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*Research Note*

# Technical Efficiency in Crop Production: A Region-wise Analysis[§]

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**Abstract**

The technical efficiency in crop production has been reported in different regions as well as in the state of Punjab to show how different regions have adopted the latest technology. Technical efficiency of individual farms has been estimated through stochastic frontier production function analysis. The production function estimates have pointed towards the presence of disguised unemployment in the sub-mountainous region of the Punjab state. The technical efficiency has shown a wide variation across regions. The average technical efficiency has been found maximum in the central region (90 per cent), followed by south-western and sub-mountainous regions. The main drivers of inefficiency have been identified as experience in agriculture and age of a farmer. The policy intervention to improve technical efficiency being not the same for all the regions, the study has observed that the state would benefit more if policy interventions are developed at the local level.

## Introduction

During late-1960s and early-1970s, farm-size productivity relationship was well debated (Sen, 1962; 1964). The latest debate has been based on the alleged confirmation of inverse relationship in agriculturally advanced zones (Kahn, 1979; Dyer, 1991; Chattopadhyay and Sengupta, 1997; 1999). In recent years, one common debate has been on the ability of small farmers to reap the benefits of new technology (Sharma and Sharma, 2000). The argument advanced in this debate is that technology adoption among different segments of the same state/region widely varies. To work out the technical efficiency, land productivity and input intensity are the valid measures. The present study has dealt this issue in the context of agriculturally advanced state of Punjab in India. In the context of Punjab agriculture, only scanty literature on factor productivity was available (Dhillon and Ali, 2002; Singh and Hossain,. 2002), and no study seems to have been conducted using frontier production function approach for different regions. Only a study from this university has been conducted using district-wise data for aggregate farms (Kaur and Sekhon, 2005).

Inefficiency in crop production is one of the major factors hindering the exploitation of full potential of the innovated technologies, particularly in the developing countries (Bravo-Vrata and Evenson, 1994; Jayaram *et al*., 1992; Taylar and Shonkwiler, 1986; Ali and Flinn, 1989; Kalirajan and Shand, 1989; Arindam, 1994; Sharma and Datta, 1997 and Thomas and Sundaresan, 2000). Inefficiency, the inability of a farmer to realize optimum output, is influenced by various socio-economic factors that interfere in the decision-making process of a farmer (Dawson, 1985; Kalirajan and Shand, 1989; Kalaitzandonakes *et al*.,1992;). In this study, the level of technical inefficiency in crop production among different regions has been investigated along with the influence of various farm-specific socio-economic variables.

## Data Set and Variables

The present study was undertaken in the state of Punjab by dividing it into three zones; sub-mountainous

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zone (9%), central plain zone (65%) and south-western zone (26%). Three-stage stratified random sampling technique was adopted for the study. Two blocks from the sub-mountainous zone, five blocks from the central plain zone and three blocks from the south-western zone were selected at the first stage. Two villages from each block and 15 families [five marginal (up to 1 ha), five small (1.01 to 2 ha) and five from other categories (> 2ha)] were selected. Thus, the total sample comprised 100 marginal, 100 small and 100 other categories of farmers. A well-structured comprehensive schedule was designed and pre-tested in Ludhiana district of Punjab. It was personally administered to obtain the yield level, input and other farm-specific variables used by the farmers in different regions of the Punjab state. Technical inefficiency of individual farm was estimated through stochastic frontier production function analysis. The specific stochastic frontier production function model estimated was:

$$\ln Yi = \beta_o + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + (V_i - U_i)$$

where,

$Y_i$ = Gross income from crops of the i-th farm per acre,

$\beta_o, \ldots, \beta_6$ = Parameters to be estimated,

$X_1$ = Human labour (hours/acre),

$X_2$ = No. of irrigations per acre,

$X_3$ = Seed value (Rs/acre),

$X_4$ = Cost of fertilizer (Rs/acre),

$X_5$ = Plant protection cost (Rs/acre),

$X_6$ = Machine cost (Rs/acre),

$V_i$ = Random-error having zero means associated with random factors ( e.g. measurement errors in production, weather, etc.) not under control of a farmer, and

$U_i$ = One-sided inefficiency component.

The technical inefficiency effect, $U_i$ is defined as:

$$U_i = \delta_0 + \delta_j Z_i + W_i$$

where,

$Z_1$ = Age of the farmer (years),

$Z_2$ = Education of the farmer (No. of years in school),

$Z_3$ = Farm size (acres),

$Z_4$ = Family size (No.),

$Z_5$ = Occupations (No.), and

$Z_6$ = Experience in agriculture (years).

### Farm-specific Variables

The mean value of gross returns, input use and farm-specific variables involved in the stochastic production frontier and technical inefficiency index for crop production for different regions of the Punjab state are presented in Table 1. The mean value of gross income from crop per acre was highest for the central region ( Rs 30619), followed by south-western ( Rs 23448) and sub-mountainous (Rs 19220) regions. The use of human labour was the highest for the central region, followed by south-western and sub-mountainous regions. The use of seed measured in value terms for all the crops grown in different regions varied between Rs 639 and Rs 1029. The use of both fertilizers and insecticides and machine labour was the highest for the south-western region, followed by central and sub-mountainous regions.

In describing how the inefficiency effects in stochastic frontier production function vary across different regions, six variables, viz. age, education, farm size, family size, number of occupations, and experience in agriculture were used (Table 1)

### Production Function Estimates

The Cobb Douglas Production Function estimated using ordinary least square (OLS) technique, has been given Table 2. In the sub-mountainous region, the quantity of fertilizers used has significantly contributed to the value of gross returns. The coefficient of human labour has been found to be negative and significant, pointing towards the presence of disguised unemployment in this region; it supports the Krishna's belief of early-1960s on the existence of disguised unemployment in Punjab (Krishna, 1964). In the central region, production responded significantly and positively to human labour, number of irrigations, value of seed, fertilizer, and machine cost. It indicated that there was room for improving gross returns from crop production by increasing the level of these inputs. The coefficient of insecticide cost was negative but non-significant. In the south-western region, the coefficient of irrigation was -0.445, which was significant at five per cent level.

**Table 1. Summary statistics of study variables in the stochastic frontier model for crop production among different regions: Punjab**

(per acre)

| Particulars | Gross returns (Rs/acre) | Labour (hours) | No. of irrigations | Seed cost (Rs/acre) | Fertilizer cost (Rs/acre) | Insecticides costs (Rs/acre) | Machinery costs (Rs/acre) | Age | Education | Farm size | Family size | No. of occupations | Experience in agriculture |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sub-mountainous region** | | | | | | | | | | | | | |
| Mean | 19219 | 129.63 | 13.96 | 638 | 1512 | 885 | 4677 | 45.0 | 10.6 | 7.9 | 5.0 | 1.4 | 29.9 |
| C V | 26.91 | 65.20 | 41.98 | 48 | 38 | 46 | 46 | 24.56 | 26.32 | 43.67 | 25.80 | 35.71 | 37.95 |
| Max | 34443 | 529.17 | 35.00 | 2385 | 4369 | 3018 | 17597 | 75 | 15 | 50 | 9 | 2 | 60 |
| Min | 7480 | 18.00 | 6.15 | 133 | 555 | 240 | 134960 | 22 | 0 | 1 | 3 | 1 | 7 |
| **Central region** | | | | | | | | | | | | | |
| Mean | 30618 | 265.37 | 12.05 | 711 | 2068 | 1123 | 5036 | 39.0 | 9.4 | 8.3 | 5.0 | 1.3 | 21.7 |
| C V | 38.68 | 134.79 | 30.29 | 111 | 54 | 49 | 47 | 33.96 | 38.19 | 114.46 | 29.20 | 35.38 | 47.97 |
| Max | 96100 | 2660.00 | 18.26 | 4400 | 6390 | 4642 | 16650 | 68 | 17 | 50 | 11 | 2 | 50 |
| Min | 12330 | 59.88 | 1.75 | 220 | 634 | 266 | 1640 | 17 | 0 | 0.63 | 2 | 1 | 2 |
| **South-western region** | | | | | | | | | | | | | |
| Mean | 23448 | 242.73 | 13.17 | 1027 | 2297 | 1750 | 6709 | 38.1 | 9.0 | 8.6 | 5.6 | 1.3 | 21.8 |
| C V | 33.40 | 66.72 | 43.13 | 65 | 45 | 48 | 31 | 33.96 | 35.78 | 118.26 | 40.89 | 36.15 | 56.97 |
| Max | 41440 | 1140.00 | 25.00 | 4450 | 7517 | 3790 | 14300 | 75 | 16 | 50 | 16 | 2 | 56 |
| Min | 7400 | 135.00 | 2.00 | 40 | 490 | 450 | 2000 | 15 | 0 | 1 | 3 | 1 | 1 |
| **Punjab** | | | | | | | | | | | | | |
| Mean | 26120 | 230.55 | 12.78 | 790 | 2021 | 1261 | 5462 | 40.0 | 9.5 | 8.3 | 5.2 | 1.3 | 23.4 |
| C V | 41.01 | 118.78 | 38.11 | 88 | 51 | 56 | 43 | 31.10 | 35.47 | 115.30 | 33.46 | 36.15 | 49.91 |
| Max | 96100 | 2660.00 | 35.00 | 4450 | 7517 | 4642 | 17597 | 75 | 17 | 50 | 16 | 2 | 60 |
| Min | 7400 | 18.00 | 1.75 | 40 | 490 | 240 | 1349 | 15 | 0 | 0.63 | 2 | 1 | 1 |

**Table 2. OLS estimates of the production function, region-wise, Punjab: 2005-06**

| Variables | Regions/coefficients | | | |
|---|---|---|---|---|
| | Sub-mountainous | Central | South-western | Overall |
| Constant | 6.552*** | 5.744*** | 4.356*** | 6.831*** |
| | (8.533) | (18.117) | (5.167) | (15.783) |
| Human labour | -0.125 | 0.212*** | 0.059 | 0.144*** |
| | (-1.342) | (8.137) | (0.934) | (3.944) |
| Irrigation | -0.175* | 0.189*** | -0.445*** | -0.238*** |
| | (-1.649) | (5.108) | (-6.078) | (-4.926) |
| Seed | -0.035 | 0.081*** | -0.009 | -0.036 |
| | (-0.206) | (2.504) | (-0.165) | (-0.834) |
| Fertilizers | 0.327** | 0.080*** | 0.118 | 0.216*** |
| | (2.132) | (2.127) | (1.162) | (3.548) |
| Insecticides | 0.109 | -0.004 | 0.059 | 0.045 |
| | (1.01) | (-0.166) | (0.645) | (0.915) |
| Machine costs | 0.173 | 0.220*** | 0.592*** | 0.168*** |
| | (1.185) | (4.451) | (4.523) | (2.206) |

*Note:* *, **, *** indicate significance at 10, 5 and 1per cent levels, respectively

The coefficient of machine cost was 0.592 and significant at one per cent level, indicating that the higher use of this variable will add to the gross returns from crop production in this region.

Overall for the Punjab state, human labour, fertilizers and machine costs were positive and contributed significantly, which indicated that there was further scope of increasing the returns by enhancing input-levels of these inputs. It is contrary to the general impression that Punjab agriculture is over-fertilized, over-mechanized and labour-intensive. It may be that inputs were not in the optimal combination on the majority of farms. The coefficients of irrigation and seed value were significant at five per cent level. The sign of irrigation was not expected as negetive, because of large variation in the use of this input by different farm-size categories.

## Region-wise Coefficients of Frontier Production Function

The technical efficiency was examined by fitting a frontier production function model, including the explanatory factors and the analysis was carried out region-wise.

### Sub-mountainous Region

The response of human labour was highly significant and negative, pointing towards the existence of disguised unemployment in this region (Table 3). The coefficients of all variables remained significant as in OLS estimation; only the seed value became significant.

The estimation of gamma, which is the ratio of variance of farm-specific performance of TE to the total variance of value productivity per acre was 0.5193, implying that 52 per cent of the difference between the observed and frontier output is primarily due to the factors which are under the control of farmers. The estimated technical efficiency of individual farm varied between 45 and 98 per cent, with mean technical efficiency of about 66 per cent, implying that on average, the sample farmers tendrd to realize only 66 per cent of their technical abilities. Hence, on an average, approximately 34 per cent of their technical potential was not being realized by the sample farms in crop production in the sub-mountainous region of Punjab.

The examination of technical efficiency of individual farmers revealed that 12 per cent of the farmers realized less than 60 per cent of the potential value output, whereas 19 per cent of the farms harvested 71-80 per cent of the potential value output of crop production (Table 4). About 12 per cent of farmers were operating near the potential output, i.e. 91-100 per cent of technical efficiency.

The negative and significant coefficients for age suggested that with maturity, inefficiency decreases.

**Table 3. Region-wise maximum likelihood estimates of stochastic production frontier and technical inefficiency models in crop production, Punjab: 2005-06**

| Variables | Sub-mountainous region | | Central region | | South-western region | | Punjab state | |
|---|---|---|---|---|---|---|---|---|
| | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value |
| **Frontier production function** | | | | | | | | |
| Constant | 6.9391*** | 8.0826 | 5.5613*** | 14.9871 | 5.0158*** | 5.5764 | 7.6903*** | 16.8574 |
| Human labour | -0.1870** | -2.0253 | 0.2774*** | 10.3831 | 0.2150*** | 3.9031 | 0.2016*** | 5.5824 |
| Irrigation | -0.1583 | -1.4843 | 0.1266*** | 2.9965 | -0.5182*** | -9.0503 | -0.2184*** | -4.1425 |
| Seed | 0.2313 | 1.2718 | 0.0198 | 0.6577 | 0.0737** | 1.6346 | -0.0178 | -0.4219 |
| Fertilizer nutrients | 0.2093 | 1.4210 | 0.0721** | 2.2098 | -0.0006 | -0.0061 | 0.1465** | 2.6547 |
| Insecticides/ pesticides | 0.0378 | 0.3458 | 0.0207 | 0.6511 | -0.06144 | -0.7777 | -0.0012 | -0.0257 |
| Machinery costs | 0.1633 | 1.0927 | 0.2654*** | 5.5644 | 0.6145*** | 4.7752 | 0.1462** | 2.0248 |
| Sigma square | 0.03960*** | 3.9802 | 0.0869 | 0.8112 | 0.0689*** | 3.5612 | 0.1975** | 2.4758 |
| Gamma | 0.5193* | 1.6566 | 0.9357*** | 12.0509 | 0.9999*** | 10.7786 | 0.8866*** | 16.8489 |
| log likelihood | 11.0305 | - | 97.3831 | - | 33.2647 | - | -26.1951 | |
| **Technical inefficiency effect** | | | | | | | | |
| Constant | 5.8893*** | 3.1165 | -2.1397 | -0.6117 | -0.2528 | -0.2566 | -0.1909 | -1.4651 |
| Age | -3.1146*** | -3.0545 | 0.5355 | 0.6432 | -0.0531 | -0.1381 | 0.2709 | 0.8725 |
| Education | 0.1060* | 1.5490 | -0.1546 | -0.7464 | -0.2401*** | -2.5867 | 0.0179 | 0.22769 |
| Farm size | -0.0435 | -0.7612 | -0.2742 | -0.8621 | -0.1284 | -0.7702 | -0.2178* | -1.8142 |
| Family size | -0.12193 | -0.5636 | 0.1575 | 0.5583 | 0.3643 | 0.5889 | 0.4189 | 0.1639 |
| No. of occupation | -0.2263 | -1.1217 | 0.1833 | 0.4553 | 0.5647 | 0.0138 | 0.2722 | 0.1055 |
| Experience in agriculture | 1.9702*** | 3.1772 | -0.0011 | -0.0059 | -0.0751 | -0.4252 | 0.0587 | 0.3579 |
| Mean technical efficiencies (%) | 66.46 | - | 90.09 | - | 78.07 | - | 76.21 | |

*Note:* *, **, *** indicate significance at 10 per cent, 5 per cent and 1per cent levels, respectively

**Table 4. Technical efficiency (TE) estimates for different regions in Punjab: 2005-06**

| Level of TE (%) | Region/Frequency | | | |
|---|---|---|---|---|
| | Sub-mountainous | Central | South-western | Overall |
| 21-30 | 0 (0) | 0 (0) | 1 (1.23) | 1 (0.37) |
| 31-40 | 0 (0) | 0 (0) | 1 (1.23) | 2 (0.74) |
| 41-50 | 2 (3.57) | 1 (0.75) | 0 (0) | 10 (3.69) |
| 51-60 | 15 (26.79) | 0 (0) | 6 (7.41) | 32 (11.81) |
| 61-70 | 23 (41.07) | 2 (1.49) | 12 (14.81) | 38 (14.02) |
| 71-80 | 10 (17.86) | 13 (9.70) | 19 (23.46) | 52 (19.19) |
| 81-90 | 4 (7.14) | 27 (20.15) | 23 (28.40) | 104 (38.38) |
| 91-100 | 2 (3.57) | 91 (67.91) | 19 (23.46) | 32 (11.81) |
| Total | 56 (100) | 134 (100) | 81 (100) | 271 (100) |

*Note:* Values within the parentheses are percentages to respective column.

The coefficients of farm size, family size and number of occupations were also negative but non-significant indicating that improvement in these variables resulted in decrease in inefficiency.

**Central Region**

The maximum likelihood estimates of the stochastic frontier production function, given in Table 3, reveal that except the cost on seed and insecticide/pesticide, all other variables significantly influenced the returns from crop production in this region. The output elasticity was highest for human labour use (0.27), followed by costs on machinery (0.26), irrigation (0.12) and fertilizer (0.07). Most of the production elasticties, as estimated by the frontier model, were higher than the average elasticties given by the average production function estimated through ordinary least square (OLS) method. These differences were the results of better management practices, which required more knowledge and time allocation on the part of farmers and there was a scope to increase the value productivity of crop production under the existing condition and technology. The coefficient for gamma was higher (0.9357) and significant, indicating the appropriateness of the model. If the coefficient of gamma was not significant, an OLS function would have been sufficient, as the component technical inefficiency is small (Battese and Coelli, 1995).

About 90 per cent of the difference between the observed and the frontier value productivity was mainly due to inefficient use of resources, which was under the control of sample farmers. These findings corroborate the observations made by Battese and Coelli (1995), Datta and Joshi (1992), Jayaram *et al*. (1992) and Rama Rao *et al*. (2003). The technical efficiency of individual farms was found to vary between 49 per cent and 97 per cent (Table 3) with the mean technical efficiency of about 90 per cent in the central region. This suggests that productivity could be increased by about 10 per cent with the given level of input-use and technologies in the central region of Punjab. It was also observed that most of the farmers operated at technical efficiency level between 90 per cent and 100 per cent. A perusal into the factors affecting technical efficiency suggests that education, farm size and experience in agriculture were positively related with efficiency of a farmer. However, age, family size and number of occupations were negatively related with the efficiency. But, none of these coefficients could significantly influence the efficiency; These were only indicative of the relationship with the efficiency.

**South-western Region**

The coefficients of human labour, seed value and machinery cost were positive and significant in this region (Table 3). A high value of gamma (0.9999) indicated the presence of significant inefficiency in the production of crop. The average level of technical efficiency was estimated to be about 78 per cent, indicating that it was possible to improve the yield by 22 per cent by following efficient crop management practices. The distribution of sample farms by the level of technical efficiency revealed that maximum (75.32) concentration of sample farms was in the TE range of 70-100 per cent. The negatively significant coefficient for education suggests that as education level of the farmers improves, the inefficiency would decrease (Tilak, 1993). The coefficients of age, farm size and experience in agriculture were negatively correlated with inefficiency, but were non-significant. The coefficients of family size and number of occupations had a positive sign to correlate with inefficiency in crop production.

**Punjab State**

The maximum likelihood estimates of the stochastic production function for the state as a whole, presented in Table 3, revealed that costs on human labour, fertilizers and machinery influenced the value output of crops positively and significantly, whereas the coefficient of irrigation was negative and significant, indicating the over- use of water in crop production in the Punjab state.

Most of the production elasticties, as estimated by the frontier model, were higher than average elasticties given by average production function through ordinary least squares (OLS) method. The higher value of intercept in maximum likelihood estimates as compared with ordinary least square estimates and comparable values of estimated parameters provide credence to Hick’s neutral change (Shanmugam and Venkataramani, 2006). A significant and high value of gamma (0.89) indicates the presence of significant inefficiency in crop production and supports the findings of Kaur and Sekhon (2005) that total factor productivity has shown a dismal performance in Punjab agriculture since1980s. It is also reported that increasing inefficiency is the main factor responsible for the declining TFP in Punjab agriculture in spite of increase in input growth and positive technological change. The estimated technical efficiency ranged between 0.39 and 0.97, with a mean technical efficiency of 0.76 for all farms for the state as a whole. Thus, sample farms realized only 76 per cent of their potential value of output from crops and it is possible to increase the value crop output by about 24 per cent with the given level of input use and technologies. It was astonishing to observe that only about 50 per cent of the farmers realized more than 80 per cent of the potential returns from crop production (Table 4). Therefore, there is a scope to bridge the gap between the actual and potential output by using available resources more efficiently. A look into the factors affecting technical efficiency suggested that only farm size had a significant influence on technical efficiency. Its coefficient was negative and significant, indicating that technical efficiency of value production from crops increases as the size of landholding increases.

## Conclusions

The study has shown that even in an advanced agricultural region like in Punjab, there is a need to improve the technical efficiency of majority of the farmers. A perusal of farm-specific variables indicates low crop returns, low use of fertilizers, insecticides, and machinery and small farm-size in the sub-mountainous region. The highest gross return from crops has been observed in the central region. In the south-western region, use of fertilizer and machinery has been found higher. Ordinary least square production function estimates have indicated the presence of disguised unemployment in the sub-mountainous region.

Overall for the state, all the variables have been found to contribute positively towards production of crops. It is contrary to the general impression that Punjab agriculture is over-fertilized, over- mechanized and labour-intensive. The average technical efficiency has been estimated to be about 76 per cent. Mean technical efficiency has been recorded to vary across regions of the state; the central region being most technically efficient. The value of gamma has been found as 0.52, 0.93, 0.99 and 0.88, indicating 48, 7, 1 and 12 differences between observed and frontier output, mainly due to controlled factors in various regions and in the Punjab state. The main drivers are the experience in agriculture and age of a farmer. Negative coefficient of age implies that older farmers are more technical-efficient. The policy intervention to improve the technical efficiency being not the same for all the regions, the study has observed that the state would benefit more if policy interventions are developed at the local levels.

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## References

Ali, M. and Flinn, J.T. (1989) Profit efficiency in basmati rice production, *American Journal of Agricultural Economics*, **71** (2): 303-310.

Arindam, Banik (1994) Technical efficiency of irrigated farms in a village of Bangladesh, *Indian Journal of Agricultural Economics*, **49**(1): 70-78.

Battese, G.E. and Coelli T.J. (1995) A model for technical inefficiency effects in a stochastic frontier production function for panel data, *Empirical Economics*, **20**: 325-332.

Bravo-Vrata, B.E. and Evenson, R.E. (1994) Efficiency in agricultural production: The case of peasant farmers in eastern Paragnay, *Agricultural Economics*, **10**(1): 27-37.

Chadha, G.K. (1978) Farm size productivity re-visited: Some notes from recent experiences form Punjab, *Economic and Political Weekly*, **13** (9): A87- A96.

Chattopadhyay, M. and Senguptga, A. (1997) Farm size and productivity: A new look at the old debate, *Economic and Political Weekly*, **32 (**52): A172-A175.

Chattopadhyay, M. and Senguptga, A. (1999) Farm size and productivity, *Economic and Political Weekly*, **34 (**19): 1147-48.

Coelli, T. (1996) *A Guide to FRONTIER Version 4.1: A Computer Programme for Stochastic Frontier Production and Cost Function Estimation*, CEPA working paper 96/07Ccentre for Efficiency and Productivity Analysis, University of New England, Armidale, NSW, 2351, Australia.

Crom, A. (1996) *Government, Farmers and Seeds in Changing Africa*, CAD International, Wallingfont, Oxon, U.K. 174 p.

Datta, K.K. and Joshi, P.K. (1992) Economic efficiencies and land augmentation to increase agricultural production: A comparative analysis of investment priorities, *Indian Journal of Agricultural Economics*, **47**(3): 468-476.

Dawson, P.J. (1985) Measuring technical efficiency from production function: Some further estimates, *Journal of Agricultural Economics*, **38** (1): 27-37.

Dhillon, P.K. and Ali, Jabir (2002) Productivity growth in the agriculture sector of Punjab, *Agricultural Economics Research Review*, **15** (2):201-216.

Dyer, G. (1991) Farm-size productivity re-examined: Evidence from rural Egypt, *The Journal of Peasant Studies*, **19**(1):51-92.

Jayaram, H., Chandrashekar, G.S. and Achoth, L. (1992) An economic analysis of technical efficiency in rice cultivation in Mandya: Some issues in resource pricing, *Indian Journal of Agricultural Economics*, **47**(4): 677-682.

Kahn, H.M. (1979) Farm size and land productivity in Pakistan, *Pakistan Development Review*, **18**(1): 69-77.

Kalaitzandonakes, N.G., Wu, S. and Ma, J. (1992) The relationship between technical efficiency and farm size revisited, *Canadian Journal of Agricultural Economics*, **40**: 427-442.

Kalirajan, K.P. and Shand, R.T. (1989) A generalized measure of technical efficiency, *Applied Economics*, **21**: 25-34.

Kaur, Manjeet and Sekhon, M.K. (2005) Input growth, total factor productivity and its components in Punjab agriculture: District-wise analysis, *Indian Journal of Agricultural Economics*, **60** (3): 319-334.

Krishna, Raj (1964) Some production functions for Punjab, *Indian Journal of Agricultural Economics,* **28**, (1):1-14.

Meeusen, W. and den Brock, J.V. (1977) Efficiency estimation form Cobb Douglas production function with composed error, *International Economic Review*, **18** (2): 435-444.

Rama Rao, C.A., Chowdry, K.R., Reddy, Y.V.R. and Krishna Rao, G.V. (2003) Measuring and explaining technical efficiency in crop production in Andhra Pradesh, *Indian Journal of Agricultural Economics*, **58**(4): 768-780.

Sen, A.K. (1962) An aspect of Indian agriculture, *The Economic Weekly*, **24** (4):243-226**.**

Sen, A.K. (1964) Size of holding and productivity, *The Economic Weekly*, **16** (17-18): 777-778.

Shanmugam, K.R. and Venkataramani, A. (2006) Technical efficiency in agricultural production and its determinants :An exploratory study at the district level, *Indian Journal of Agricultural Economics*, **61**(2):169-184.

Sharma, V.P. and.Datta, K.K. (1997) Technical efficiency in wheat production on reclaimed alkali soils, *Productivity*, **38** (2): 334-338.

Sharma, H.R. and Sharma, R.K. (2000) Farm size productivity relationship: Empirical evidence from an agriculturally developed region of Himachal Pradesh, *Indian Journal of Economics*, **55** ( 4): 605-615.

Singh, J. and Hossain, M. (2002) Total factor productivity analysis and components in a high potential rice-wheat system: A case study of Indian Punjab. In: *Development in the Asian Rice Economy*, Eds: Hossain and Bhardy. International Rice Research Institute, The Philippines.

Taylor, G.T. and Shonkwiler, J.S. (1986) Alternative stochastic specialization of the frontier production function in the analysis of agricultural credit programmes and technical efficiency, *Journal of Development Economics*, **21**: 149-160.

Thomas, K. and Sundaresan, R. (2000) Economic efficiency of rice production in Kerla, *The Bihar Journal of Agrilcultural Marketing*, **8** (3): 310- 315.

Tilak, T.B.G. (1993) Education and agricultural productivities in Asia: A review, *Indian Journal of Agricultural Economics*, **48 (**2): 187-200.