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Research Note

Technical Efficiency of Wheat Production in Punjab: A Regional Analysis

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Abstract

The study has analysed the technical efficiency in wheat production across different regions of the Punjab state. It is based on the cross sectional data collected from a random sample of 564 farm households comprising 58, 318, and 188 households from semi-hilly, central and south-western regions for the year 2005-06. The mean technical efficiency of wheat production has been found as 87 per cent, 94 per cent, 86 per cent and 87 per cent in semi-hilly, central, south-western and Punjab state as a whole, respectively. The results signify that farmers of the central region do not have much scope to increase productivity of wheat through technical efficiency improvement under the existing conditions of input-use and technology. In the semi-hilly and south-western regions, the yield of wheat can be improved to the extent of 13 per cent and 15 per cent, respectively through adoption of better practices of technology. Across different regions, wheat area has contributed positively and significantly, the coefficient being highest and only significant variable for the central region. The coefficient of expenditure on insecticides and pesticides has been found significant for the semi-hilly region, demanding boost in the expenditure on insecticides and pesticides to increase wheat production in this region. The coefficient of fertilizer nutrients has been observed positive and significant for the semi-hilly and south-western regions, indicating that there is scope for increasing production of wheat by enhancing the use of fertilizers in these regions. Further, the technical efficiencies are positively and significantly related to age, education and experience of a farmer and percentage area under the crop.

Introduction

A number of studies have been conducted to estimate the technical efficiency of various crops/ enterprises in different states/regions of India (Shanmugam, 2003; Rama Rao *et al*., 2003; Reddy and Sen, 2004; Saha and Jain, 2004; Goyal *et al*., 2006; Ara *et al*., 2004; Kalirajan and Bhende, 2007). But no study seems to have been conducted in the state of Punjab, which is known as the food basket of the country and contributes about 60 per cent of wheat and 40 per cent of rice to the central pool. Sekhon *et al*. (2008) have estimated the technical inefficiency in crop production in Punjab using stochastic frontier production function. According to them, farms realize only 76 per cent of their potential value of output from crops. They have observed that value of crop output may be increased by about 24 per cent even with the given level of input use and technologies. They have stressed on the need of measuring the technical inefficiencies of major crops in the Punjab State. Evidences show a plateau in the crop yield levels, especially during the 1990s even in the well-endowed regions. Such a slow down or stagnation in yield levels is attributed, among other factors, to low efficiency in the production process, non-availability of new technologies, and resource degradation associated with input intensification. In this study, the level of technical inefficiency present in wheat production in the Punjab state has been investigated along with the influence of various farm-specific socio-economic factors on these inefficiencies.

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Methodology

The technical inefficiency of wheat-cultivating farms was estimated across different agro-climatic regions and at the aggregate level in Punjab using production frontier approach. The farm level cross sectional data was used for the reference year 2005-06. The sample farms were selected using the three-stage random sampling technique. The Punjab state was divided into three agro-climatic regions, viz. semi-hilly region (region-I), central region (region-II) and south-western region (region-III), which occupy 9 per cent, 65 per cent and 26 per cent of the total area in the state. A total of 20 blocks were selected randomly consisting of 2, 11 and 7 from regions I, II and III, respectively at the first stage of sampling. A cluster of two villages (depending upon the size of village) was randomly selected from each selected block and finally operational holdings were selected randomly. A total of 58, 318 and 188 farm households were selected randomly from semi-hilly, central and south-western regions, making a sample of 564 holdings. The operational holdings were categorized into marginal (> 1 ha), small (1.01-2 ha), semi-medium (2.01 – 4 ha), medium (4.01- 6ha) and large (> 6 ha) cateogries.

The technical inefficiency of an individual farm was estimated using the stochastic frontier production function proposed by Aigner *et al.* (1977) and Meeusen and Van den Brock (1977). The general form of the stochastic frontier production function is:

$$\ln (Y_i) = X_i\alpha + V_i - U_i \quad \ldots(1)$$

For the inefficient farm, the actual output produced is less than (or equal to) the potential output. Therefore, the ratio of actual output and potential output can be treated as a measure of technical efficiency. Using Equation (1), technical efficiency (TE) of the i-th farm is derived as :

$$TE_i = \exp(-U_i) = Q_i/Q_i^*$$

where, Q_i^* is the maximum possible output.

To study the effect of socio-economic factors on inefficiency, it was observed that it is better done in a single-step rather than in two-step procedures (Wilson and Hadley, 1998; Battese and Coelli, 1995). Therefore, the following functional form was used to estimate the individual technical efficiency and to examine the factors affecting them:

$$\ln Y_i = \alpha_o + \sum_{k=1}^{6} \alpha_k \ln X_{ki} + \sum_{j=1}^{2} d_j D_{ji} + v_i - u_i$$

$$u_i = \delta_0 + \sum_{m=1}^{6} \delta_m Z_m$$

where,

Y_i = Output of the ith farmer (q),

X_{ki} = Use of the k-th input by the i^{th} farmer,

D_{ji} = The j^{th} region of the i^{th} farmer,

v_i = The random-error assumed to be identically and independently distributed $N(0, \sigma^2_v)$,

u_i = Firm-specific inefficiency effect assumed to follow a truncated (at zero) normal distribution $N(\mu_i, \sigma^2_u)$,

Z_m = Factors affecting technical inefficiencies, and

αs and δs are the regression coefficients to be estimated.

The model was estimated using the computer programme FRONTIER 4.1 (Coelli, 1996) to estimate simultaneously the parameters of the stochastic production frontier and the technical inefficiency effects.

Specification of Variables

Y = Actual output of wheat on the ith farm (in quintals) (region I, region II, region III, / aggregate)

X_1 = Area under the wheat crop (ha),

X_2 = Expenditure on plant protection chemicals (Rs),

X_3 = Irrigation (No.),

X_4 = Human labour used (Family plus hired in hours),

X_5 = Machine labour used (hours),

X_6 = Quantity of fertilizer (N+P+K) in kg of nutrients,

D_1, D_2 = Regional dummies; D_1 for semi- hilly region; D_2 for south-western region;

Z_1 = Education of the farmer (number of years of schooling),

Z_2 = Experience of farmer in crop production (years),

Z_3 = Per cent area under wheat crop,

Z_4 = Number of family members working on farm, and

Z_5 = Farm size (ha)

Table 1. Mean and standard deviations of key variables

S. No.	Variables	Semi-hilly region	Central region	South-western region	Aggregate/ Punjab
1	Output (q/ha)	16.98	44.78	38.01	39.68
		(9.03)	(6.69)	(10.26)	(11.70)
2	Area (ha)	1.73	3.12	3.45	3.07
		(2.03)	(2.65)	(2.72)	(2.66)
3	Expenditure on plant protection chemicals (Rs/ha)	95	100	1336	1021
		(220.74)	(643.34)	(412.44)	(644.42)
4	Irrigation (No./ha)	3.86	4.47	4.72	4.49
		(1.55)	(1.11)	(0.88)	(1.12)
5	Human labour (hours/ha)	234.71	201.50	217.42	210.26
		(39.44)	(44.04)	(50.46)	(47.07)
6	Machine labour (hours/ha)	12.50	22.13	21.23	20.87
		(7.31)	(11.11)	(12.33)	(11.56)
7	Fertilizer nutrients (kg/ha)	102	340	220	257
		(99.18)	(358.70)	(59.07)	(284.48)
	Farm-specific variables				
1	Education of the farmer(School years)	6.93	6.11	5.40	5.96
		(3.44)	(4.51)	(4.45)	(4.41)
2	Experience in cropproduction (Years in farming)	24.10	30.25	28.41	29.00
		(13.10)	(13.05)	(12.59)	(13.01)
3	Area under wheat crop (%)	82.80	84.99	84.40	84.57
		(19.08)	(14.65)	(10.34)	(13.92)
4	No. of family members working on the farm	3.34	2.67	3.42	3.00
		(1.47)	(1.26)	(1.62)	(1.46)
5	Farm size (ha)	2.05	3.54	4.05	3.55
		(2.16)	(2.89)	(3.09)	(2.94)

Note: The values within the parentheses denote standard deviations.

Results and Discussion

Sample Characteristics

The mean and standard deviations of the variables used in the estimation of technical efficiency and its determinants across different regions are presented in Table 1.

The output of wheat was highest for the central region (44.78 q/ha), followed by south-western region (38.01 q/ha) and semi-hilly region (16.98 q/ha). The average area under the crop was highest (3.45 ha/ farm household) in the south-western region, and the lowest (1.73 ha/ farm household) for semi-hilly region. The highest expenditure on plant protection chemicals was incurred in the south-western region, which is the cotton belt of the Punjab state. The expenditure on plant protection chemicals was quite low in the sub-mountainous region for the wheat crop. The average number of irrigations per acre was around four in each region. The use of chemical fertilizer as nutrients was highest in the central region (340 kg/ha), followed by south-western region (220 kg/ha) and the lowest for the semi-hilly region (102 kg/ha).

Estimation of Frontier Production Function

The technical efficiency and the factors influencing technical efficiency were examined by fitting a frontier production function model including the explanatory factors of technical efficiency. The results obtained for different regions and aggregate for Punjab are presented in Tables 2-4. The maximum likelihood estimates of production function for the Punjab state revealed that the area, fertilizer nutrients, number of irrigations and expenditure on plant protection chemicals contributed positively and significantly towards the production of wheat in the state. These

Table 2. Maximum likelihood estimates of stochastic frontier production model among different regions of Punjab: 2005-06

Variables	Regions			
	Semi-hilly region	Central region	South-western region	Punjab
1. Constant	0.4225	1.1803***	0.1113	0.8335***
	(4.807)	(25.3492)	(0.4239)	(20.8911)
2. Wheat area	1.0068***	1.1729***	0.5798***	1.0129***
	(15.451)	(54.1307)	(4.0968)	(39.1593)
3. Insecticides	0.1576***	0.0032	-0.0455	0.0071**
	(14.961)	(1.1814)	(-0.7640)	(1.9316)
4. Irrigation	0.0741	-0.1128	0.5532***	0.0808*
	(0.783)	(-2.6056)	(4.6574)	(1.8114)
5. Human labour	0.0499	-0.0143	-0.0052	-0.0053
	(1.119)	(-0.1000)	(-0.1152)	(-0.3177)
6. Machine labour	-0.0009***	0.0089	0.04113	0.0073
	(-3.465)	(1.0189)	(1.5410)	(0.6825)
7. Fertilizers	0.0276***	-0.0067	0.4429***	0.1105***
	(2.137)	(-0.3777)	(4.5944)	(8.2289)
8. Dummy (for semi-hilly)	-	-	-	-0.2835***
				(-13.5600)
9. Dummy (for south-western)	-	-	-	-0.0381***
				(-3.6215)
Sigma square	0.0317*	0.0596***	0.0302***	0.2239***
	(1.814)	(6.7677)	(5.6482)	(2.5873)
Gamma	0.9744***	0.9723***	0.9999***	0.9832***
	(38.196)	(148.8683)	(8740.0025)	(153.2126)
log likelihood function	61.0557	424.4376	159.1847	490.97

Notes: ***, **, * indicate significance at 1 per cent, 5per cent and 10 per cent levels, respectively.
Figures within the parentheses are t values.

positive and significant values indicate that there is scope for increasing production of wheat by enhancing the level of these inputs. The area under the crop has the highest elasticity (1.012), followed by fertilizer nutrients (0.1105), number of irrigations (0.0808) and expenditure on plant protection chemicals (0.007). The coefficient of human labour was negative but non-significant, indicating the tendency of disguised employment in agriculture. Two dummy variables were included in the regression equation representing semi-hilly region and south-western region. The significant value of these coefficients indicates regional differences in the productivity of wheat. The coefficients of dummy variables for both semi-hilly and south-western regions were significant but negative, indicating significant regional differences in wheat yield. It confirms that the wheat yield is higher in the central region than semi-hilly and south-western regions.

Across different regions, wheat area contributed positively and significantly, the coefficient being highest for the central region (1.1729), followed by semi-hilly (1.0068) and south-western (0.5798) regions. It indicates that increase of one unit in area will add more in the central than other two regions. The coefficient of expenditure on insecticides and pesticides was only significant for the semi-hilly region, demanding increase in the expenditure on insecticides and pesticides to increase wheat production in this region, whereas the coefficient was negative but non-significant for the south-western region, indicating over-use of insecticides/pesticides in this region in wheat crop. Higher application of irrigation would add to the production of wheat in the south-western region; increase of one irrigation would add 0.5532 units to the production of wheat in the south-western region. The coefficient of machine labour was unexpectedly

Table 3. Distribution of the sample farms by level of technical efficiency, among different regions of Punjab, 2005-06

(Per cent)

Technical efficiency (%)	Semi-hilly region	Central region	South-western region	Overall/Punjab
≤ 60	2	1	1	3
61-70	9	0	6	6
71-80	16	3	16	11
81-90	22	8	35	26
91-100	51	88	42	54
Mean efficiency	87.0	94.49	85.92	87.51
	(58)	(318)	(188)	(564)

Note: Figures within the parentheses indicate number of sample farm households.

negative and significant in the semi-hilly region. The coefficient of fertilizers was positive and significant for the semi-hilly and south-western regions, indicating that there is scope for increasing production of wheat by increasing the use of fertilizers in these regions.

The significant value of ã being 0.9744, 0.9723, 0.9979 and 0.9832 for the semi- hilly, central, south-western regions and Punjab state, respectively indicates the presence as well as dominance of inefficiency effect over the random error in all the regions and for the state as a whole, i.e. more than 97 per cent of the difference between the observed and frontier outputs was mainly due to inefficient use of resources by the farmers of different regions.

Table 3 shows the frequency distribution of estimated technical efficiency for the sample households. The estimated mean technical efficiency for the state as a whole was 87 per cent, implying that on an average 13 per cent of their technical potentials were not being realized in wheat production in the state. Among different regions, the average level of technical efficiency being 87 per cent in the semi-hilly region, indicated possibility of improving wheat yield by 13 per cent by following efficient crop management practices. It was also observed that more than 50 per cent of the farmers operated in the 91-100 per cent efficiency range, followed by 81-90 per cent range (22%). The percentage of farmers operating below 70 per cent of technical efficiency was highest in the semi-hilly region (11%), followed by south-western region (7%) and was least (1%) in the central region.

The inefficiency could be due to a number of personal, household and farm-specific factors (Table 4). Overall in the Punjab state, education and experience of the family-head, percentage area under wheat crop to the total operational area and farm size had significant impact on improving the efficiency in wheat production. Among different regions, the difference in technical efficiency levels was significantly influenced by education and per cent area under the crop in the semi-hilly region. The negative and significant coefficient of education and proportion of area under the wheat to the total operational area suggest that as the educational level of the farmers improves, the inefficiency decreases or efficiency improves. The education not only helps in better crop management decisions but also places the farmer in better services (Tilak, 1993). The number of workers had a positive and significant relationship with technical inefficiency, indicating that households with higher number of members working on farm are relatively less efficient in raising wheat crop in the semi-hilly region of the Punjab state. Farm size had a negative but non-significant coefficient, indicating that higher the farm size, lower was the technical inefficiency in the semi- hilly region.

In the central region, education and experience depicted negative and significant coefficients, suggesting that improvement in human capital increases technical efficiency. The association between technical inefficiencies and proportionate area under the crop was also negative and significant, i.e. large farmers were comparatively more efficient in this region. Unlike in the semi-hilly region, the number of workers had a negative and significant coefficient, thus having a positive relation with efficiency.

In the south-western region, per cent area and number of farm workers working on the farm had a negative and significant coefficient, indicating higher use of these variables will reduce the presence of

Table 4. Estimates of the influence of farm-specific factors on technical efficiency across different regions of Punjab: 2005-06

Variables	Coefficients			
	Semi-hilly region	Central region	South-western region	Punjab
Constant	1.3133	4.5137***	1.5034**	8.2034***
	(1.4759)	(9.2299)	(2.3605)	(3.6215)
Education	-0.3031**	-0.2561***	-0.0353	-0.3311***
	(-1.9631)	(-8.3361)	(-0.8454)	(-3.9589)
Experience	-0.3038	-1.0736***	0.0685	-1.8447***
	(-1.4241)	(-9.0504)	(0.7995)	(-3.055592)
Percentage area under wheat	-0.6862*	-1.4878***	-0.6612**	-3.3262***
	(-1.8530)	(-5.8525)	(-2.3208)	(-3.1791)
No. of farm workers	1.0285*	0.0823	0.3277	-0.1184
	(1.8330)	(0.4439)	(-2.3774)	(-0.9322)
Farm size	-0.1395	-0.0596***	-0.0066	-0.1404***
	(-0.4848)	(-16.8963)	(-0.0796)	(-2.7582)

Note: ***, **, * indicate significance at 1 per cent, 5 per cent and 10 per cent levels, respectively.
Figures within the parentheses are t values.

inefficiency in the wheat production in this area and vice-versa. Education and farm size also had negative relationship with inefficiency but non-significant, whereas the coefficient of experience was unexpectedly positive but non-significant.

Conclusions

Study has concluded that wheat area, plant protection chemicals and fertilizers are the significant determinants of output in the semi-hilly region. Only the area under wheat is significant in the central region and irrigation and fertilizers influence positively the yield of wheat in the south-western region. The mean technical efficiency

of wheat production has been found to be around 87 per cent for the state as a whole. Among different regions, it has been estimated to be highest for the central region (94%), followed by semi-hilly region (87%) and south-western region (85%)

The results signify that the farmers of the central region do not have much scope to increase productivity of wheat through technical efficiency improvement under the existing conditions of input use and technology. In the semi-hilly and south-western regions, the yield of wheat can be improved to the extent of 13 per cent and 15 per cent, respectively through better practices of technology. If the efficiency could be improved, farmers will gain considerably in terms of higher profit. Further, the technical inefficiencies are significantly related to age, education, experience and percentage area under the crop. The results are important as they provide detailed information to the policymakers on the nature of production technology used in wheat production among different regions of Punjab.

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