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An Efficiency Analysis of Punjab's Cotton-Wheat System

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Abstract

This study examines the technical, allocative, and economic efficiencies of the cotton-wheat farming system in Punjab, Pakistan. It also investigates the determinants of these efficiencies using a non-parametric data envelopment analysis (DEA) technique. Technical, allocative, and economic inefficiency scores are separately regressed on socioeconomic and farm-specific variables to identify the sources of inefficiency using a Tobit regression model. The mean technical, allocative, and economic efficiencies calculated for the system were 0.87, 0.44, and 0.37, respectively. Our results indicate that years of schooling and the number of contacts with extension agents have a negative impact on the inefficiency of cotton-wheat farming in Punjab.

Keywords: Cotton, wheat, economic efficiency, data envelopment analysis.

JEL Classification: C14, D61.

I. Introduction

Cotton and wheat are the most important crops grown in Pakistan. The current market share of cotton (among fibers used for apparel and furnishings) in the world is 56 percent (Ahmad 2008), and Pakistan is the fourth-largest cotton producing country in the world after the USA, China, and India. Cotton is Pakistan's major export-earning crop and it also provides raw material to the local textile industry. Cotton accounts for 8.6 percent of the value-added in agriculture and 1.9 percent of Pakistan's gross domestic product (GDP). Under the World Trade Organization (WTO)'s

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post-quota scenario[1], Pakistan has the potential to become a leading force in the worldwide cotton and textile market (Government of Pakistan 2007).

Wheat is the country's main staple food; 75-80 percent of households' food budget is spent on wheat alone (Hassan 2004). It is Pakistan's largest grain crop, and contributes 14.4 percent to the value-added in agriculture and 3.0 percent to GDP (Government of Pakistan 2007).

The recent food scarcity and rises in price have affected almost every country in the world, including Pakistan. The present food crisis is an eye opener for policymakers in Pakistan. Riots have erupted in several parts of the country due to the scarcity of food and price hikes. In order to obtain self-sufficiency in food production and earn foreign exchange, policymakers need to formulate policies both for the short and long term. Possible ways to enhance agricultural production include expanding the cultivated area, increasing cropping intensity, technological changes, and improvements in production efficiency. The latter option seems to be the most suitable in the short run.

In order to model production increases in efficiency, it is useful to look at analyses of firm level efficiency. Farrell (1957) proposes that the efficiency of a firm has two components: (i) technical efficiency, and (ii) allocative efficiency. Technical efficiency is the ability of a firm to produce a maximal output from a given set of inputs or the ability of a firm to produce a given level of output with the minimum quantity of inputs and available technology (Bukhsh 2006). Allocative efficiency is the ability of a firm to use inputs in optimal proportions, given the market prices of inputs and outputs. Economic efficiency is the multiplicative product of technical and allocative efficiency (Coelli, *et al* 1998).

Eight types of farming systems are practiced in Pakistan: cotton-wheat, rice-wheat, mixed crops, pulses-wheat, maize-wheat-oilseed, maize-wheat, orchards/vegetable-wheat and peri-urban around Quetta. Among these systems, the cotton-wheat system is of great importance for the economy of Pakistan. This system not only ensures food security to a large population, but is also a major source of foreign exchange earnings. The total agricultural area under the cotton-wheat farming system in Pakistan is 7.1 million hectares (ha) [Food and Agriculture Organization (FAO) 2004].

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[1] For decades, global trade in textiles and clothing has been subjected to quantitative restrictions imposed by many developed countries to protect their domestic textile industry. By 1 January 2005, under the WTO, all quotas on the import of textiles were eliminated and importing countries are no longer be able to restrict trade in textiles and clothing unless it can justify such restrictions under the provision of Article XIX of the GATT.

This study is designed to estimate the technical, allocative, and economic efficiency of cotton-wheat farming in Punjab, Pakistan. Punjab is the country's most populated and second-largest province in terms of area. The total agricultural area under the cotton-wheat system in Punjab is 5.5 million ha, or about 77 percent of the total agricultural area under cotton-wheat farming in Pakistan (FAO 2004).

The paper is organized as follows: our analytical framework is described in the second section. The sampling procedure and data are described in the third section. The fourth section provides the empirical models. The fifth section provides the results and discussion. Our conclusions are given in the last section.

II. Analytical Framework

A. Production Efficiency Estimates

According to Farrell (1957), efficiency is defined as the actual productivity of a firm relative to its maximal productivity. Maximal productivity (also called best practice) is defined by the production frontier (Lissitsa *et al.* 2005).

The principal approaches to estimating the production frontier are:

(i) The parametric approach through stochastic frontier analysis (SFA),

(ii) The nonparametric approach through data envelopment analysis (DEA).

Both approaches estimate the best practice frontier and calculate the efficiency of a firm relative to that frontier (Latruffe 2002).

Nonparametric or DEA models are based on mathematical programming techniques. Specifically, a linear programming technique that uses data on inputs and outputs is used to construct a best practice production frontier over the data points. The efficiency of each firm is measured by the distance between the observed data points and the frontier. Firms lying on the frontier are the most efficient within the sample while the remaining firms lying below the frontier are inefficient. Their inefficiency increases with the increase in distance from the production frontier.

Charnes, *et al* (1978) proposes an input-oriented DEA model with assumed constant returns to scale. DEA can be either input- or outputoriented (Coelli, *et al* 1998). In the first case, the DEA technique defines the frontier by seeking the maximum possible proportional reduction in input usage with output levels held constant. In the second case, the DEA method defines the frontier by seeking the maximum possible proportional expansion in output, with the same input levels (Lissitsa, *et al* 2005).

Coelli, *et al* (1998) suggests that the orientation be selected according to the quantities (output or inputs) the manager has more control over. As farmers have more control over inputs than output, an input-oriented DEA model is used in this study.

The DEA technique has the following advantages:

(i) It does not require the assumption of a functional form to specify the relationship between inputs and outputs (Krasachat 2003).

(ii) It does not require any assumption about the distribution of the underlying data.

(iii) It can readily incorporate multiple inputs and outputs.

(iv) It provides a means of decomposing economic efficiency into technical and allocative efficiency and also technical efficiency into pure technical and scale efficiency.

Estimation of Technical Efficiency

Technical efficiency scores can be obtained by running a constant returns to scale DEA model or a variable returns to scale DEA model. DEA was first developed by Charnes, Cooper and Rhodes under the assumption of constant returns to scale in 1978 (Coelli, *et al* 1998). Coelli, *et al* (1998) suggest that a constant returns to scale DEA model is only appropriate when all firms are operating at an optimal scale; this is not possible in agriculture due to many constraints. The use of a constant returns to scale DEA model when all firms are not operating at an optimal scale results in measures of technical efficiencies that are confounded by scale efficiencies. In order to avoid this problem, Bankers, *et al.* (1984) modifies the constant returns to scale DEA model into a variable returns to scale model by adding convexity constraints.

An input-oriented DEA model under the assumption of variable returns to scale was used to estimate technical efficiency in this study.

Assuming we have data on K inputs and M outputs of N farms, x_i is an input vector for the ith farm and y_i is an output vector for the ith farm. The KxN input matrix, X, and MxN output matrix, Y, represent the data of all for N farms. For each farm, we obtain a measure of the ratio of all outputs over all inputs, such as $u'y_i/v'x_i$, where u is an Mx1 vector of output weights and v is Kx1 vector of input weights.

To select optimal weights we solve the mathematical programming problem as specified by Coelli*, et al* (1998).

$$\max_{u,v} (u'y_i/v'x_i)$$

$$\text{subject to} \qquad u'y_j/v'x_j \le 1, \ j= 1,2,\ldots\ldots N, \quad u, v \ge 0$$

This problem involves finding the value of u and v, such that the efficiency measure of the ith farm ($u'y_i/v'x_i$) is maximized, subject to the constraints that all efficiency measures must be less than or equal to 1.

One problem with this particular ratio formation is that it has an infinite number of solutions. To overcome this problem, we impose the constraints $v'x_i = 1$ to the above problem.

$$\max_{u,v} (u'y_i/v'x_i)$$

$$\text{subject to} \qquad v'x_i = 1, \quad u'y_j/v'x_j \le 1, \ j= 1,2,\ldots\ldots N, \quad u, v \ge 0$$

Using the duality problem in linear programming, we can derive an equivalent form of this problem:

$$\min_{\theta,\lambda} \theta,$$

$$\text{subject to} \qquad -y_i + Y\lambda \ge 0, \quad \theta x_i - X\lambda \ge 0, \quad \lambda \ge 0$$

where θ is a scalar and represents the technical efficiency score of the ith farm. The value of θ must satisfy the restriction: $\theta \le 1$. If θ is equal to 1, it indicates that the farm is on the production frontier and is a fully technically efficient farm. λ is a Nx1 vector of constants. The linear programming problem must be solved N times, once for each farm in the sample. A value of θ is then obtained for each farm.

The constant returns to scale DEA model assumes that all farms are operating at optimal level but this may not be possible for a number of reasons such as imperfect competition and financial constraints, etc. The use of the constant returns to scale specification when not all farms are operating at the optimal scale will result in a measure of technical efficiency that is confounded by scale efficiencies. In order to overcome this problem, Banker, *et al* (1984) modify the constant returns to scale DEA model into a variable returns to scale model by adding convexity constraints; this permits the estimation of technical efficiency devoid of scale efficiency effects.

The linear problem for the ith firm under the assumption of a variable returns to scale DEA model is given as:

$$\min_{\theta,\lambda} \theta,$$

$$\text{subject to} \quad \begin{aligned} -y_i + Y\lambda &\geq 0 \\ x_i - X\lambda &\geq 0 \\ N1'\lambda &= 1 \\ \lambda &\geq 0 \end{aligned}$$

where N1 is an Nx1 vector of ones and $N1'\lambda = 1$ is a convexity constraint that ensures that an inefficient farm is only benchmarked against farms of a similar size.

Estimation of Economic Efficiency

Economic efficiency is the ratio of the minimum cost to the observed cost. Following Coelli, *et al* (1998), a cost minimization DEA model was used to estimate the minimum cost as follows:

$$\min_{\lambda, X_i^E} X_i^E \boldsymbol{w}_i$$

$$\text{subject to} \quad \begin{aligned} -y_i + Y\lambda &\geq 0 \\ X_i^E - X\lambda &\geq 0 \\ N1'\lambda &= 1 \\ \lambda &\geq 0 \end{aligned}$$

where w_i is a vector of input prices for the ith firm and x_i^E is the cost minimizing vector of input quantities for the ith firm, given the input prices w_i and output level y_i.

Economic efficiency = minimum cost/observed cost, thus

$$EE = w_i x_i^E / w_i x_i$$

Estimation of Allocative Efficiency

Allocative efficiency was estimated by dividing economic efficiency by technical efficiency:

Allocative efficiency = Economic efficiency/technical efficiency

B. Factors Affecting Production Inefficiency

There are two approaches to investigating the relationship between farm inefficiency and various socioeconomic and farm-specific factors. The first method is to compute correlation coefficients or conduct a simple nonparametric analysis. The second method is to measure inefficiency and use a regression model in which inefficiency is expressed as a function of socioeconomic and farm-specific factors. The second approach is also known as the 'two-step procedure' and is the most commonly used (Haji 2006). This approach was adopted in this study.

We have used DEA models to estimate technical, allocative, and economic efficiency. The method adopted by Featherstone, *et al* (1997) and Ogunyinka and Ajibefun (2004) was followed to calculate inefficiency indices by subtracting the efficiency estimates from 1. The technical, allocative, and economic inefficiency scores were separately regressed on socioeconomic and farm-specific variables to identify the sources of technical, allocative, and economic inefficiency, respectively.

Dhangana, *et al* (2000) shows that the inefficiency scores from DEA are limited to between 0 and 1. Therefore, the dependent variable in our regression model does not have a normal distribution. This suggests that ordinary least square (OLS) regression is not appropriate because it would lead to a biased parameters estimate (Krasachat 2003). We therefore use a Tobit regression model (Tobin 1958), as mentioned in Long (1997). This takes the form:

$$E_i^* = Z_i\beta + \mu_i$$

$$E_i = 0 \qquad if \; E_i^* \leq 0$$
$$E_i = E_i^* \qquad if \; E_i^* > 0$$

where E_i is an inefficiency score, $ß$ is a vector of unknown parameters and Z_i is a vector of socioeconomic and farm-specific variables. E_i^* is an index variable (sometimes called the latent variable) with $E = [E_i^* | Z_i]$ equals $Z_i\beta$, and μ_i is the error term with a normal distribution $\mu \sim N(0, \delta^2)$.

III. Sampling Procedure and Data

The data used in this study were generated by a cross-sectional survey using a multistage random sampling technique. A four-stage sample design was used to collect data from the field. First-stage units were districts, second-stage units were tehsils, third-stage units were villages, and fourth-stage units were farmers. During the first stage, Rahimyar Khan and Muzaffargarh districts were selected randomly from the cotton-wheat system in Punjab. Sadiqabad and Rahimyar Khan tehsils were selected from Rahimyar Khan district, and Muzaffargarh and Alipur tehsils were selected from Muzaffargarh district using a simple random sampling technique. Two villages from each tehsil were randomly selected, followed by 25 farmers from each village using a simple random technique. A total of 200 farmers, 100 from each district, were sampled from the cotton-wheat system. All selected farms were viewed as a random sample from the whole farming system. The data were collected for the crop year 2005/06 (kharif 2006 and rabi 2005/06). A comprehensively designed and pretested questionnaire was used to collect information from farm respondents.

IV. Empirical Models

The output variable used to estimate technical efficiency was total farm income (Y), which includes income from crops and livestock. The total income from crops was estimated by multiplying the output of each crop by the price received by the farmer; total income from livestock was obtained by aggregating the value of milk and live animals sold.[2] The inputs used in this study included land (X_1), tractors (X_2), seed (X_3), NPK (X_4), pesticide (X_5), labor (X_6), irrigation (X_7), fodder (X_8), and concentrates (X_9).

Following Coelli, *et al* (1998), an input-oriented variable returns to scale DEA model was used to estimate technical efficiency as follows:

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[2] Farmers receive different prices for commodities from local shopkeepers, vendors, and arhtiyas.

$$\min_{\theta,\lambda} \theta,$$

subject to

$$-y_i + Y\lambda \geq 0$$
$$\theta x_i - X\lambda \geq 0$$
$$N1'\lambda = 1$$
$$\lambda \geq 0$$

θ represents the total technical efficiency of the ith farm.

λ represents Nx1 constants.

$N1'\lambda = 1$ represents a convexity constraint which ensures that an inefficient firm is only benchmarked against firms of a similar size.

Y represents the output matrix for N farms.

θ represents the total technical efficiency of the ith farm.

λ represents Nx1 constants.

X represents the input matrix for N farms.

y_i represents the total farm income of the ith farm in rupees.

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

x_{1i} represents the total cropped area in acres on the ith farm.

x_{2i} represents the total quantity of seed (kg) used on the ith farm.

x_{3i} shows the total number of tractor-hours used for all farm operations including plowing, planking, ridging, hoeing, fertilizing, spraying, and land leveling, etc. on the ith farm.

x_{4i} represents NPK nutrients (kg) used on the ith farm. It was observed that some farmers in the sample area also used farmyard manure. It was therefore more plausible to determine the quantity of NPK present in farmyard manure. These nutrients were calculated on the basis of chemical composition as given by Brady (1990).

x_{5i} represents the total quantity of pesticides (active ingredient) (g) used on the ith farm.

x_{6i} indicates the labor input consisting of family and hired labor, and was calculated as the total number of person-days required to perform various farming operations on the ith farm.

x_{7i} represents the total number of irrigation hours used on the ith farm.

x_{8i} represents the total quantity of fodder (kg) used to feed animals on the ith farm.

x_{9i} represents the total quantity of concentrates (kg) used to feed animals on the ith farm.

Following Coelli, *et al.* (1998), a cost minimization DEA model was used to estimate the minimum cost:

$$\min_{\lambda, X_i^E} X_i^E w_i$$

$$\text{subject to} \quad -y_i + Y\lambda \geq 0$$
$$X_i^E - X\lambda \geq 0$$
$$N1'\lambda = 1$$
$$\lambda \geq 0$$

where

w_i is the vector of input price $w_{1i}, w_{2i}, \ldots\ldots\ldots, w_{9i}$ of the ith farm.[3]

X_i^E is the cost minimizing vector of input quantities for the ith firm.

N refers to the total number of farms in the sample.

w_{1i} represents the land rent of the ith farm in rupees.

w_{2i} represents the total cost of seed used on the ith farm in rupees.

w_{3i} represents the total amount paid for the use of tractors on the ith farm in rupees.

w_{4i} represents the total cost of NPK used on the ith farm in rupees.

[3] Information on prices paid were collected from each farmer. Farmers pay different prices for inputs according to the availability of cash and inputs, the distance of the village from the market, and availability of transport facilities.

w_{5i} represents the total cost of pesticide/weedicide used on the ith farm in rupees.

w_{6i} represents the total cost of labor used on the ith farm in rupees.

w_{7i} represents the total cost of irrigation water used on the ith farm in rupees.

w_{8i} represents the total cost of fodder used to feed animals on the ith farm in rupees.

w_{9i} represents the total cost of concentrates used to feed animals on the ith farm in rupees.

Economic efficiency is the ratio between minimum cost and observed cost and was estimated using the following formula.

$$EE = w_i x_i^E / w_i x_i$$

Allocative efficiency was obtained by dividing economic efficiency by technical efficiency.

A question of great interest to policymakers is why efficiency differentials occur across farmers from the same farming system. These could be a reflection of the managerial ability and skill of a farm's operator and the interaction of various socioeconomic factors. The present study made an attempt to investigate the impact of various socioeconomic and farm-specific factors on the technical, allocative, and economic inefficiency of the cotton-wheat and rice-wheat systems in Punjab. In order to estimate the sources of technical, allocative, and economic inefficiency of farms, various socioeconomic and farm-specific variables were regressed on the inefficiency estimates of farms using a Tobit regression model.

The socioeconomic and farm-specific variables included in this study were: years of schooling of the household head, age of the farm operator, contact with extension agents, farm-to-market distance, access to credit, and tenancy status of the farm's operator.

In order to examine the impact of these socioeconomic and farm-specific variables on inefficiency estimates, we use the following Tobit regression model:

$$E_i = E_i^* = \beta_0 + \beta_1 Z_{1i} + \beta_2 Z_{2i} + \beta_3 Z_{3i} + \beta_4 Z_{4i} + \beta_5 Z_{5i} + \beta_6 Z_{6i} + \beta_7 Z_{7i} + \mu_i \quad if \quad E^* > 0$$

$$E = 0 \quad if \quad E_i^* \leq 0$$

where

i refers to the ith farm in the sample.

E_i is an inefficiency measure representing the technical, allocative, and economic inefficiency of the ith farm.

E_i^* is the latent variable.

Z_{1i} represents the education of the ith farmer in terms of years of schooling.

Z_{2i} represents the age of the ith farm's operator in terms of number of years.

Z_{3i} represents the number of times contact was made by the ith farmer with extension agents.

Z_{4i} represents the distance of the ith farm from the main market in kilometers.

Z_{5i} is a dummy variable with a value equal to 1 if the farmer has access to credit. Otherwise it is 0.

Z_{6i} is a dummy variable with a value equal to 1 if the renter is the farm operator. Otherwise it is 0.

Z_{7i} is a dummy variable with a value equal to 1 if the farm operator is a sharecropper. Otherwise it is 0.

β's are unknown parameters to be estimated.

μ_i is the error term.

V. Results and Discussions

A. Summary Statistics

A summary of the values of key variables included in our DEA models and Tobit regression model is given in Table-1. The table reveals that the average total income per farm is Rs40,349.1 with a standard deviation of Rs14,405.13. The average cropped area is 30.44 acres with a standard deviation of 24.75 acres. The large variability in the standard deviation values of total income per farm and cropped area indicates that sample farmers operate at different levels of farm size, which tends to affect their income level and cropped area. The average quantity of seed used per acre was 48.51 kg with a standard deviation of 10.14 kg, and average number of tractor-hours per acre was 4.99 with a standard deviation of 1.52 hours. The small values of the standard deviations of average quantity of seed used and tractor-hours per acre among sample farmers indicates a low level of variability in the use of these two inputs among farmers who are part of the cotton-wheat system.

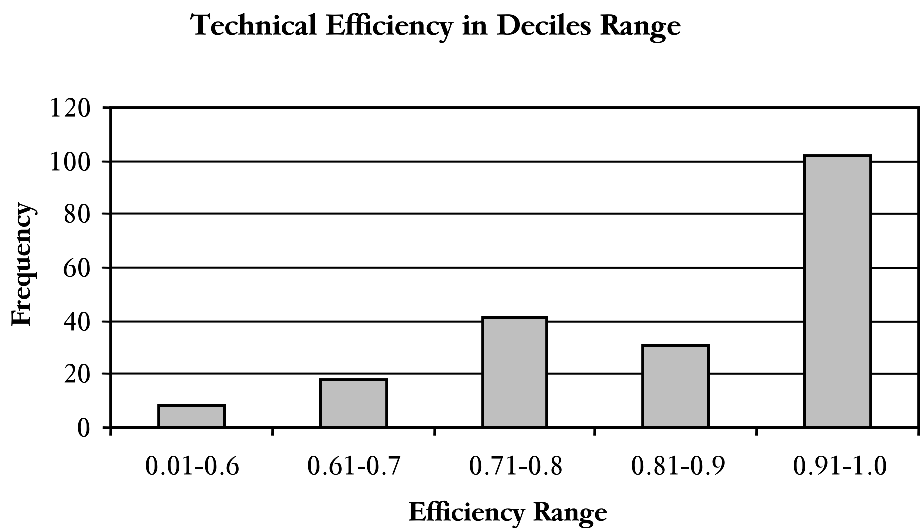
The average quantity of NPK used per acre was 162.44 kg with a standard deviation of 40.51 kg, indicating a large variability in the use of NPK among sampled farmers. It is generally assumed that the use of pesticides in the cotton-wheat system is high, and it is evident from Table-1 that the average quantity of pesticide used per acre is 732.52 g with a standard deviation of 565.99 g. A high standard deviation value indicates a large variability in the use of pesticides among farmers. The average use of labor per acre was 87.08 person-days with a standard deviation of 51.24 person-days, which showed that sampled farmers in the cotton-wheat system depend heavily on human labor to perform most farm operations, in turn indicating a large variability in the use of labor per acre in the sample area. The average number of irrigation-hours per acre was 41.89 with a standard deviation of 25.35 hours, which showed a large variability of irrigation-hours per acre among the sampled farms. The average quantity of fodder and concentrates used per animal was 15,746.79 kg and 539.22 kg, respectively, with large values of standard deviation. The large values of standard deviation for both inputs indicated a large variability in the use of fodder and concentrates per animal among the sampled farmers.

The average age of farm operators in the sample area was 32.17 years with a standard deviation of 11.38 years. The average level of education among farmers in the sample area was 6.67 years of schooling with a minimum of 0 and maximum of 14. The average number of times contact was made by farmers with extension agents was 13.5 with a standard deviation of 8.46. The average distance of sample farms from the nearest market was 12.19 km with a standard deviation of 3.59 km.

B. Efficiency Estimation

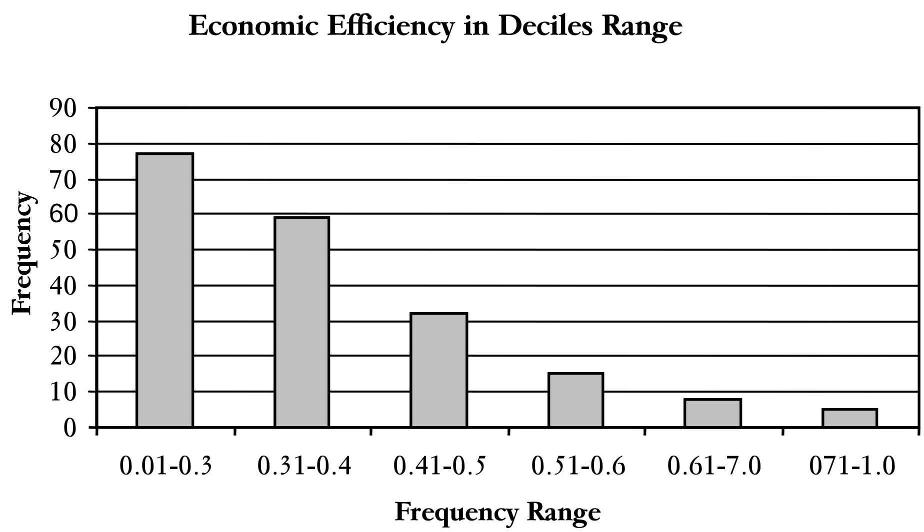
The technical and economic efficiencies of the cotton-wheat system were obtained by using DEA models. Allocative efficiency is the ratio of economic efficiency to technical efficiency; therefore, it was obtained by dividing the economic efficiency estimates by the technical efficiency estimates. The empirical results obtained from our DEA models are presented in Table-2. It is evident from the table that the mean technical efficiency of sample farms is 0.87, with a low of 0.41. The results of the study imply that if the average farmers operated at the same technical efficiency as the most efficient farms in the sample, they could reduce, on average, their input use by about 13 percent and still produce the same level of output. The results of the study also indicate that the majority of sampled farmers were fairly technically efficient in utilizing their scarce resources. It was found that 51 percent of sampled farms operated at a level of technical efficiency greater than 0.90, 15.5 percent of farms operate at a level of technical efficiency between 0.80 and 0.90, 20.5 percent of farms operate at a level of technical efficiency between 0.70 and 0.80, 9 percent of farms operate at a level of technical efficiency between 0.61 and 0.70, and only 4 percent of farms operate at a level of technical efficiency of less than 0.61. In other words approximately two thirds of the sampled farms operate at a level of technical efficiency greater than 0.8 while only 13% of sample farms operate at a level of technical efficiency less than 0.7. There are no significant technical efficiency differentials among farmers from the two districts. The mean technical efficiency level is 0.89 for farmers in Muzaffargarh district and 0.86 in Rahimyar Khan district.

Figure-1: Frequency Distribution of Technical Efficiency of Cotton-Wheat System



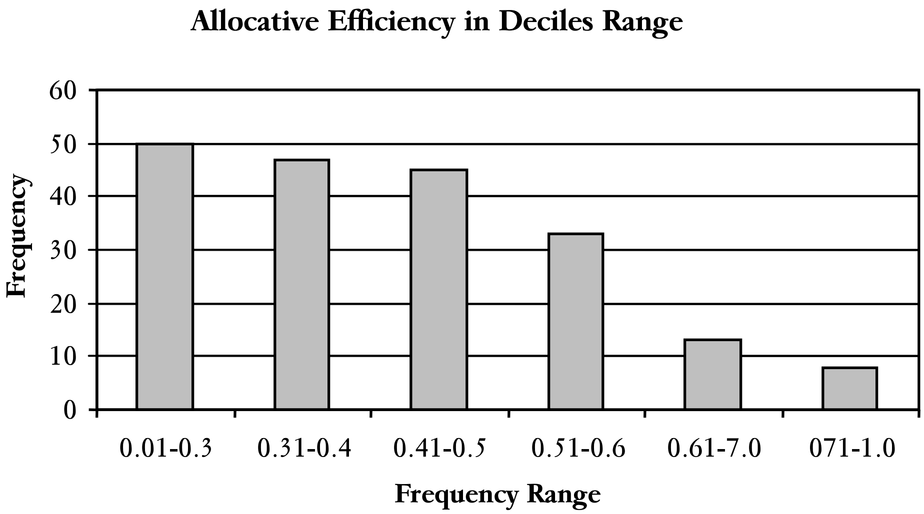
The mean economic efficiency of sample farms is 0.37, with a minimum of 0.052. This indicates the existence of substantial economic inefficiencies in the study area. Our findings reveal that, if sample farms operated at full efficiency, they could reduce their cost of production by about 63 percent without reducing the level of output and with the existing technology. The results of the study also reveal that the economic efficiency of the majority of sampled farms falls within the range of 0.21 and 0.60. Out of 200 sample farms, only 2 percent of farms operate at a level of economic efficiency greater than 0.90, 2.5 percent of farms operate at a level of economic efficiency between 0.71 and 0.80, 4 percent of farms operate at a level of economic efficiency between 0.61 and 0.70, 7.5 percent of farms operate at a level of economic efficiency between 0.51 and 0.60, 16 percent of farms operate at a level of economic efficiency between 0.40 and 0.51, 29.5 percent of farms operate at a level of economic efficiency between 0.30 and 0.40, 28.5 percent operate at a level of economic efficiency between 0.21 and 0.30 and 10 percent of farms operate at a level of economic efficiency less than 0.21. In other words, our economic efficiency scores are dominated by inefficient farms. Only 2% (4 out of 200) of farms lie on the efficiency frontier. It is worthwhile to note that farmers in Rahimyar Khan are economically more efficient than farmers in Muzaffargarh. The mean economic efficiency level was 0.46 for farmers in Rahimyar Khan and 0.39 in Muzaffargarh districts.

Figure-2: Frequency Distribution of Economic Efficiency of Cotton-Wheat System



The mean allocative efficiency level of sampled farms is 0.44 with a low of 0.052. Table-3 shows that the allocative efficiencies of the majority of sampled farms fall within the range of 0.21 and 0.6. Out of 200 sample farmers, 4 percent of farms operate at a level of allocative efficiency between 0.71 and 0.80, 6.5 percent of farms operate at a level of allocative efficiency between 0.61 and 0.70, 16.5 percent of farms operate at a level of allocative efficiency between 0.51 and 0.60, 22.5 percent of farms operate at a level of allocative efficiency between 0.41 and 0.50, 23.5 percent of farms operate at a level of allocative efficiency between 0.31 and 0.40, 17.5 percent of farms operate at a level of allocative efficiency between 0.21 and 0.30, and 7.5 percent of farms operate at a level of allocative efficiency less than 0.21. These results reveal that allocative efficiencies are dominated by inefficient farms. Only 2% (4 out of 200) farms are allocatively efficient.

Figure-3: Frequency Distribution of Allocative Efficiency of Cotton-Wheat System



The low level of economic and allocative efficiency among farms in the cotton-wheat system indicates that there is considerable room for an increase in agriculture output without additional inputs and with existing technology.

C. Inefficiencies Differentials among Sample Farmers

Socioeconomic and farm-specific factors are likely to affect the level of technical, allocative, and economic inefficiency of farmers. The present study attempts to investigate the sources of inefficiency of the cotton-wheat system in Punjab. In order to do this, technical, allocative, and economic inefficiency estimates are separately regressed on socioeconomic and farm-specific variables, respectively, by using a Tobit regression model.

Our results are presented in Table-4. The table shows that the number of years of schooling and number of times contact was made with extension agents are negatively related to the technical, economic, and allocative inefficiency of farms in the cotton-wheat system. These results imply that farmers with more years of schooling and more contact with extension agents are more efficient than their counterparts who are less educated and have fewer/no contacts with extension agent. Our results also indicate that farmers with better access to credit are technically less inefficient than those farmers who have poor/no access to credit. Our findings are consistent with those of Bravo-Uretta and Evenson (1994), Ali and Flinn (1989), Hassan (2004), Bozogolo and Ceyahan (2006), and Idiong

(2007). The obvious reason for this relationship is that credit availability improves liquidity and facilitates the purchase of inputs such as fertilizers, pesticides, and improved seed, etc. during peak seasons. The farm-to-market distance variable is used as a proxy for the development of road and market infrastructure. The results of the study shows that farms located closer to the market are technically less inefficient than those farms located away from the market. These results suggest that the technical inefficiency of sample farms would decrease significantly with the development of a road and market infrastructure. Table-4 also shows that sharecroppers are technically more inefficient that owner-operators. Pearson, *et al* (1991) argues that sharecropping contracts are often arranged so that the benefits of higher returns go to owners rather than tenants, which discourages tenants from increasing their productivity. The obvious reason for this relationship may be that insecurity and financial stringency dissuade sharecroppers from investing in activities such improvement in land and managerial capabilities.

VI. Conclusions and Recommendations

Despite the fact that agriculture has been growing at a reasonable rate, the pace of agricultural productivity is not adequate if it is to meet the increasing demand of the country's population. Per capita land and water availability is shrinking due to the rapid increase in population, and therefore sustainable growth in agriculture is required to ensure food security and sustainable economic development. Possible ways of enhancing agricultural growth include expanding the cultivated area, increasing cropping intensity, bringing about technological change, and improving production efficiency.

This study used the DEA technique to estimate the technical, economic, and allocative efficiency scores of the sampled farms. The average technical, economic, and allocative efficiency of sampled farms was estimated at 0.87, 0.37, and 0.44, respectively, in the cotton-wheat system. The DEA results indicate the existence of a substantial degree of economic and allocative inefficiency in the system. These results imply that if sample farms operated at full efficiency level, they could reduce their cost of production by about 63 percent without reducing the level of output with the existing technology.

Tobit analyses were used to identify the sources of inefficiency differentials among sample farmers. The results of the Tobit model showed that the number of years of schooling and number of times contact was made with extension agents had a negative impact on the technical, allocative, and economic inefficiency of the cotton-wheat farming system in Punjab. Access to credit had a negative and significant impact on technical inefficiency. Younger farmers were found to be technically less inefficient, while farms located close to the market were technically less inefficient than those located away from the market.

The most obvious implication of the results of this study is that sound policies are needed to promote formal education among rural households as a means of enhancing efficiency in the long run. This will enable farmers to make better technical decisions and help them allocate their inputs efficiently and effectively. In the short run, informal extension education could be effective, especially when targeted at those who have limited formal education. Policymakers should focus on enhancing farmers' access to information via the provision of better extension services. The government should allocate more funds to strengthening the extension department and expanding the net of extension services in remote areas.

Increasing age tends to lead to a decline in the efficiency of farmers. The study suggests that the government devise policies to attract and encourage younger people in farming by providing them incentives. This would enhance agricultural productivity and efficiency. Policymakers should also focus on the development of market and road infrastructure, and supply outlets should be located closer to the farm gate.

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Table-1: Summary Statistics of Variables of DEA Models and Tobit Regression Model

Variable	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Total Farm Income (Rs/acre)	40349.10	14405.13	10321.43	89400
Farm Area (acre)	18.04	13.66	4	75
Cropped Area (acre)	30.44	24.75	5.87	148
Seed (kg/acre)	48.51	10.14	17.53	81.95
Tractor (hours/acre)	4.99	1.52	1.25	12.1
NPK (kg/acre)	162.44	40.51	59.97	278.7
Pesticide (gram/acre)	732.52	565.99	50.89	3151.15
Labour (man-days/acre)	87.08	51.24	26.03	353.67
Irrigation (hours/acre)	41.89	25.35	12	142
Fodder (kg/animal)	15746.79	5454.65	5823.53	32933.33
Concentrate (kg/animal)	539.22	357.27	63.8	2980
Land Rent (Rs/acre)	8613.64	1897.32	400	15816.10
Seed (Rs/acre)	1004.53	272.45	308.85	2023.42
Tractor (Rs/acre)	2660.12	922.89	905.4	6680
NPK (Rs/acre)	4427.74	1135.42	1684	8742.10
Pesticide (Rs/acre)	1545.89	837.34	183.33	5195.45
Labour (Rs/acre)	6686.27	3820.66	2223.09	24281.67
Irrigation (Rs/acre)	2255.46	2137.20	62.25	8886.43
Fodder (Rs/animal)	13283.26	4650.58	4950	27993.33
Concentrate (Rs/animal)	6633.70	3668.46	1200	20000
Age of Farm's Operator (years)	32.17	11.38	18	65
Years of Schooling	6.67	3.53	0	14
Contact with Extension Agents (No.)	13.50	8.46	0	48
Distance (km)	12.19	3.59	6	20

Table-2: Technical, Allocative and Economic Efficiency of Cotton Wheat System

Farmer's Number	Technical Efficiency	Allocative Efficiency	Economic Efficiency	Farmer's Number	Technical Efficiency	Allocative Efficiency	Economic Efficiency
1	0.761	0.306	0.223	26	1.0	0.206	0.206
2	0.861	0.404	0.348	27	1.0	0.137	0.137
3	0.635	0.43	0.273	28	0.829	0.198	0.164
4	0.779	0.403	0.314	29	0.935	0.232	0.217
5	0.903	0.3	0.271	30	0.634	0.107	0.068
6	0.767	0.271	0.208	31	1.0	0.786	0.786
7	1.0	0.426	0.426	32	1.0	0.334	0.334
8	0.9	0.418	0.376	33	1.0	0.215	0.215
9	0.725	0.45	0.326	34	1.0	0.226	0.226
10	1.0	0.29	0.29	35	1.0	0.32	0.32
11	0.872	0.462	0.403	36	1.0	0.482	0.482
12	0.897	0.687	0.616	37	0.967	0.202	0.195
13	0.888	0.281	0.252	38	0.659	0.312	0.205
14	0.729	0.371	0.27	39	0.947	0.286	0.271
15	0.91	0.522	0.475	40	1.0	0.301	0.301
16	1.0	0.78	0.378	41	1.0	1.0	1.0
17	1.0	0.283	0.283	42	1.0	0.241	0.241
18	1.0	0.323	0.323	43	0.984	0.242	0.238
19	0.687	0.396	0.272	44	0.822	0.294	0.242
20	0.805	0.165	0.133	45	1.0	0.251	0.251
21	0.937	0.298	0.279	46	0.652	0.44	0.287
22	0.975	0.333	0.325	47	0.677	0.307	0.208
23	0.907	0.518	0.47	48	0.941	0.437	0.411
24	1.0	0.429	0.429	49	0.59	0.645	0.38
25	0.709	0.524	0.372	50	1.0	0.717	0.717
51	0.894	0.443	0.396	76	1.0	1.0	1.0
52	1.0	0.182	0.182	77	1.0	0.581	0.581
53	1.0	0.239	0.239	78	0.967	0.581	0.561
54	0.871	0.415	0.361	79	1.0	0.717	0.717
55	0.745	0.475	0.354	80	0.824	0.515	0.425
56	1.0	0.337	0.337	81	0.66	0.547	0.361
57	0.411	0.339	0.14	82	0.88	0.412	0.362

58	1.0	0.184	0.184	83	1.0	0.429	0.429
59	1.0	0.233	0.233	84	1.0	0.378	0.378
60	1.0	0.264	0.264	85	0.794	0.471	0.374
61	1.0	0.069	0.069	86	1.0	0.536	0.536
62	1.0	0.211	0.211	87	1.0	0.645	0.645
63	0.983	0.273	0.269	88	0.784	0.305	0.239
64	0.888	0.226	0.2	89	0.895	0.312	0.28
65	0.624	0.339	0.21	90	1.0	0.337	0.377
66	0.992	0.4	0.397	91	0.785	0.553	0.434
67	1.0	0.427	0.427	92	0.936	0.287	0.269
68	0.76	0.302	0.229	93	1.0	1.0	1.0
69	0.489	0.736	0.36	94	0.992	0.317	0.314
70	1.0	0.398	0.398	95	1.0	0.25	0.25
71	1.0	0.381	0.381	96	0.693	0.603	0.421
72	0.767	0.356	0.273	97	0.896	0.16	0.143
73	1.0	0.236	0.236	98	0.771	0.158	0.121
74	0.84	0.266	0.224	99	0.914	0.281	0.257
75	0.741	0.404	0.299	100	1.0	0.686	0.686
101	11.0	0.467	0.467	126	0.855	0.414	0.354
102	0.631	0.601	0.379	127	0.858	0.389	0.333
103	1.0	0.429	0.429	128	0.749	0.442	0.331
104	1.0	0.369	0.369	129	0.733	0.478	0.35
105	1.0	0.631	0.631	130	0.587	0.395	0.232
106	0.477	0.411	0.196	131	0.766	0.494	0.378
107	1.0	0.325	0.325	132	0.916	0.581	0.532
108	1.0	0.149	0.149	133	0.725	0.466	0.338
109	1.0	0.178	0.178	134	1.0	0.61	0.61
110	0.777	0.699	0.519	135	0.78	0.457	0.356
111	0.803	0.509	0.409	136	1.0	0.172	0.172
112	0.753	0.348	0.262	137	0.892	0.435	0.388
113	1.0	0.54	0.54	138	0.791	0.373	0.295
114	1.0	0.456	0.456	139	1.0	0.338	0.338
115	0.802	0.515	0.413	140	1.0	0.576	0.576
116	0.756	0.366	0.277	141	0.566	0.608	0.344
117	0.873	0.411	0.359	142	1.0	0.367	0.67
118	1.0	0.45	0.45	143	0.683	0.589	0.402

119	0.743	0.577	0.414	144	1.0	0.712	0.712
120	11.0	0.472	0.472	145	1.0	0.052	0.052
121	0.947	0.3	0.284	146	0.615	0.096	0.059
122	1.0	0.344	0.344	147	0.773	0.221	0.171
123	1.0	0.254	0.254	148	0.785	0.579	0.455
124	1.0	0.358	0.358	149	0.935	0.286	0.68
125	1.0	0.768	0.768	150	0.807	0.408	0.329
151	0.84	0.611	0.513	176	1.0	0.503	0.503
152	0.921	0.557	0.512	177	1.0	0.316	0.316
153	0.76	0.398	0.302	178	1.0	0.366	0.366
154	0.726	0.505	0.367	179	1.0	0.422	0.422
155	0.674	0.612	0.412	180	0.656	0.566	0.371
156	1.0	0.598	0.598	181	1.0	0.598	0.598
157	0.796	0.42	0.335	182	1.0	0.67	0.67
158	0.887	0.51	0.452	183	0.604	0.564	0.34
159	1.0	0.361	0.361	184	0.56	0.509	0.285
160	1.0	0.604	0.604	185	0.773	0.61	0.471
161	1.0	0.51	0.51	186	0.71	0.7	0.497
162	1.0	0.367	0.367	187	0.762	0.38	0.29
163	0.663	0.457	0.303	188	1.0	0.364	0.364
164	0.648	0.528	0.342	189	0.863	0.538	0.465
165	0.727	0.538	0.391	190	0.651	0.446	0.291
166	0.827	0.496	0.409	191	0.827	0.453	0.375
167	1.0	0.249	0.249	192	0.75	0.438	0.328
168	0.898	0.56	0.503	193	0.922	0.471	0.434
169	1.0	1.0	1.0	194	0.719	0.319	0.229
170	1.0	0.519	0.519	195	1.0	0.5	0.5
171	0.71	0.343	0.244	196	0.88	0.404	0.356
172	0.745	0.75	0.559	197	1.0	0.292	0.292
173	0.742	0.409	0.304	198	0.896	0.441	0.395
174	0.807	0.231	0.186	199	0.652	0.356	0.232
175	0.787	0.352	0.277	200	1.0	0.493	0.493
				Mean	**0.874**	**0.442**	**0.367**
				Minimum	**0.411**	**0.052**	**0.052**
				Maximum	**1.0**	**1.0**	**1.0**

Table-3: Frequency Distribution of Technical, Allocative and Economic Efficiencies of Cotton-Wheat System

Efficiency Range	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0.01 – 0.10	-	-	3	1.5	4	2.0
0.11 – 0.20	-	-	12	6.0	16	8
0.21 – 0.30	-	-	35	17.5	57	28.5
0.31 – 0.40	-	-	47	23.5	59	29.5
0.41 – 0.50	3	1.5	45	22.5	32	16
0.51 – 0.60	5	2.5	33	16.5	15	7.5
0.61 – 0.70	18	9	13	6.5	8	4
0.71 – 0.80	41	20.5	8	4.0	5	2.5
0.81 – 0.90	31	15.5	-	-	-	-
0.91 – 1.0	102	51	4	2.0	4	2.0
Total	**200**	**100**	**200**	**100**	**200**	**100**

Table-4: Sources of Technical, Economic and Allocative Inefficiencies of Cotton-Wheat System in Punjab

	Technical Inefficiency			Economic Inefficiency			Allocative Inefficiency		
Variables	**Coeffi-cient**	**Std. Error**	**Prob.**	**Coeffi-cient**	**Std. Error**	**Prob.**	**Coeffi-cient**	**Std. Error**	**Prob.**
Constant	0.034	0.070	0.627	0.727	0.070	0.000	0.744	0.056	0.000
Years of Schooling	-0.007	0.004	0.064	-0.007	0.004	0.085	-0.008	0.003	0.012
Age of Farm's Operator (years)	0.003	0.001	0.008	0.001	0.001	0.684	0.001	0.001	0.424
Contact with Extension Agents (No.)	-0.005	0.002	0.002	-0.010	0.002	0.000	-0.011	0.001	0.000
Farm to Market Distance (km)	0.007	0.003	0.058	-0.001	0.004	0.695	0.003	0.003	0.256
Access to Credit Dummy	-0.047	0.026	0.072	0.033	0.027	0.212	0.017	0.021	0.426
Renter Dummy	-0.041	0.026	0.11	0.016	0.025	0.521	0.019	0.020	0.354
Sharecropper Dummy	0.105	0.033	0.001	-0.020	0.033	0.539	0.022	0.027	0.414