ANALYZING THE IMPACT OF FARMER FIELD SCHOOL ON TECHNICAL EFFICIENCY OF COTTON GROWERS IN SOUTHERN DISTRICTS OF PUNJAB-PAKISTAN: STOCHASTIC PRODUCTION FRONTIER APPROACH

KHURRAM NAWAZ SADDOZAI[1]*, ABDUL SABOOR[1], MUHAMMAD AZEEM KHAN[2], DAWOOD JAN[3] and GHAFFAR ALI[3]

1 *Department of Economics & Agriculture Economics, Arid Agriculture University, Rawalpindi, Pakistan.*
2 *Social Sciences Research Institute, National Agriculture Research Center, Islamabad, Pakistan.*
3 *Department of Agriculture & Applied Economics, The University of Agriculture, Peshawar – Pakistan*
**Email: ksaddozai@hotmail.com*

ABSTRACT

This study was designed to assess the impact of Farmer Field Schools (FFS) on technical efficiency and to compare the cotton production of FFS and Non-FFS cotton growers in southern districts of Punjab Province, Pakistan. The four districts namely Khanewal, Bahawalpur, Rahim Yar Khan and Vehari were selected as a study universe. The multi-stage and equal allocation sampling technique was used to estimate the sample size. The data was collected in the year 2011 from 400 respondents, which includes 200 FFS Farmers and 200 Non FFS Farmers. The Stochastic Frontier Production approach of Cobb-Douglas type followed by Technical Efficiency estimates was employed to achieve the objectives of the study. The major findings of the study indicate that the farmers who were members of FFS have 38 percent more cotton yield compared to that of Non FFS Farmers. The analysis further reveals that cotton growers are confronted with diminishing returns to scale as the coefficient of chewing and sucking pest sprays are negative and statistically significant. The technical efficiency estimates illustrate that the mean technical efficiency score was 77.65 percent that implies that there is substantial room to enhance the technical efficiency by 22.34 percent of the cotton growers in the study area. The technical efficiency results also confirmed that no FFS farmer found in the lowest two ranges i.e. 36.83 to 46.83 percent and 46.84 to 56.84 percent. However, the lowest technical efficiency range of Non-FFS farmers was 36.83 to 46.83 percent, which implies that FFS Farmers are more technically efficient as compared to Non-FFS Farmers. The inefficiency model shows that increase in respondent's age and high educational level have a positive contribution for cotton yield. Conversely, the contact of cotton growers with Agriculture Extension department contributes for high inefficiency shows the weak linkages between extension staff and the cotton growers of the study area. It is recommended that FFS approach should be a non-developmental programme and should be executed under the umbrella of single institution for its proper implementation and monitoring.

Keywords: **Farmer Field School, Stochastic Frontier Analysis, Technical Efficiency, Cobb-Douglas, Cotton, Pakistan.**

Citation: Saddozai, K. N., A. Saboor, M.A. Khan., D. Jan and G. Ali. 2013. Analyzing the impact of Farmer Field School on Technical Efficiency of Cotton Growers in Southern districts of Punjab-Pakistan: Stochastic Production Frontier Approach. Sarhad J. Agric. 29(2): 291-298

INTRODUCTION

The agricultural economy of Pakistan is confronted with a declining growth rate and has plunged down from 5.3 percent to 3.7 percent in the past seven years. Similarly, the cotton crop sector is also suffering with insignificant growth which resulted in a drop-off of cotton production from 12.9 million bales to 11.5 million bales in 2009-10 (GoP, 2011-12).

In the agriculture realm, various crop management practices such as Best Management Practices (BMP), Organic Agriculture, Zero Tillage and Farmer Field Schools (FFS) are adopted for high and sustainable crop production as stated by Buhler *et al.* (2000). Among the said approaches FFS is a participatory approach which facilitates the growers to enhance the crop production efficiency and secure better profit margin (Braun *et al.*, 2006). The FFS approach is an informal education system that helps the farmer to learn optimally from field observation and experimentation. The FFS approach was started to facilitate the farmers regarding Integrated Pest Management (IPM) practices according to diverse and dynamic ecological condition (Berg and Jiggins, 2007).

In Pakistan, a FFS approach became more popular when Food Agriculture Organization (FAO) took an initiative to implement IPM Programme for cotton crop in Sindh province in 2001 (Khan *et al.*, 2005) and then extended to rest of Pakistan by National Integrated Pest Management (IPM) Project, National Agriculture Research Center (NARC) in September, 2004. The National IPM project had successfully completed its targets and converted into the non-development sector in 2011.

Though large investment has been made in FFS in Asia (Tripp *et al.,* 2005), surprisingly there are a few impact evaluations of FFS programmes. Impact assessment and scientific research are important to support the innovation process, priority setting and also to reflect the successes and failures of the research endeavors.

Keeping in view the significance of impact assessment and research on production efficiency of cotton growers in southern districts of Punjab this study is intended to: 1. analyze the impact of FFS on cotton production frontier and technical efficiency of cotton growers; 2. Identify the inefficiency factors affecting cotton production; and 3. develop empirical foundation for recommending policy interventions and up scaling of FFS approach.

MATERIALS AND METHODS

Study Universe

The study was conducted in four southern districts Khanewal, Vehari, Bahawalpur and Rahim Yar Khan of Punjab province, Pakistan. The main reason for the selection of these districts was the successful completion of Farmer Field Schools (FFS) programme established under aegis of National IPM Project, National Agriculture Research Center, Islamabad, Pakistan with collaboration of Provincial Extension Department, Pakistan.

Sampling Design and Sample Size

The four stages sampling design was employed to select a total of 400 respondents including 200 FFS and 200 Non-FFS cotton growers, as utilized by previous studies i.e. Javed, 2009. In the first stage, four southern districts of Punjab were selected. The eight tehsils were selected in the second stage of sampling by selecting two tehsils from each district. Further, in third stage two villages from each teshils were selected to get total of 16 villages. Among these 16 villages, eight FFS and eight Non-FFS villages were selected purposively however, Non-FFS villages are considered as controlled villages where no FFS was established, the procedure is adopted as employed by Rejesus *et al.* (2009). Finally in the fourth stage the overall 400 respondents were selected through equal allocation sampling technique through the following formula:

N_n = n/k

n = Total respondents from all four districts

k = Number of strata (1: FFS Farmers, 2: Control Farmers/Non-FFS)

N_n = 400/2 = 200

These 200 FFS and 200 Non-FFS respondents from each Village (8 FFS and 8 Non-FFS) were interviewed randomly.

Data Collection and Data Analysis Procedure

The data was collected through prescribed questionnaire through face to face interview method. The questionnaire was pretested and desired amendments were incorporated in it. The survey team consisted of five enumerators who interviewed the 400 respondents. The collected data was further analyzed through various computer software named as STATA, SPSS, Frontier 4.1 and MS Excel. A blend of statistical and econometric technique is utilized to estimate the major results of the research study.

Analytical Framework

The Stochastic Production Frontier Analysis

The pioneering work of Farrell (1957) had provided the paved way for estimation of frontier production function. Later on the theoretical underpinning of stochastic frontier production function was illustrated by Aigner *et al.* (1977) and Meeusen and Broeck (1977). This research study also utilized the stochastic frontier model which is extensively employed in previous studies such as (Timmer, 1971; Greene, 1990; Iinuma *et al.,* 1999; Fousekis and Klonaris, 2003 and Binam *et al.,* 2004) and can be expressed in the following form:

$$q_i = X_i \beta + v_i - \mu_i \qquad (1)$$

Where:

q = represents the output of the i-th firm;

x_{i} = is a K x 1 vector containing the logarithms of inputs;

β= is a vector of unknown parameters to be estimated;

v_i =systematic random error which account for statistical noise

μ_i =is a non-negative random variable associated with technical inefficiency

Further a Cobb-Douglas type stochastic frontier model takes the form as under as stated by Coelli *et. al.* 2005:

$$\text{In } q_i = \beta_0 + \beta_1 \text{ In } x_i + v_i - u_i \tag{2}$$

$$qi = \exp(\beta_0 + \beta_1 \text{ In } x_i + v_i - u_i) \tag{3}$$

$$qi = \underbrace{\exp(\beta_0 + \beta_1 \text{ In } x_i)}_{\substack{\text{determinstic}\\ \text{Component}}} \text{ x } \underbrace{\exp(v_i)}_{\text{noise}} \text{ x } \underbrace{\exp(-u_i)}_{\text{inefficiency}} \tag{4}$$

Technical Efficiency Estimation

The stochastic frontier analysis further facilitates in the forecasting of the inefficiency effects (Coelli *et al.*, 2005). The most common output-oriented measure of technical efficiency can be expressed as the ratio of observed output to the corresponding stochastic frontier output:

$$TE_i = \frac{q_i}{\exp(x_i\beta + v_i)} = \frac{\exp(x_i\beta + v_i - u_i)}{\text{epx}(x_i\beta + v_i)} = \exp(-u_i) \tag{5}$$

Model Adequacy Checking

To detect the multicollinearity issue in the data set of this research study Variance Inflation Factor (VIF) has been utilized.

Empirical Modeling

The Cobb-Douglas Production was utilized to accentuate the relationship between yield and inputs as illustrated in previous studies by Battese and Coelli (1992). A Cobb-Douglas type Stochastic Production Frontier Model is fitted to data as under,

$$\ln Y = \ln\beta_0 + \beta_1 \ln LD + \beta_2 \ln Sed + \beta_3 \ln Iri + \beta_4 \ln FYM + \beta_5 \ln DAP + \beta_6 \ln Urea + \beta_7 \ln Nitro + \beta_8 \ln Amon + \beta_9 \ln Wed + \beta_{10} \ln Chew + \beta_{11} \ln Suk + D_1\, FFS + D_2\, KNW + D_3\, BWP + D_4\, RYK + (Vi - Ui)$$

Where,

In =	Natural Logarithm
β_{0}..... β_{15}=	Betas are parameter to be estimated
Y =	Yield of cotton in maunds per acre (1 maund = 40 Kg)
LD =	Labor Man Days per acre for various crop operations
Sed =	Cotton Seed application in kgs per acre
Iri =	Number of Irrigation per acre
FYM =	Number of Farm Yard Manure used in trolley (1000 kgs) per acre
DAP =	Number of DAP Fertilizer used in bags (50 kgs) per acre
UREA =	Number of Urea Fertilizer used in bags (50 kgs) per acre
Nitro. =	Number of Nitrophosphite Fertilizer used in bags (50 kgs) per acre
Amon. =	Number of Amonium Nitrate Fertilizer used in bags (50 kgs) per acre
Wed =	Number of Weedecide application per acre
Chew =	Number of Pesticide application for chewing pest per acre
Suk =	Number of Pesticide application for sucking pest per acre
DFFS =	Dummy Variable = 1, if Farmer Field School Member and 0 otherwise
DKNW =	Dummy Variable = 1, if Khanewal District's farmer and 0 otherwise
DBWP=	Dummy Variable =1, if Bahawalpur District's farmer and 0 otherwise

DRYK= Dummy Variable = 1, if Rahim Yar Khan District's farmer and 0 otherwise
(Vi – Ui) = Composite error term

Technical Inefficiency Measures

The firm is considered as technically efficient if it operates on the frontier line and technically inefficient if operated beneath the frontier line. In this research, the following variables are assumed to influence the technical inefficiency because these factors can affect the crop management practices which can be written as below:

$$Ui = \delta 0 + \delta 1\,(Age) + \delta 2\,(Edu) + \delta 3\,(Agri.\ Ext.)$$

Where,

δ = Parameters to be estimated
Age = Age of the Respondents
Edu = Schooling years of the Respondents
Agri. Ext. = Contact of respondents with Agricultural Extension Department

RESULTS AND DISCUSSION

Non-Economic Variables

The descriptive statistics of non-economic variables of 200 FFS and 200 Non-FFS cotton growers from all four districts are highlighted in Table 1. These non-economic variables include age, farming experience and house-hold size of the respondents, which usually play a significant or non significant role in the crop management activities. The previous studies e.g. Ahmad *et al.* (2002) and Binam *et al.* (2004) indicate that age, education etc. usually play a significant role in decision making of farmers. The range; mean and standard deviation values of these non-economic variables are estimated and are presented in Table 1 to provide a demographic glimpse of the study area.

Table 1. ***Descriptive statistics of non-Economic variables of the respondents.***

	FFS Cotton Growers					*Non-FFS Cotton Growers*				
Respondent's Attributes	***Obs.***	***Min.***	***Max.***	***Mean***	***Std. Dev.***	***Obs.***	***Min.***	***Max.***	***Mean***	***Std. Dev.***
Age (in years)	200	21.00	70.00	41.60	11.37	200	18.00	68.00	36.98	9.88
Farming Experience (in years)	200	4.00	52.00	21.21	11.05	200	2.00	50..00	19.54	9.72
Adult Male (> 16 Years) in House Hold	200	1.00	8.00	3.36	1.62	200	1.00	8.00	2.92	1.57
Adult Female (> 16 Years) in House Hold	200	1.00	9.00	3.16	1.46	200	1.00	7.00	2.79	1.28
Children (Male + Female) in House Hold	200	0.00	18.00	3.77	2.31	200	0.00	10.00	3.45	1.75
House Hold Size	200	4.00	35.00	10.30	4.18	200	4.00	18.00	9.16	3.24

Source: Author's Calculation

Major economic variables

The major economic variables such as crop's inputs used by FFS and Non-FFS Farmers are presented in Table 2. The units of all inputs are presented in brackets in front of each input. It has been evident from Table 2 that labour man days as an input has a major contribution in cotton crop management utilized by FFS and Non-FFS Farmers which explains that cotton crop is labor intensive. However, the mean value of majority of cotton crop's input reveal that FFS farmers applies less quantity of inputs as compared to Non- FFS farmers with exception of inputs including seed, farm yard manure (FYM) and urea.

Table 2. ***Summary Statistics of major economic variables used in the analysis.***

	FFS Cotton Growers			Non-FFS Cotton Growers		
Crop Inputs	***Obs.***	***Mean***	***Std. Dev.***	***Obs.***	***Mean***	***Std. Dev.***
Labour days (numbers per acre)	200	20.42	1.30	200	21.53	1.31
Seed (kgs per acre)	200	4.77	1.03	200	4.49	1.07
Irrigation (number per acre)	200	12.05	2.38	200	14.21	2.25
FYM (trolley per acre)	200	2.65	1.64	200	2.04	1.25
DAP (50 kgs bag per acre)	200	1.24	0.62	200	1.33	0.57
Urea (50 kgs bag per acre)	200	2.73	1.30	200	2.43	1.15
Nitrophosphate (50 kgs bag per acre)	200	0.67	0.68	200	0.92	0.57
Amonium Nitrite (50 kgs bag per acre)	200	0.58	0.64	200	0.75	0.70
Weedicide (50 kgs bag per acre)	200	1.10	0.57	200	1.15	0.51
Chewing Pest Spray (number per acre)	200	0.95	1.02	200	2.08	1.14
Sucking Pest Spray (number per acre)	200	0.69	0.99	200	1.80	1.10

Source: Author's Calculation

Model Adequacy Checking

Multicollinearity can be defined as existence of a relationship between the independent variables in a multiple regression i.e. a change in one variable causes a change in another variable (Gujarati, 2003). To detect the multicollinearity in the data the variance inflation factors (VIF) is often used and therefore, this research study employed VIF which is estimated for each variable and is given at appendix I. The existence of multicollinearity is considered as high if the value of VIF is greater than value of 5. The result reveals that variance inflation factors for all variables are satisfactory enough and are less than 5, therefore, there is no existence of multicollinearity in our collected data. The values of VIF are presented in descending order.

Stochastic Frontier Production Analysis

The Cobb-Douglas type stochastic frontier production analysis (SFA) is demonstrated in Table 3. The estimated results of SFA corroborate the expected sign of the majority of coefficients of explanatory variables except two coefficients of chewing and sucking pesticide. The estimation further illustrates that among the explanatory variables the coefficient of Labour Days has the greatest elasticity to cotton yield. This reveals that for a one percent increase in Labour days there is a 0.50 percent increase in cotton yield. The results underscores that timely availability of labour can optimize the crop yield. Among explanatory variables labour days and seed are significant at 5 percent level of significance ($P < 0.05$). While both chewing as well as sucking pests spray have negative sign with their coefficient but are also significant at 5 percent level of significance ($P < 0.05$). The remaining explanatory variables irrigation, FYM, DAP, urea, amounium nitrite and weedicide are significant at 1 percent level of significance ($P < 0.01$). Further to this, nitrophosphate is the only explanatory variable which is statistically non-significant. The negative sign with coefficient of chewing and sucking pesticide shows that these pesticides have negative effect on cotton yield. The inverse relation of pesticide to cotton yield implies that cotton growers are confronted with diminishing returns to scale as the coefficients of said pesticides are negative and statistically significant. This result is consistent with preceding research study of Ahmad *et al.* (2002) who argued that the coefficient of crop area (land) is negative and statistical significant which implies that farmers are facing diminishing returns to scale. However, the overall contribution of the explanatory variables ratifies increasing returns to scale (Elasticity of inputs > 1) in the study area. The four dummy variables include one dummy for Farmer Field School approach and the remaining three dummies for districts of the research study. The dummy variable for FFS shows presence and absence of FFS farmers, district dummies implies the comparison of cotton production in three districts as compared to the reference group district. The results of FFS dummy divulge that those respondents who were FFS member have 38 percent more cotton yield as to Non-FFS farmers. The district dummies reveals that cotton yield of Khanewal District's Farmer followed by Bahawalpur District's Farmers is statistically different and more i.e. 0.133 and 0.093 percent respectively different from the reference group (Vehari District). However, the cotton yield of Rahim Yar Khan District was found to be statistically insignificant from Vehari District and explains that there is no difference in cotton yield of Rahim Yar Khan District as compared to Vehari District. Moreover, Battese and Coelli (1995) revealed that if the value of lambda $\gamma = 0$ this shows that inefficiency doesn't exist however, if $\gamma = 1$ this depicts inefficiency exists. In our study the estimated value of γ was found 0.829 which is near to 1 and reveals that inefficiency exists in the analyzed data.

Table 3. ***Maximum likelihood estimates of Cobb-Douglas stochastic production frontier function.***

Independent Variables	Coefficient	Std. Err.	t-ratio	P Value
ln Labour days	0.501	0.218	2.29	0.022
ln Seed	0.152	0.060	2.52	0.012
ln Irrigation	0.224	0.055	4.05	0.000
ln FYM	0.134	0.026	5.23	0.000
ln DAP	0.036	0.012	3.15	0.002
ln Urea	0.203	0.029	6.90	0.000
ln Nitrophosphate	0.009	0.006	1.58	0.114
ln Amonium Nitrite	0.016	0.006	2.85	0.004
ln Weedicide	0.063	0.018	3.46	0.001
ln Chewing Pest Spray	-0.016	0.007	-2.37	0.018
ln Sucking Pest Spray	-0.013	0.006	-2.01	0.045
Sum of elasticity of inputs	**1.309**			
Dummy FFS	0.389	0.038	10.21	0.000
Dummy Khanewal District	0.133	0.039	3.38	0.001
Dummy Bahawalpur District	0.093	0.040	2.33	0.020
Dummy R.Y. Khan District	0.003	0.038	0.07	0.945
Constant	0.540	0.694	0.78	0.437
ln sig^2 v	-3.015	0.225	-13.4	0.000
ln sig^2 u	-3.390	0.882	-3.85	0.000
Sigma v	0.222	0.025		
Sigma u	0.184	0.081		
$Sigma^2$	0.083	0.020		
Lambda	0.829	0.104		
Log likelihood = - 9.026		Number of obs = 400		
Wald chi2(15) = 597.00		Prob > chi2 = 0.000		

Source: Author's Calculation

Inefficiency Model Estimates

The inefficiency model results are reported in Table 4. The table reveals that the entire three exogenous variable of inefficiency model had a significant coefficient. However, the age and education variable have a negative sign which suggests that with an increase in age of farmers and a high educational level of the farmers inefficiency decreases. It appears that cotton growers with less education are less technically efficient as compared to those having higher education. The result reveals that the inefficiency decreases with the increase in cotton grower's age. The said results of age and education variable are in line with Fousekis and Klonaris (2002). The schooling year negatively affect the inefficiency also similar to the study results of Abedullah *et al.* (2007). In contrast, the cotton growers contact with Agriculture Extension department has positive sign and statistical significant which implies that contact with Agriculture Extension department increases the inefficiency of the cotton growers in the study area. These results are similar to the previous study of Binam *et al.* (2004). This shows that there may be weak linkages among extension staff and cotton growers of the study area owing to the lack of extension field staff and non availability of funds.

Table 4. ***Inefficiency model estimates.***

ln Yield	Coefficient.	Std. Err.	t-ratio	P Value
Age	-2.682	0.733	-3.66	0.000
Agri. Extension	0.602	0.303	1.98	0.047
Education	-1.274	0.256	-4.97	0.000
Constant	8.224	2.010	4.09	0.000

Source: Author's Calculation

The results of technical efficiency are illustrated in Table 5 and 6 respectively. It is revealed from Table 6 that technical efficiency scores ranges from 36.83 percent to 96.88 percent. However, the mean value of technical efficiency 77.656 depicts that there is substantial room to enhance the technical efficiency of the cotton growers. Moreover, the comparison of FFS and Non-FFS Farmers on the basis of Technical Efficiency Scores are underscored in Table 7. The estimated scores of Technical Efficiency confirms that FFS farmers were more technical efficient as compared to Non-FFS farmers. The overwhelming majority of FFS Farmers falls in the range of 76.87 to 86.87 and 86.88 to 96.88, however, no FFS Farmer plunges in the range of 36.83-46.83 and 46.84-56.84. Contrary to this, technical efficiency scores of Non-FFS farmers starts with minimum scores i.e. 36.83-46.83 followed by a higher efficiency score range.

Table 5. ***Descriptive statistics of technical efficiency scores.***

Obs.	Min.	Max.	Mean	Std. Deviation
400	36.83	94.72	77.6569	11.76691

Source: Author's Calculation

Table 6. ***Estimates of variance inflation factor (VIF).***

	VIF	1/VIF
Dummy FFS	2.04	0.491
Dummy Bahawalpur District	1.98	0.505
Dummy Khanewal District	1.91	0.523
ln Sucking Pest Spray	1.68	0.595
Dummy Vehari District	1.65	0.605
ln FYM	1.52	0.658
ln Urea	1.5	0.668
ln Labour	1.43	0.698
ln Chewing Pest	1.39	0.721
ln Irrigation	1.35	0.739
ln Amonium	1.25	0.801
ln Nitrophos	1.24	0.804
ln DAP	1.23	0.814
ln Weedicide	1.17	0.855
ln Seed	1.08	0.924
Mean VIF	**1.49**	

Source: Author's Calculation

Table 7. ***Technical efficiency score ranges of FFS and Non-FFS farmers.***

Technical Efficiency Range	Non FFS	FFS	Total
36.83-46.83	09 (100.0%)	00 (0.0%)	09 (100.0%)
46.84-56.84	17 (100.0%)	00 (0.0%)	17 (100.0%)
56.85-66.85	44 (93.6%)	03 (6.4%)	47 (100.0%)
66.86-76.86	54 (77.1%)	16 (22.9%)	70 (100.0%)
76.87-86.87	57 (31.7%)	123 (68.3%)	180 (100.0%)
86.88-96.88	19 (24.7%)	58 (75.3%)	77 (100.0%)
Total	**200 (50.0%)**	**200 (50.0%)**	**400 (100.0%)**

Source: Author's Calculation

CONCLUSIONS AND RECOMMENDATIONS

In all the four districts studied it has been observed that the respondents who were Farmer Field School's participant have 38 percent more cotton yield compared to non FFS farmers. The major contribution to cotton's yield was of input labor man days as compared to other cotton crop inputs, which indicates that cotton crop is more labor intensive. However, the irrational use of chewing and sucking pesticides has a negative impact on cotton's yield. The mean efficiency of all the farmers were estimated as 78 percent, which shows that 22 percent improvement is still possible in technical efficiency of cotton growers. The FFS farmers were found more technically efficient as compared to non-FFS farmers. The inefficiency variables such as age and education shows that these two factors have a negative impact on technical inefficiency however, contact of farmers with agriculture extension department is increasing inefficiency, which shows that there are weak linkages between Agriculture extension department and farming community of the study area.

The high yield of FFS farmers urged the need that FFS approach should be the part of non-development programme in all the four provinces of Pakistan. The FFS approach should be executed under the umbrella of a single institution which will provide a paved way for proper implementation of this approach. The focus of FFS approach on rational use of crop inputs and environmental benign practices can also help to meet World Trade Organization (WTO) obligations. These obligations under sanitary and phytosanitary (SPS) measures of WTO emphasis on reasonable use of pesticide spray on crops.

REFERENCES

Abedullah, S. Kouser and K. Mushtaq. 2007. Analysis of Technical Efficiency of Rice Production In Punjab (Pakistan) Implications for Future Investment Strategies. Pak. Econ. Soc. Rev. 45: 231-244

Ahmad, M., G. C. Mustafa, and M. Iqbal. 2002. Wheat Productivity, Efficiency, and Sustainability: A Stochastic Production Frontier Analysis. The Pak. Dev. Rev. 41: 643-663

Aigner, D., C.A. K. Lovell, and P.Schmidt. 1977. Formulation and estimation of Stochastic Frontier Production Function Models. J. Econometrics 6: 21-37.

Battese, G. E. and T. J. Coelli. 1992. Frontier Production functions, technical efficiency and panel Data: With application to paddy Farmers in India. J. Prod Anal; 3: 153-169.

Berg, H. V. D. and J. Jiggins. 2007. Investing in farmers: The impacts of Farmer Field Schools in relation to integrated pest management. World dev 35: 663–686.

Binam, J. N., J. Tonye, N. Wandji, G. Nyambi, and M. Akoa. 2004. Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. Food Policy 29: 531–545

Braun, A., J. Jiggins, N. Röling, H.V. Berg and P. Snijders. 2006. A Global Survey and Rev. of Farmer Field School Experiences. Int'l. Livest. Res. Instt. Nairobi.

Buhler, D. D., M. Liebman, and J. J. Obrycki. 2000. Theoretical and practical challenges to an IPM approach to weed management. Weed Sci 48: 274-280.

Coelli, T. J., D. S. P. Rao, C. J. Odonnell, and G. E. Battese. 2005. An introduction to efficiency and productivity analysis. Book published by Springer Science Business Media, Inc.

Farrell, M. J. 1957. The measurement of productive efficiency. J. Royal Stat. Soc.120: 253-290.

Fousekis, P. and S. Klonaris. 2003. Technical efficiency determinants for fisheries: a study of trammel netters in Greece. Fish Res 63: 85–95

Government of Pakistan, 2011-12. Pakistan Economic Survey, Ministry of Finance, Finance Division, Pak. Secretariat Islamabad.

Greene, W. H. 1990. A gamma-distributed Stochastic Frontier Model. J. Econometrics 46: 141-163.

Gujarati, D. 2003. Basic Econometrics. NY: Mcgraw-Hill.

Iinuma, M., K. R. Sharma, and P. S. Leung. 1999. Technical efficiency of carp pond culture in peninsula Malaysia: an application of stochastic production frontier and technical inefficiency model. Aquaculture 175: 199–213

Javed, M. I. 2009. Efficiency Analysis of Cotton-Wheat and Rice-Wheat Systems in Punjab, Pakistan. Ph.D. Dissert. Univ of Agriculture Faisalabad-Pakistan : pp. 54.

Khan, M. A., I. Ahmad, and G. Walter-Echols. 2005. Impact of an FFS-based IPM Approach on Farmer Capacity, Production Practices and Income: Evidence from Pakistan. Pesticide Policy Project Publication Series Special Issue No. 9: 45-58. School of Economics and Management, University of Hannover, Germany

Meeusen, W. and J. V. D. Broeck. 1977. Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. Int. Econ. Rev. 18: 435-444

Rejesus, R. M., F. G. Palis, A. V. Lapitan, T. T. N. Chi, and M. Hossain, 2009. The Impact of Integrated Pest Management Information Dissemination Methods on Insecticide Use and Efficiency: Evidence from Rice Producers in South Vietnam. Rev. Agric. Econ. 31: 814–833.

Timmer, C. P. 1971. Using a Probabilistic Frontier Production Function to Measure Technical Efficienc. J. Polit. Econ. 79: 776-794

Tripp, R. M.Wijeratne, and V. H. Piyadasa. 2005. What should we expect from Farmer Field Schools? A Sri Lanka Case Study. World Dev. 33: 1705–1720.

Walter-Echols, G. and P.A.C. Ooi. 2005. The Impact of the FAO-EU IPM Programme for Cotton in Asia. Pesticide Policy Project Publication Series Special Issue No. 9: 1-15.