-cotton fields and only 10% and 8% of farmers used drill method on Non-BT and BT-cotton field respectively.

Table 13. Wheat sowing dates spread at sample farms

Wheat planting dates	**Non-BT Cotton Field**	**BT-cotton fields**	**All**	**Prob.**
	Percent Area			
Before 15th November	0	0	0	.000
15 to 30th November	100	0	50	
Above 30th November	0	100	50	

In the study area 0% of farmer planted wheat after Non-BT and BT- cotton fields before 15th November. 100% of farmers planted wheat in between 15th of 30th November on Non-BT cotton field. In case of wheat planted after BT- cotton 100% of farmers sowing wheat in December. Studies conducted by Razzaq *et al.* (1986) showed that November planting produced higher wheat grain yield. Ansari (2002) while studying the influence of seeding time on grain yield of wheat varieties observed that wheat planted on November 10, displayed more grain yield than November 1 and November 20. He further concluded that each successive delay in sowing beyond November 10 significantly reduced grain yield. Ansari *et al.* (1989) and (Majid and Razzaq, 1999) concluded that best time of planting wheat with the present cultivars is early November.

IV-1.i. Wheat Management Differential on Non-BT and BT-cotton:

Table 14. Wheat Management differential on Non-BT and BT cotton fields

Particulars	**Non-BT Cotton Field**		**BT-cotton fields**		**All**		**Prob**
	Mean	Std	Mean	Std	Mean	Std	
Use of Nitrogen(Kg) Per ac	79.4	4.4	82.4	5.4	8.09	5.5	.000
Use of phosphorus (Kg)per ac	25.1	6.1	31.6	8.8	28.3	8.02	.000
NP ratio (Per ac)	3.46	0.194	3.59	0.269	3.52	0.244	.000
FYM applied(tones per ac)	2.32	1.09	2.45	0.94	2.39	1.02	0.171

Weedicide cost (per ac)	1007.7	507.8	1007.7	507.8	1007.7	507.2	1.000
Total number of Ploughing (per ac)	3.55	0.57	3.27	0.65	3.41	0.63	.000
Total number of irrigation (per ac)	3.95	0.50	3.76	0.50	3.85	0.51	.000

Above table shows the wheat management differential, when wheat planted after Non-BT and BT-cotton fields. All farmers were aware of the requirement to apply both nitrogenous and phosphatic fertilizers, although fertilizer application rates were slightly dissimilar among the farmers of sample area. Chemical fertilizer was used by 100% of sample farmer. The quantity of nitrogen applied on Non-BT cotton field was 79.4 kg and approximately 81 kg per acre on BT-cotton field. In case of phosphorus 25.1kg applied on Non-BT cotton field and 31.6 kg on BT-cotton field. NP ratio on Non-BT and BT-cotton field was 3.46 and 3.59 respectively. Though there was negligible variation in nitrogen, phosphorus and NP magnitude, when wheat planted on Non-BT and BT-cotton field. This may partly compensate for other negative aspects of wheat planted after BT-cotton (e.g. late planting, poor seed bed preparation and lower fertility). Niterogen, phouphous and NP ratio is statistically significant at 1 percent level, while wheat planted on Non-BT and BT- cotton field. The variation in the quantity of fertilizer applied is summarized in above table.

Application of farm yard manure (FYM) on Non-BT cotton field was 2.32 ton per acre on average and 2.45 on BT-cotton field. Application of FYM is statistically insignificant on wheat after Non-BT and BT-cotton field.

Weeds are the major problem of the study area. Use of weedicide spray was the most common method exercised by the farmer to control weeds. Application of weedicide spray was same on Non-BT and BT-cotton field. Consequently weedicide cost almost the same on both fields.

In case of wheat following Non-BT cotton the total number of ploughings was 3.55. In comparison, an average of 3.27 ploughings was done after BT-cotton. This is due to a number of factors especially the reduced time for tillage.

Total number of irrigation given to wheat in the study area slightly varied; in case of Non-BT cotton field average number of irrigation was approximately 4 and 3.76 number of irrigation on BT-cotton filed. The relationship between all wheat management differential on Non-BT and BT-cotton field is statistical significant except FYM application.

IV-1.ii. Wheat-Cotton Yield:

Table 15. Wheat – Cotton yield per ac on Non-BT and Bt-cotton fields

Particulars	**Non-BT Cotton Field**		**BT-cotton fields**		**All**		**Prob.**
	Mean	Std	Mean	Std	Mean	Std	
Wheat yield per ac (maund)	39.86	5.66	33.01	5.40	36.43	6.50	.000
Cotton yield per ac (maund)	22.9	5.7	25.4	6.7	24.4	6.3	.000

Table 15 demonstrates the wheat - cotton yield per ac on Non-BT and BT-cotton field. It evidently shows the difference when wheat planted on Non-BT cotton and BT-cotton fields. The average wheat yields for the Non-BT sampled field was just about 40 maunds per acre and approximately 33 muands on BT-cotton fields. The result evidently shows 7 maunds wheat yield differential per acre in between Non-BT and BT-cotton fields. The factors responsible for differences between high yield on Non-BT cotton field and low yield on BT-cotton fields are as follows:

i. The major differences between high and low yield are the high yielding generally followed by Non-BT cotton fields while low yielding fields followed BT-cotton fields. On Non-BT cotton field's farmers had about 7 muands per acre greater wheat yield as compared to Non-BT cotton fields.

ii. The Non-BT fields received slightly more ploughing for land preparation and more irrigation than BT-cotton fields.

iii. The Non-BT cotton fields likely to be planted before 30 November and BT-cotton fields tended to planted after 30 November.

iv. The largest differential factor of wheat yields in between Non-BT and BT cotton fields are the late planting of wheat after BT-cotton. Furthermore this late planting have an effect on soil fertility and land preparation.

Next part of the table shows the Non-BT and BT-cotton yield per acre in Kharif. Non-BT yield per acre was approximately 23 maund per acre; on the other hand BT cotton yield per acre was 25.4 maund. Several farmers in study area obtained lower cotton BT cotton yield per acre as contrast to Non-BT cotton and supposed that next *kharif* season they are not going cultivate BT cotton variety because it conferred lower cotton yield and less wheat yield while wheat planted on BT cotton field.

IV-1.iii.<u>Wheat Gross Margin after Non-BT and BT-cotton:</u>

Table16. Wheat Gross Margin after Non-Bt Cotton

Inputs	Unit	Quantity	Price	Value

Leaser Leveler	Rs.	1	2141	2141
Rotavator	Rs.	1	2005	2005
Ploughing	Rs.	1	1150	3918
Planking	Rs.	1	470	470
Tractor	Cost	1	1750	1750
Seed	Rs/ 50 kg	50kg	965	965
Urea	Price per bag	3 - 3.5	1000	3028
DAP	Price per bag	1 – 1.5	3100	3375
FYM	Rs /per ton	2.3	1255	2887
Weedicide	Cost	1	1006	1006
Irrigation	(#)	4	1279.535	5118.14
Total Variable Cost	Cost			26663.14
Outputs				
Price of wheat straw	Rs			6866.372
Price of wheat output	Rs			34181.93
Gross Margin Effect	Rs			14385.162

Table17. Wheat Gross Margin on BT- Cotton field

Inputs	Unit	Quantity	Price	Value
Leaser Leverler	Rs.	1	2142	2142
Rotavator	Rs.	1	2005	2005
Ploughing	Rs.	3 to 4	1140	3780
Planking	Rs.	1	470	470
Tractor	Cost	1	1755	1755
Seed	Rs/ 50 kg	60kg	1232	1232
Urea	Price per bag	3 to 4	1000	3046
DAP	Price per bag	1 to 2	3100	4261
FYM	Rs /per ton	2.45	1420	1420
Weedicide	Cost	1	1008	1008

Irrigation	(#)	3.76		4811.05
Total variable cost		RS/mds		25930
Output				
Price of wheat straw		RS/mds		5679
Price of wheat output		RS/mds		28315
Gross Margin Effect		Rs		8064

The gross margin of in wheat production on Non-BT and BT-cotton field are portrayed in table 16 and 17 respectively. On average gross margin of wheat on Non-BT cotton field is RS. 14385.16 and on BT- Cotton field is RS. 8064. There is a wide variation among gross margin of wheat on Non-BT and BT-cotton field. The gross margin in Non-BT cotton fields is greater than the wheat on BT-cotton fields. The reason behind this wide difference is wheat on Non-BT cotton fields received better land preparation and early planted as compare to Bt-cotton. It seems that a potential gain in wheat productivity, on Non-Bt cotton fields is higher for farmers of study area as compare to wheat on BT cotton fields.

IV-2. <u>Empirical Analysis:</u>

In FRONTIER 4.1 by (Coelli 1996) the C-D production frontier function and the inefficiency model are together estimated by the maximum-likelihood (ML) method. Before proceeding to examine the parameter estimates of the production frontier and the factors that affect the efficiency of the wheat farmers, we first investigate the validity of the model used for the analysis.

IV-2.i <u>Hypothesis Testing:</u>

These various tests of null hypotheses for the parameters in the frontier production functions and in the inefficiency models are performed using the generalized likelihood-ratio test statistic.

Table 18. Hypothesis Testing

Tests of Hypotheses				
Hypotheses	***Log Likelihood Function***	***Test Statistics*** χ^2	***Critical Value*** $\chi^2_{0.95}$	***Decision***
$H_o: \gamma=\delta_0=\ldots\delta_9=0$	-63.815	127.62	29.8	Rejected
$H_o: \delta_1=\delta_2\ldots\delta_9=0$	-44.103	60.59	32.80	Rejected

The first null hypothesis that was tested Ho: $\gamma=\delta_0=\ldots\delta_9=0$, which specifies that the technical inefficiency effects are not present in the model. This mean that the stochastic frontier productions function is not different than the traditional average production function. It should be noted that the log likelihood function for the full stochastic production frontier model is calculated to be 26.61 and the value for the OLS for the production function is -37.20. This implies that the generalized likelihood-ratio statistic for testing the absence of technical inefficiency effect from the frontier is calculated to be LR= -2*(-37.20-26.61) = 127.62(see table 18). The log likelihood test indicates that no inefficiency effects in wheat production rejected.

The second null hypothesis of this study which is tested is Ho: $\delta_1=\delta_2\ldots\delta_9=0$ implying that the farm level technical inefficiencies are not affected by the independent variables included in the model. This provides a likelihood ratio test statistics of 60.59, which is larger than the critical value of 0.95. Thus this hypothesis is also rejected.

IV-2.ii. Production Frontier and Technical Efficiency Estimates:

Table 19 shows the result of both the OLS and MLE estimates. The gamma estimate which is 0.92 shows the amount of variation resulting from the technical inefficiencies of wheat farms. This means that 92% of the variation in farmers' output is due to difference in technical efficiency. The value of gamma estimate is significantly different from one demonstrating that random shocks are playing a major role in explaining the variation in wheat production. In agriculture uncertainty is assumed to be the main source of variation due to the weather condition diseases etc. This result is very much according to our expectation. Out of the 22 parameters estimated, 18 are statistically significant.

Table 19.

		OLS		***Frontier Function***	
Variables	***Parameters***	***Coefficient***	***t-ratio***	***Coefficient***	***t-ratio***
Stochastic Production Frontier					
Constant	β_o	-1.4765	-0.3220	-1.0951	-0.3098
DNonBt/Bt	β_1	-0.1244	-1.9094	-0.1506	-2.6639***
Ln(Warea)	β_2	0.0416	4.9993	0.0347	5.1459***
Sowing	β_3	-0.6744	-2.1101	-0.4871	-1.9170**
Ln(land pre days)	β_4	1.2500	4.4132	1.1473	5.6013***
Ln(weedcost)	β_5	0.1197	5.7473	0.0852	4.8883***
Ln(irri)	β_6	0.2643	5.4066	0.1317	2.9588***
NP ratio	β_7	0.1988	2.8493	0.1885	3.1819***
Ln(seed)	β_8	-0.0511	-0.5013	-0.0280	-0.2593
Ln(Plough)	β_9	0.1862	5.3629	0.1446	5.1249***
Variance Parameters					
	Σ			0.1637	3.8060

	Γ			0.9226	37.651
Log Likelihood function		-37.201		26.614	

***: 1% significance, **: 5% significance, *: 10% significance,

To examine the affect of double cropping on wheat productivity, where wheat is planted after Non-Bt and BT-cotton. We used a dummy variable in the wheat production frontier model, that defined as the wheat after BT-cotton is one and in case of Non-BT cotton zero. The parameter estimate of wheat after BT or non BT cotton is negative and statistically significant. This result shows that production per acre declines significantly when wheat cultivated after BT-cotton. The major causes of this are less time for land preparation and late planting of wheat.[5]

Area under wheat crop comes as important factor of production with an elasticity of 0.0347. This result show that, an increase in the area under wheat crop would significantly lead to increased wheat yield. Similar results are acquired by Hassan (2005); Barnes (2008); Basnayake and Gunaratne (2002) along with Pakistani wheat farmers, Scottish cereal producers and Sri Lanka tea smallholders respectively.

To see the impact of sowing timing on wheat productivity we used a variable that is defined as the sowing week of wheat crop. The parameter estimate of sowing week is negative and significant. This result shows that production per acre declines significantly with each week successive delay in wheat sowing beyond November. In study area cotton wheat cropping pattern farmers frequently have difficulty in sustaining high-quality of wheat yield due to late sowing. Ansari *et al.* (1989) articulated that wheat crop sown from November 1 to December 1 gave

[5] As mention in descriptive analysis Bt-cotton have the characteristics of early sowing and late harvesting that leads to negative influence of wheat production.

significantly higher yield; further delay in sowing reduced the yield. Sowing date is one of the important factors that strongly influence wheat yield. According to (Khan and Salim, 1986) early planting wheat resulted in higher yields as compared with late planting in cotton-wheat cropping pattern. As figure out in descriptive analysis, when wheat planted after BT-Cotton, it leads to further delay in wheat sowing as compare to wheat planted after Non Bt-cotton.

The coefficient of land preparation days for wheat crop has positive sign and statistically significant. For attaining better wheat yield, land preparation practices is very important and it is only possible when farmer have sufficient time, for the reason that farmer has more time for destroying the weeds, removing residues of the cotton crop and capable to obtain good seed bed for wheat. As a result land preparation days significantly help in increasing wheat productivity.

The coefficient for weedicide cost variable is positive and statistically significant. This implies that, as farmers spend more money for purchase of weedicide spray leads to increase the wheat productivity positively. This result is according to our expectations because growth of weeds tends to reduce the wheat yield and lower the quality of wheat grains, so farmers of study area very much conscious about weeds affect on wheat production. This result is in line with (Hassan and Ahmad 2005) they also found positive and significant association between weedicide cost and wheat yield. (Rajaram, *et al.* 1988) estimated that 10 percent increase in wheat yield could be achieved by effectively controlling weeds. According to (Nayyar *et al*., 1992) weed infestation is one of the main reason of low wheat yield in Pakistan, which may reduce yield approximately 30% because wheat crop usually suffer from stress created by weeds through competition for water, nutrients, space and sunlight (Anderson, 1983)

The coefficient of number of irrigation is also significant and carries the positive sign. The magnitude of the parameter estimates shows that wheat productivity arises as number of irrigation increases. Looney (1999) explains that the application of other inputs can be effective only if an adequate and continued supply of water is available through irrigation. Bashir et al (2004) also mentions that basic reason of low wheat yield was the shortage of water at critical stages of wheat crop. (Hassan 2004); (Ahmad et al, 1998) and (Chuadhry 2002) also found the positive relationship between number of irrigation and wheat productivity.

The NP ratio variable has a positive sign and is also statistically significant at five. This result shows that there is scope of for increasing production of wheat by raising the use of NP ration in study area. According to (Salam 1981) intensive use of fertilizer on wheat crop is one of the major sources of higher wheat yield. (Bettese *et al.* 1993); (Chuadhry et al, 2002); (Hassan and Ahmad 2004); (Ghaderxadeh and Rahimi2008) and (Manjeet et al, 2010) also found that higher use of NP ratio positively and significantly affect on wheat yield.

The coefficient for the seed (Kg.) variable is 0.0280 with negative sign. This indicates that one percent increase in seed usage results in 0.28 % decline in wheat yield but insignificant. (Manjeet et al, 2010) and (Hassan 2005) also found the negative and insignificant relationship in between seed rate and wheat production. On the other hand (Bettese and Hassan 1999) found negative and significant result at less than five percent level. The primary reason for this negative sign is that farmers use much higher seed rate than the recommended one (45-50 kg.). No doubt seeding rate is important factor of production for wheat crop but for higher wheat yield mainly require appropriated seed rate. According to (Rafique et al., 2010) increase in seed rate above the optimum level only result in higher production cost without any increase in wheat yield.

The parameter of number of ploughing variable is positive and statistically significant. This result shows that a 1% increase in number of ploughing increases the wheat production by 0.14%. This result is in line with (Bettese *et al.* 1993) and (Hassan and Ahmad 2004).

IV-2.iii. Inefficiency Model

In order to investigate the factor of inefficiency, we estimated the technical inefficiency model by using equation 8 where inefficiency is assumed to be the dependent variable. The parameter estimates of the variables used in the inefficiency model are provided in Table 20.

Table 20. Inefficiency Model

Variables	*Parameter*	*Coefficient*	*t-ratio*
Constant	δ_0	-1.7876	-1.6956*
Edu	δ_1	-0.3339	-2.2261**
Exp	δ_2	-0.1404	-1.8300*
Age	δ_3	0.3253	1.8220*
Crop sale	δ_4	0.2881	2.9434***
Tubewell	δ_5	0.3606	2.6048***
Tractor	δ_6	0.2019	2.1051**
Tenant	δ_7	-0.6724	-2.4409**
Owner-Tenant	δ_8	-0.3687	-1.5166
Owner	δ_9	-0.4119	-1.6330

***: 1% significance, **: 5% significance, *: 10% significance,

The parameter of age of the farmers is positively and statistically significant at 10 percent level of significance. Age of farmer is one of the very important factors in case of decision making. This result shows that as age of farmer increases the farm efficiency declines. The reason for this association is that the aged farmers may be avoiding taking risks and experiments with new technologies. Subsequently we can say that older farmer is technically less efficient than the younger farmers. This result is in line with (chaudary et al 2002)

The parameter of experience of the farmer is negatively and statistically significant at 10 percent level. This result shows that experience is inversely related with inefficiency, as year of experience increases the farm efficiency increase. This result is in line with (Bakhsh etl al, 2006).

The coefficient for the education variable is negative consistent with our expectations and statistically significant at five percent level. This result implies education of farmer is a very important factor in enhancing wheat productivity. Wheat farmer with greater year of schooling tends to be less technically inefficient. According to (Ghura and Just 1992) educated farmers usually have higher tendency to adopt and use modern inputs and have better access to information related to prices and new technology and its use. This result is in line with those of Hussain (1999), Ahmad (2001), (chaudary et al 2002) ;Coelli (1996), Bettese *et al.* (1993, 1996), Rauf (1991), and Ali and Flinn (1989) and (Bakash 2006).

The parameter estimates of the sale of crop used as dummy variable .This dummy explains that sale of crop in village is 1 and towards market 0. The parameter estimates of the sale of crop carry the positive association with inefficiency and statistically significant at five percent level. The result very clearly demonstrates that the farm efficiency and thus the productivity would significantly increase with the sale of crop in market. The reason for this relationship may be due to the fact that in case of the sale of crop in market, farmer may be able to get right prices of wheat output as compare to sale of crop in village. Chaudhary (1995) reported that right prices in agriculture cause the rapid growth in farm yield. Under pricing of agriculture commodity appears in low wheat production.

The parameter estimates of tubewell ownership used as dummy variable representing value equal to one if tubewell on rent and zero if farmer is owner of tubewell. The coefficient for the tubewell ownership dummy is positive and statistically significant at five percent. This result shows that those farmers having their own tubewells are technically less inefficient than those who do not have their own tubewells. The reason for this relationship may be due to the fact those farmer have their own tubewell are able to provide timely supply of water throughout the cropping season. Especially the application of seed and fertilizer depends on the farmers controlled water supplies.

The parameter estimates of tractor ownership used as dummy variable. Dummy variable represents value equal to one if tractor on rent and zero if farmer is owner of tractor. The coefficient for the tractor ownership dummy is positive and statistically significant at five percent. This result shows that those farmers having their own tractor are technically less inefficient than those do not have their own tractor.

The parameter estimates of tenant used as dummy variable. Dummy variable showing value of tenant is equal to one if the farmer is tenant, otherwise zero. The parameter estimates of the tenant dummy variable carry negative sign and statistically significant at five percent level. The result reveals that tenants are technically more efficient. This result implies that the farm efficiency would significantly increase if farmer is tenant.

The parameter estimates of owner cum tenant used as dummy variable. Dummy showing value of owner cum tenant is equal to one if the farmer is owner cum tenant, otherwise zero. The coefficient of the owner cum tenant variable is negative, but it is non-significant so we cannot say that owner cum tenant farmers are technically less inefficient. The parameter estimates of owner of farm used as dummy variable. Owner dummy variable also carry the negative sign but statistically non-significant too. As a result it holds the identical case like owner cum tenant.

Tenurial arrangements one of the important factor and playing significant role in determining the farm level inefficiencies. According to (Chuadhary 2002) the tenants usually hold small area under cultivation and are generally under economic pressure paying the rent of land, facing high variable cost also have a pressure to save something for their families survival. Hence all these factors make tenant to liable to struggle more to achieve higher level of production.

IV-2.iv. Elasticity of Production and Returns to Scale:

Cobb-Douglas is a homogenous function with return to scale equivalent to the sum of parameters β. while elasticity of substitution is equal to the unity. Based on the production parameter estimates, we computed production elasticities and returns-to-scale for wheat farms, shown in Table 21.

Table. 21. Elasticity of production and return to scale

Variables	*Parameters*	*Elasticity*
DNonBt/Bt	β_1	-0.2862
Ln(Warea)	β_2	0.0347
Sowing	β_3	-0.4871
Ln(land preparation days)	β_4	1.1473
Ln(weedcost)	β_5	0.0852
Ln(irri)	β_6	0.1317
NP ratio	β_7	0.1885
Ln(seed)	β_8	-0.0280

Ln(Plough)	β_9	0.1446
Return to Scale		***0.9307***

The elasticity of production shows that farmers were experiencing decreasing returns to scale in wheat production in the study area with a value of 0.93. This value is less than one, indicating decreasing returns to scale in wheat production. The implication of such a result is that a proportional increase of all the factors of production leads to a less than proportional increase in production. The elasticities of frontier output with respect to inputs were estimated to be -0.28 for dummy wheat on Bt or Non Bt farm, 0.034 for wheat farm area, -0.48 for wheat sowing week, 1.14 land preparation days, 0.08 for weedicide cost, 0.13 for number of irrigation, 0.18 for NP ration, -0.02 for seed rate and 0.144 for number of ploughing. Of all input variables, land preparation days had the highest effect on productivity level with elasticity equal to 1.14. That is, a 1% increase in the land preparation day's results in an estimated increase in wheat production of 1.14%. The next highest elasticity was NP ratio 0.18 .That is, a 1% increase in NP ratio results in an estimated increase in wheat production of 0.18%. On the other hand, dummy of wheat on BT or non BT farms, sowing week and seed rate negatively influence on wheat production. However, the wheat farmer can do well by using appropriate seed rate, timely wheat planting and cultivation of wheat on Non-Bt cotton farms instead of Bt-cotton farms.

IV-2.v. __Technical Efficiency Analysis:__

The frequency distribution of estimated technical efficiency for wheat growers is given in table 22. The predicated technical efficiency for wheat farms ranges from 0.27 to 0.97 suggesting that there is great potential to increase per acre wheat yield. The mean technical efficiency turned out to be 76 percent at the aggregate level.

Table. 22 Frequency Distribution of Technical Efficiency of Wheat Farmers

Over all			***Non BT wheat***			***BT Wheat***		
Efficiency Level	***Frequency***	***%***	***Efficiency Level***	***Frequency***	***%***	***Efficiency Level***	***Frequency***	***%***
<0.20	0	0.00	<0.20	0	0.0	<0.20	0	0.0
0.21 -0.30	1	0.23	0.21 -0.30	0	0.0	0.21 -0.30	1	0.5
0.31-0.40	10	2.33	0.31-0.40	4	1.9	0.31-0.40	6	2.8
0.41-0.50	21	4.88	0.41-0.50	7	3.3	0.41-0.50	14	6.5
0.51-0.60	36	8.37	0.51-0.60	15	7.0	0.51-0.60	21	9.8
0.61-0.70	69	16.05	0.61-0.70	33	15.3	0.61-0.70	36	16.7
0.71-0.80	74	17.21	0.71-0.80	33	15.3	0.71-0.80	41	19.1
0.81-0.90	138	32.09	0.81-0.90	71	33.0	0.81-0.90	67	31.2
>0.90	81	18.84	>0.90	52	24.2	>0.90	29	13.5
Total	430	100	***Total***	215	100	***Total***	215	100
Mean	0.76		***Mean***	0.78		***Mean***	0.74	

If we separately observed the case of wheat after Non-BT and BT cotton groups, the results reveals that the mean technical efficiency ranged from 78 percent on wheat after Non-BT-cotton farms to 74 per cent on after BT-cotton. The mean technical efficiencies were 0.78 percent for wheat after Non-BT and 0.74 percent for wheat after BT-cotton farms. This indicated that those farmers cultivate wheat after Non BT-cotton were about 4 percent technically more efficient technically than those farmers who cultivate wheat after BT-cotton.

It was also observed that on aggregate level majority of the wheat farms (32.09%) operated at technical efficiency levels between 81 and 90 percent. About 17.2 percent and 16.05 percent, of the wheat farms lied in between 71-80 and 61-70 percent of the technical efficiency level. Further, the analysis revealed that about 18.8 percent of sample farmers were operating close to the frontier with the technical efficiency of more than 90 per cent. Around 16 percent of wheat farmers reclined below 60 percent of technical efficiency level.

On the other hand, around 33 percent, and 31.2 percent of wheat after Non BT and BT-cotton farms were found to be at efficiency level of less than 90 per cent. Around 15.3 percent and 19.1 of wheat on Non-BT and BT-cotton farms operated at the efficiency levels between 71 and 80 percent. The results also shows that around 24 percent of farms of wheat after Non-Bt and 13.2 percent of wheat after Bt-cotton farms operated closer to the frontier level with technical efficiency of more than 90 per cent.

The estimates of technical efficiency indicated a high degree of inefficiency in the production of wheat in Rahim Yar Khan. The stochastic frontier estimates of technical inefficiency worked out to be 24 percent at the aggregate level and 22 percent, 26 percent for wheat after Non-Bt and BT-cotton farms, respectively. In other words, wheat-cultivating farms in Rahim Yar Khan can increase the production of wheat by 22-26 per cent just by way of realizing efficiency, without necessarily increasing the quantity of inputs. The stochastic frontier analysis has further shown that 92 per cent of the observed inefficiency was due to farmers' inefficiency in decision making and only 8 percent of it was due to random factors outside their control. Hence, it is possible for wheat farmer of study area to improve wheat yield by 26 percent without increasing the level of inputs by using efficient management practices.

V-5.i. Efficiency Level of Each Farm:

The numbers of observations are 215 for wheat after Non-Bt and 215 also for wheat after BT cotton farms. The predicted technical efficiencies of the individual sample wheat farmers are presented in Table 23, together with the mean, maximum, minimum and standard deviation of wheat after Non BT and BT cotton. The highest level of technical efficiency is 0.97, while the lowest level is 0.34 for wheat after Non-BT cotton, in case of Wheat after BT-cotton the highest level of technical efficiency is 0.95, while the lowest level is 0.29. The frequencies of occurrence of technical efficiencies of farmers in different ranges and mean technical efficiency were previously discussed.

Table .23 Efficiency level of each firm

Efficiency Level of Each Farm			
Wheat on Non BT Farms	***Efficiency Estimate***	***Wheat on BT-Farms***	***Efficiency Estimate***
1	0.48	1	0.48
2	0.52	2	0.41
3	0.50	3	0.62
4	0.46	4	0.43
5	0.53	5	0.42
6	0.89	6	0.78
7	0.80	7	0.65
8	0.82	8	0.71
9	0.80	9	0.73
10	0.88	10	0.79
11	0.77	11	0.70
12	0.67	12	0.65
13	0.52	13	0.36
14	0.63	14	0.59
15	0.65	15	0.58
16	0.69	16	0.52
17	0.58	17	0.40
18	0.85	18	0.83
19	0.87	19	0.83
20	0.72	20	0.68
21	0.76	21	0.67
22	0.52	22	0.62
23	0.69	23	0.66
24	0.88	24	0.79
25	0.67	25	0.50
26	0.85	26	0.53
27	0.79	27	0.71
28	0.57	28	0.56

29	0.81	29	0.56
30	0.85	30	0.65
31	0.89	31	0.79
32	0.41	32	0.39
33	0.45	33	0.52
34	0.66	34	0.65
35	0.48	35	0.47
36	0.86	36	0.81
37	0.43	37	0.36
38	0.64	38	0.52
39	0.79	39	0.73
40	0.60	40	0.56
41	0.69	41	0.61
42	0.34	42	0.33
43	0.66	43	0.55
44	0.54	44	0.51
45	0.62	45	0.60
46	0.70	46	0.64
47	0.84	47	0.75
48	0.57	48	0.52
49	0.58	49	0.47
50	0.63	50	0.61
51	0.57	51	0.42
52	0.78	52	0.64
53	0.74	53	0.64
54	0.63	54	0.61
55	0.61	55	0.55
56	0.91	56	0.82
57	0.72	57	0.49
58	0.68	58	0.45
59	0.73	59	0.69
60	0.74	60	0.70
61	0.83	61	0.76
62	0.87	62	0.84
63	0.83	63	0.83
64	0.60	64	0.61
65	0.95	65	0.84
66	0.75	66	0.69
67	0.93	67	0.86
68	0.94	68	0.88
69	0.71	69	0.69
70	0.70	70	0.66
71	0.65	71	0.63
72	0.63	72	0.61
73	0.68	73	0.54
74	0.69	74	0.69
75	0.78	75	0.83
76	0.61	76	0.60
77	0.74	77	0.74
78	0.82	78	0.81
79	0.85	79	0.79
80	0.82	80	0.77

81	0.38	81	0.29
82	0.91	82	0.86
83	0.69	83	0.63
84	0.65	84	0.61
85	0.94	85	0.91
86	0.86	86	0.76
87	0.86	87	0.76
88	0.66	88	0.60
89	0.68	89	0.65
90	0.93	90	0.77
91	0.36	91	0.32
92	0.59	92	0.57
93	0.64	93	0.59
94	0.91	94	0.88
95	0.94	95	0.80
96	0.93	96	0.85
97	0.77	97	0.70
98	0.63	98	0.52
99	0.83	99	0.73
100	0.79	100	0.70
101	0.90	101	0.82
102	0.76	102	0.64
103	0.93	103	0.85
104	0.94	104	0.88
105	0.52	105	0.46
106	0.85	106	0.74
107	0.74	107	0.71
108	0.92	108	0.86
109	0.95	109	0.92
110	0.53	110	0.45
111	0.70	111	0.62
112	0.86	112	0.73
113	0.89	113	0.83
114	0.96	114	0.87
115	0.86	115	0.83
116	0.89	116	0.88
117	0.93	117	0.82
118	0.92	118	0.87
119	0.93	119	0.90
120	0.94	120	0.84
121	0.95	121	0.93
122	0.92	122	0.90
123	0.86	123	0.85
124	0.89	124	0.85
125	0.72	125	0.66
126	0.85	126	0.70
127	0.89	127	0.86
128	0.77	128	0.83
129	0.91	129	0.88
130	0.90	130	0.86
131	0.95	131	0.93
132	0.96	132	0.95

133	0.91	133	0.87
134	0.92	134	0.87
135	0.89	135	0.82
136	0.90	136	0.86
137	0.83	137	0.80
138	0.85	138	0.76
139	0.89	139	0.83
140	0.77	140	0.68
141	0.64	141	0.54
142	0.85	142	0.83
143	0.93	143	0.91
144	0.78	144	0.87
145	0.89	145	0.86
146	0.78	146	0.85
147	0.78	147	0.79
148	0.73	148	0.76
149	0.81	149	0.87
150	0.87	150	0.88
151	0.86	151	0.82
152	0.79	152	0.75
153	0.94	153	0.89
154	0.92	154	0.90
155	0.89	155	0.75
156	0.93	156	0.84
157	0.92	157	0.74
158	0.94	158	0.85
159	0.94	159	0.92
160	0.94	160	0.93
161	0.79	161	0.79
162	0.83	162	0.73
163	0.87	163	0.90
164	0.92	164	0.92
165	0.91	165	0.94
166	0.93	166	0.94
167	0.88	167	0.90
168	0.83	168	0.80
169	0.89	169	0.95
170	0.87	170	0.77
171	0.37	171	0.48
172	0.72	172	0.64
173	0.77	173	0.79
174	0.87	174	0.83
175	0.89	175	0.82
176	0.88	176	0.88
177	0.94	177	0.94
178	0.90	178	0.87
179	0.91	179	0.91
180	0.81	180	0.87
181	0.85	181	0.93
182	0.92	182	0.92
183	0.69	183	0.78
184	0.94	184	0.69

185	0.70	185	0.75
186	0.95	186	0.95
187	0.97	187	0.95
188	0.93	188	0.93
189	0.63	189	0.80
190	0.90	190	0.74
191	0.83	191	0.90
192	0.85	192	0.89
193	0.88	193	0.89
194	0.93	194	0.93
195	0.87	195	0.75
196	0.90	196	0.94
197	0.94	197	0.95
198	0.89	198	0.84
199	0.92	199	0.94
200	0.87	200	0.94
201	0.85	201	0.92
202	0.94	202	0.89
203	0.96	203	0.94
204	0.82	204	0.81
205	0.92	205	0.92
206	0.82	206	0.84
207	0.89	207	0.91
208	0.86	208	0.90
209	0.71	209	0.84
210	0.96	210	0.91
211	0.85	211	0.78
212	0.79	212	0.72
213	0.86	213	0.90
214	0.93	214	0.90
215	0.82	215	0.73
Minimum	0.34	***Minimum***	0.29
Maximum	0.97	***Maximum***	0.95
Mean	0.78	***Mean***	0.74
SD	0.144	***SD***	0.157

Sufficient evidence implying that there is positive and significant relationship between land preparation days, weedicide cost, number of ploughing area under wheat crop, number of irrigation, NP ratio and wheat productivity. While sowing week and dummy of wheat after Non BT and BT cotton show inverse and significant association with wheat productivity. The coefficient for the seed (Kg.) variable also carry negative sign but insignificant. The estimates of technical efficiency signify a high degree of inefficiency in production of wheat in Rahim Yar

Khan District. The stochastic frontier estimates of technical inefficiency worked out to be 24 percent at the aggregate level and 22 percent, 26 percent for wheat after Non-Bt and BT-cotton farms, respectively. The result clearly indicates that the efficient use of resources in wheat production can contribute to increase revenue at farm level. In Pakistan several studies have tried to measure technical efficiency of farms. According to these studies farmers' technical efficiency, in Pakistan ranges from 50 to 80 percent (Ali and Chaudhry (1990); Shah, et al. (1995); Ahamd, et al. (1999)Shafiq and Rehman (2000); Hassan (2004) and Chaudary et al, (2002).

V.

Conclusion and Policy Recommendations

“Like many other developing countries, agriculture sector occupies an important place in economy of Pakistan. It is expected that due to the heavy pressure of population, demand for agricultural commodities will increase in near future. Improving the economy of the agriculture sector, achieving the self-sufficiency in food, improving the farmers' income are the top priorities of the country” (Akmal 2007).

Pakistan has been almost regularly importing wheat, except for few years. Wheat domestic production has remained short of demands. In order to fulfill the food requirement of rapidly growing population as well as to save foreign exchange and for food security, we have to increase wheat production by utilizing all possible ways. Its domestic production has remained short of demands.

The purpose of this study was to identify the factors influencing the productivity and technical efficiency of wheat crop in Pakistan. It should be apparent that the conclusion of the study are at best tentative and have been derived from available primary data. In descriptive analysis first of all discusses the nature of wheat determinants to enable the readers to develop a relatively more realistic attitude towards analysis that followed. Such a research should be specifically designed to study the impact of varying degree of factors on wheat yield, the factors include are wheat after Non-BT and BT-cotton dummy, area under wheat crop, wheat sowing week, land preparation days for wheat crop, weedicide cost, number of irrigation, NP ratio, Seed rate, and number of ploughing. In inefficiency model, the socio-economic and management factors includes are age of farmer, farmer’s experience, education, sale of crops, tubewell ownership, tractor ownership, and tenurial status dummies (tenant, owner cum tenant and owner).

One of the most important fundamental conclusions of the study has been that the wheat after BT-cotton more adversely affects the wheat yield as compare to Non-BT cotton in study area. This conclusion owes its origin to basic conclusions.

The study based on primary research. Cross-sectional data has been used. The instrument used is the "questionnaire". The respondents of the study were those farmers that cultivate wheat after Non-BT and BT cotton. These result showed that a large segment of the farmers are cultivating the area of 5-12.5 acre. The sample result explains that out of 430 farmers, the most common form of land tenure is tenancy that is 40 percent. Hence, greater number of farmers is tenant in the study area. Average education of the farm manger is six year of education. Average age of the farmer is (41) year and average experience of the farmers is (19) years. Average distance from main market is (15) kilometer and average family size of the farm manager is (9). The use of tractors and tubewells is mainly confined to larger farms. Most of the small farmers used hired tractors and tubewells. Only 7.5 percent of farmers with less than 5 acres owned a tractor compared to 81 percent of the farmers with over 25 acre of farm size. In case of tubewell, only 8 percent of farmers with less than 5 acres owned a tubewell compared with over 25 acres of farm size. Wheat and cotton are the major crops of the Rahim Yar Khan district; two varieties of cotton are grown in fields where wheat follows cotton. Survey results shows that currently 55% area was planted under conventional cotton and 45% of area under BT-cotton

The study utilizes the stochastic production frontier approach to estimate technical inefficiency in wheat production. The results of study indicate that wheat productivity has a negative relationship while wheat cultivates after BT or non BT cotton. This result shows that production per acre declines significantly when wheat cultivated after BT-cotton. The reason for this negative relationship could be the late planting of wheat, less time for land preparation. The result of study shows that wheat productivity has a positive relationship with farm size, increase in farm size under wheat crop significantly affect wheat productivity. It is observed that delay in wheat sowing has an inverse relationship with the wheat productivity. Due to late sowing of wheat, farmers of study area are not able to achieve high quality of wheat yield. The study also identifies the increase in land preparation days positively and extensively affect on wheat productivity. The coefficient of seed is negative but insignificant relationship implying that this input is possibly being over utilized. So farmers in future should focus on optimum use of seed rate in wheat production.

The coefficients of number of irrigation and NP ratio are also significant and carry the positive sign, sufficient evidence implying that there is positive relationship between both inputs and wheat productivity. On the other hand results reveal positive relationship in between weedicide cost and wheat productivity. The result of study also exposes that number of ploughing is one of the important factor and positively and significantly affect on wheat productivity.

The result of efficiency analysis shows that the average technical efficiency turned out to be 76 at aggregate level. Thus an average farmer is producing 26 percent less than achievable potential output. The result also reveals that wheat farmers those cultivate wheat after Non-BT cotton are comparatively more efficient than those farmers who cultivate wheat after BT-cotton. The case of wheat after Non-BT and BT cotton groups, the results reveals that the mean technical efficiency ranged from 78 percent on wheat after Non-BT-cotton farms to 74 per cent on after BT-cotton. This indicated that those farmers cultivate wheat after Non BT-cotton was about 4 percent technically more efficient than those farmers who cultivate wheat after BT-cotton. The reason for this difference are that Non-cotton farmers in terms of having more time for land preparation, planting of wheat at appropriate time as compare to BT-cotton farmers, having adequate time to utilize all farm inputs in better way, in case of wheat after BT-cotton vice versa.

The stochastic frontier analysis has further shown that 92 percent of the observed inefficiency was due to farmers' inefficiency in decision making and only 8 percent of it was due to random factors outside their control. The results of inefficiency model reveal that education and experience are very important factor in enhancing wheat productivity. Wheat farmer with greater year of schooling and experience tends to be less technically inefficient. Hence, it is possible for wheat farmer of study area to expand wheat productivity by increasing production efficiency at the relatively inefficient farms without increasing the level of inputs by using efficient management practices. The study concludes that to ensure desirable production of wheat crop, socio-economic and management factors play an essential role in enhancing the wheat yield. Some policies recommendations for farm sector in Pakistan are as follows:

- There is essentially need to improve the use of existing wheat farmland through more efficient use of farm inputs and management practices.
- On the other hand ways and means for transfer of agricultural technologies among farmers should be explored.
- Late sowing of wheat is a major problem, due to delayed harvesting of cotton crop, especially in case of wheat after BT cotton that has late maturing characteristics. This leaves very short time for farmer for land preparation of wheat crop. There is immense need that research programs should include evolution of short duration and HYVs of cotton and wheat which will in turn

create additional opportunities like we will be able in achieving the self-sufficiency in food, improving the farmers' income and fiber needs of a country and economy.

Appendix

Questionnaire

Cotton – Wheat Management and Productivity System

Farmer Manager Name		Village		
Education (years)		Tehsil & District		
Farming Experience (Year)		Distance from metal road (KM)		
Age of Farm Manger (Year)		Size of Family (no)		
Wheat Kept for Household Consumption (Maunds)	Seed	Animal Feed	Household use	
Crop sale in market/village: 1 = Market, 2 = Village		Distance from main Market(Km)		
Selling Agency of surplus wheat	Village dealer	Arthi	Consumer	Other
Tenancy (Tick)	Owner	Tenant	Owner cum Tenant	
Total own land Area (ac)	Rented-in (ac)	Rented-out (ac)	Operational Holding (ac)	
Total area allocated to cotton (2009)				
Total cotton output (Maunds) (2009)				
Cotton sale price (Rs/ 40kg) (2009)				
Total area allocated to wheat 2009-10				
Total wheat output (Maunds) 2009-10				
Wheat sale price (Rs/ 40kg) 2009-10				
Price of wheat straw				

	Non-BT cotton	**Bt Cotton**
Cotton area in Kharif 2009 (ac)		
Total cotton production (Maunds)		
Other corps		
Cotton sowing dates (Month, week)		
Total # of cotton pickings (no)		

Last cotton picking date (Month, week)					
Land preparation days for next crop					
Area allocated to wheat after cotton					
Area allocated for other crops on remaining cotton area	#	Crop	Area(ac)	Crop	Area(ac)
	1				
	2				
	3				
	4				
Name of **main wheat varieties** grown**:**	Number of variety	Variety	Area (ac)	Variety	Area (ac)
	Var. 1				
	Var. 2				
	Var. 3				
	Var. 4				
Seed source of main variety: 1=Own, 2=Input dealer, 3=Fallow farmer, 4=Other (sp)					
Wheat area **planted** before **15** November (Katik Month)					
Wheat area planted **between 15-30** November (Magher Month)					
Wheat area planted **after 30** November					
Length of crop (includes sowing and harvesting time)					
Tractor: 1=Owned, 2=Hired					
Deep Plg. :(ac)+(Price)/(ac)					

Leveler :(ac)+(Price)/(ac)					
Leveling area :(ac)+ (Price)/(ac)					
Mould board : (ac)+ (Price)/(ac)					
Rotavator : (ac)+ (Price)/(ac)					
Disc: (ac)+(Price)					
Ploughing (no)+(price)/(ac): Cultivator					
Planking: (ac)+(Price)/(ac)					
Main Soil Type (Tick)	Mera	Darmiani Mera	Bahri Mera	Pakki	Chikkni
Seed rate for **early** planted wheat (Kg/ac)+ (Price/kg)					
Seed rate for **late** planted wheat (Kg/ac)					
Seed treatment: 1=Yes, 2=No, If YES, Cost/acre					
Wheat Planting Method 1. Drill/line sowing 2. Broadcost (ac) **+ Cost/acre**					
Fertilizer use for per acre wheat area (bags)/(ac)+(Price per bag)					
Basal dressing: DAP	Urea				
NP	SSP				
Other (sp)					

	Other (sp)				
Top dressing DAP	Urea				
Total number of **top dressings** applied (no)					
Availability of phosphatic fertilizer: 1=Shortage, 2=No shortage					
Quality of Fertilizer available this year: 1=Same , 2=Better 3=Low					
Wheat area applied Farm Yard Manure tones per/(ac)					
Farm Yard Manure cost /(per ac)		Area	Cost	Area	Cost
Wheat area seriously **infested with weeds** (ac)					
Types of major problematic weeds					
Chemical weeding (Acres & cost per acre)		Area	Cost	Area	Cost
If No Reason		________________		________________ ________________	
Manual weeding (Acres & Cost)					
Irrigation (no): Canal	T.well	Canal +T.well			
Tubewell ownership: 1=Owned, 2=Rented					
Tubewell type: 1=Tractor, 2=Peter, 3=Engine, 4=Electric					

Canal water supply at crop develop stages: 1=Normal, 2= Less than normal		
Water Quality (tick)	Fit for irrigation	Slightly Saline
Average depth of irrigation (inches)		
Area affected with **Aphid/Jasiid** (acres)		
Wheat **yield loss** due to **Aphid/Jassid** (mds/ac)		
Wheat **Yield** mds/acres		
Credit from Bank availed for wheat inputs (Rs)		
Credit from informal sources (Arthi/V.dealer) (Rs)		
Next year estimated area allocations to wheat crop (ac)		
If **Area increased,** reasons;		1.____________________ 2.____________________
If **area decreased,** reasons;		1.____________________ 2.____________________
Farmer Suggested measures for sustaining next year wheat yield (Rank) 1. ____________ 2____________ 3 ____________ 4____________		

Wheat sale price (Rs/ 40kg) 2009-10		
Price of wheat straw		
	Non-BT cotton	**Bt Cotton**

Cotton area in Kharif 2009 (ac)					
Total cotton production (Maunds)					
Other corps					
Cotton sowing dates (Month, week)					
Total # of cotton pickings (no)					
Last cotton picking date (Month, week)					
Land preparation days for next crop					
Area allocated to wheat after cotton					
Area allocated for other crops on remaining cotton area	#	Crop	Area(ac)	Crop	Area(ac)
	1				
	2				
	3				
	4				
Name of **main wheat varieties** grown**:**	Number of variety	Variety	Area (ac)	Variety	Area (ac)
	Var. 1				
	Var. 2				
	Var. 3				
	Var. 4				
Seed source of main variety: **1=Own, 2=Input dealer, 3=Fallow farmer, 4=Other (sp)**					
Wheat area **planted** before **15** November (Katik Month)					
Wheat area planted **between 15-30** November (Magher Month)					

Wheat area planted **after 30** November					
Length of crop (includes sowing and harvesting time)					
Tractor: 1=Owned, 2=Hired					
Deep Plg. :(ac)+(Price)/(ac)					
Leveler :(ac)+(Price)/(ac)					
Leveling area :(ac)+ (Price)/(ac)					
Mould board : (ac)+ (Price)/(ac)					
Rotavator : (ac)+ (Price)/(ac)					
Disc: (ac)+(Price)					
Ploughing (no)+(price)/(ac): Cultivator					
Planking: (ac)+(Price)/(ac)					
Main Soil Type (Tick)	Mera	Darmiani Mera	Bahri Mera	Pakki	Chikkni
Seed rate for **early** planted wheat (Kg/ac)+ (Price/kg)					
Seed rate for **late** planted wheat (Kg/ac)					
Seed treatment: 1=Yes, 2=No, If YES, Cost/acre					
Wheat Planting Method 1. Drill/line sowing 2. Broadcost (ac) **+ Cost/acre**					
Fertilizer use for per acre wheat area (bags)/(ac)+(Price per bag)					

Basal dressing: DAP	Urea				
NP	SSP				
Other (sp)	Other (sp)				
Top dressing DAP	Urea				
Total number of **top dressings** applied (no)					
Availability of phosphatic fertilizer: 1=Shortage, 2=No shortage					
Quality of Fertilizer available this year: 1=Same , 2=Better 3=Low					
Wheat area applied Farm Yard Manure tones per/(ac)					
Farm Yard Manure cost /(per ac)		Area	Cost	Area	Cost
Wheat area seriously **infested with weeds** (ac)					
Types of major problematic weeds					
Chemical weeding (Acres & cost per acre)		Area	Cost	Area	Cost
If No Reason		____________		____________	
Manual weeding (Acres & Cost)					

<table>
<tr><td>Irrigation (no):
Canal</td><td>T.well</td><td>Canal
+T.well</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Tubewell ownership:
1=Owned, 2=Rented</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">Tubewell type:
1=Tractor, 2=Peter, 3=Engine, 4=Electric</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">Canal water supply at crop develop stages: 1=Normal, 2= Less than normal</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">Water Quality (tick)</td><td colspan="3">Fit for irrigation</td><td colspan="3">Slightly Saline</td></tr>
<tr><td colspan="3">Average depth of irrigation (inches)</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="4">Area affected with Aphid/Jasiid (acres)</td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td colspan="4">Wheat yield loss due to Aphid/Jassid (mds/ac)</td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td colspan="4">Wheat Yield mds/acres</td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td colspan="4"><u>Credit from Bank availed for wheat inputs (Rs)</u></td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td colspan="4"><u>Credit from informal sources (Arthi/V.dealer) (Rs)</u></td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td colspan="6">Next year estimated area allocations to wheat crop (ac)</td><td colspan="3"></td></tr>
<tr><td colspan="6">If Area increased, reasons;</td><td colspan="3">1.____________________
2.____________________</td></tr>
<tr><td colspan="6">If area decreased, reasons;</td><td colspan="3">1.____________________
2.____________________</td></tr>
<tr><td colspan="9">Farmer Suggested measures for sustaining next year wheat yield (Rank)
1. ________________ 2________________ 3 ________________ 4________________</td></tr>
</table>