Agricultural Economics Research Review
Vol. 23 July-December 2010 pp 383-390

Research Note

Technical Efficiency of Dryland and Irrigated Wheat Based on Stochastic Model

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Abstract

The technical efficiency and factors affecting efficiency of wheat farmers under dryland and irrigated conditions in the Jammu district of J &K state have been reported for the year 2006. The stochastic frontier production function has been used to determine the technical efficiency of these farmers. Technical efficiency has been found different under both the conditions. The estimated mean technical efficiency of wheat farmers under dry condition has been found to be 0.84, indicating 84 per cent efficiency in their use of production inputs, and for irrigated condition it has been found to be 0.88, that means the average output of wheat could be increased by 12 per cent by adopting technology properly. The value of γ under dry and irrigated conditions has indicated that about 99 per cent and 88 per cent of the differences between the observed and the maximum production frontier outputs are due to the factors, which are under farmers' control. The estimated value of λ under dry and irrigated conditions are significantly different from zero, indicating a good fit and the correctness of the distributional assumptions specified. The value of λ has been more than one, implying the dominance of one-sided component U_i in E_i and thus indicated high degree of technical inefficiency. In other words, the inefficiency component was not dominated by the random factors. The variance ratio γ has showed that the farm-specific variability contributed more to the variation in yield, which means that variation in output from frontier is attributed to technical inefficiency. Some of the factors found to influence the level of technical efficiency are higher level of education in irrigated condition and larger number of male workers under dry conditions.

Introduction

India, the second largest wheat producing country of the world, has an area of 27.7 Mha, with 77.6 Mt production and 28.06 q/ha yield under its cultivation (http/www.economicsurvey.com). Apart from the other wheat-growing states of the country, the state of Jammu and Kashmir also occupies a large area under its cultivation. In the year 2006-07, it had 0.26 Mha area under wheat with production of 0.49 Mt and yield of 18.70 q/ha. (Anonymous, 2008). The Jammu district of Jammu and Kashmir state (J&K) comprises 1.99 lakh ha as cultivable area, of which 72.46 per cent falls under the dryland and 27.54 per cent under irrigated farming system.

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In J&K, wheat is grown under both irrigated and dryland conditions. Dry areas contribute less as compared to irrigated areas, due to continued low productivity, inhabitancy by poorest segment of the country, frequent crop failures, highly erratic and undependable rainfall pattern, intermittent dry spells during crop growth and neglected soil and crop management practices (Govindan and Thirumurugan, 2003). Although the dryland/ rainfed farming continues to be a key priority area for the policy planners of the country, it is being realized that the farmers of these two ecosystems (irrigated and dryland) differ to a large extent in terms of crop productivity.

Many studies have revealed that in the Indian agriculture a majority of the farmers have not been able to approach the potential yield levels (Kalirajan, 1990; Mythili and Shanmugam, 2000). Therefore, for productivity improvement, studies on the technical efficiency are the need of the hour. In J&K, where resources are scarce and opportunities for new technologies are lacking, efficiency studies will be able to show that it is possible to increase productivity without additional investment, input enhancement or developing new technology. Under this background, the present study has reported technical efficiency of wheat crop under dryland and irrigated conditions in the Jammu district of J&K. The specific objectives of the study were:

- To examine the technical efficiency of wheat under dry and irrigated conditions, and
- To identify the factors influencing technical efficiency in wheat production under dryland and irrigated conditions.

Methodology and Data

The primary data on technical efficiency, resource-use and input-output level as well as other relevant information were collected by interviewing the farmers personally with the help of a specially structured and pre-tested schedule. The present study was confined to four blocks of the Jammu district — R.S. Pura and Marh, which represented the irrigated farming, and Vijaypur and Akhnoor, which represented dryland farming. To collect relevant information from the study area, three-stage sampling design was adopted. Blocks, villages and farmers formed the first, second and third stage units, respectively. Keeping in view the area under cultivation, four blocks were selected purposely from the Jammu district and then from each block, three villages were selected by simple random sampling at the secondary stage. The ultimate units, i.e. farmers were also selected by simple random sampling from each village of the four blocks so as to constitute the sample units of 50 farmers and a total of 200 farmers from the whole area under study.

Economic Analysis

The collected data were analysed to examine the technical efficiency, and factors influencing the technical efficiency in wheat production under dry and irrigated conditions.

Estimation of Technical Efficiency

For the estimation of technical efficiency, the stochastic frontier production function, proposed by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) was used, as given below:

Stochastic Frontier Model Specification

$$\ln (Y_i) = \ln \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + (v_i - u_i)$$

where,

Y = Crop yield (kg/ha),

β_0 = Constant or intercept,

X_1 = Area under wheat (ha),

X_2 = Quantity of seed used (kg/ha),

X_3 = Quantity of fertilizers used (kg/ha),

X_4 = Family labour used (humandays/ha),

X_5 = Hired labour used (humandays/ha),

β_i = Unknown parameters to be estimated,

v_i = An independently and identically distributed random error,

u_i = A non-negative variable associated with technical inefficiency in production, and

i = 1, 2, 3,…….,n.

The linear regression model used for estimating the factors affecting technical efficiency of wheat growers of dryland and irrigated wheat farming was:

$$\ln [TE/ (1- TE)] = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + u_i$$

where,

Z_1 = Farm size (ha)

Z_2 = Male workers (humandays/ha)

Z_3 = Female workers (humandays/ha)

Z_4 = Proportion of children as helpers (humandays/ha)

Z_5 = Education level of the selected farmers (up to post-graduation level)

δ_0 = Constant

δ_i = Unknown parameters to be estimated, and

i = 1,2,3,..........,n.

The β and δ are coefficients of unknown parameters to be estimated, together with the variance parameters which are expressed in terms of

$$\sigma^2 = \sigma^2_u + \sigma^2_v$$

and

$$\gamma = \sigma^2_u / \sigma^2$$

The γ parameter has values between zero and one. The parameters of the stochastic frontier production function model are estimated by the maximum likelihood method, using the computer program, Limdep (Greene, 2002).

Results and Discussion

Cost and Returns of Dryland and Irrigated Wheat Farming System

The data on cost and returns of dryland and irrigated wheat farming systems, presented in Table 1, revealed that operational cost, fixed cost and total cost were all lower under dryland farming than irrigated farming. It is also observed that though the cost involved in dryland wheat cultivation was 41 per cent of the total cost in these two farming systems, its yield was much less (20.3q/ha) than of the irrigated system (34.7q/ha). Their BCR worked out to be 1.10 for dryland and 1.44 for irrigated wheat.

Resource-use Efficiency (OLS estimates)

Ordinary least square estimates of the parameters showed the average performance of different variables of the sample farmers. The value of R^2 was 0.90 under dryland and and 0.87 under irrigated conditions, which indicated 90 per cent and 87 per cent variations in wheat crop. The estimates of the stochastic frontier showed that coefficients of the area and (manures + fertilizers) were positive and statistically significant at one per cent level of significance in dryland wheat. It indicated 1.358 per cent and 0.087 per cent increase in wheat production with one per cent increase in area and (manures + fertilizers), respectively and were thus productive and underutilized inputs under dryland conditions. The regression coefficients for area, seed and hired labour were positively significant at one per cent (area and seed) and five per cent (hired labour) levels of significance in irrigated wheat. The values revealed the possibility of 0.627 per cent, 0.359 per cent and 0.044 per cent increase in wheat crop production under irrigated conditions with one per cent increase in area, seed and hired labour, respectively. This result is in consistence with the findings of Hasan (2008) and Mohiuddin *et al.* (2007). Table 2 further revealed that the regression coefficient of seed under dryland wheat was negatively significant at one per cent level of significance. Thus, seed was being over-utilized and could rather reduce the wheat output to the extent of 0.461 per cent if it was increased by one per cent. It was further observed that the regression coefficients for (manures + fertilizers) and family labour were negatively significant at 10 per cent level of significance under the irrigated wheat. The coefficient of family labour even under dryland was negative and non-significant. Thus, all these variables were being utilized more than their optimum limits and increase in their use by 1 per cent could reduce the wheat crop output in irrigated wheat.

Table 1. Cost and returns under dryland and irrigated wheat farmings in Jammu district

Particulars	Dryland wheat	Irrigated wheat
Operational cost (Rs/ha)	12007	16001
Fixed cost (Rs/ha)	5825	9663
Total cost (Rs/ha)	17832	25664
Yield (q/ha)	20.3	34.7
Gross income (Rs/ha)	19558	36836
Benefit-cost ratio	1.10	1.44

Technical Efficiency of Wheat Crop

The estimates of the stochastic frontier showed efficient use of available technology and the regression coefficients in the frontier production function were the production elasticities, and their sum indicated the returns to scale. The estimated values of the coefficients of area (1.358) and (manures + fertilizers) (0.087) were positively significant under dryland conditions. The elasticity coefficient of area was more than one, which meant increasing returns to scale and increase in wheat crop more than proportionally with one per cent increase in area. The increase in wheat crop would be less than proportion with its one per cent increase in (manures + fertilizers). Similarly, under the irrigated conditions, regression coefficient vis-à-vis elasticity of area and seed was significantly positive. Thus, these variables were under-utilized but their elasticity with value less than one indicated the second stage of Law of Variable Proportions, i.e., law of diminishing returns, thereby their one per cent increase could increase the total wheat crop at a decreasing rate. The family labour was significantly negative under both the conditions and they could rather decrease the wheat crop by 0.060 per cent and 0.072 per cent, respectively if they were increased by 1 per cent and

Table 2. Ordinary least square (OLS) estimates of a Cobb-Douglas production function for wheat crop under dryland and irrigated conditions in Jammu district

Variable	Parameters	Dryland wheat		Irrigated wheat	
		Co-efficient	Standard error	Co-efficient	Standard error
Intercept	β_0	5.479	0.340	3.620	0.376
Area	β_1	1.358*	.134	0.627*	0.147
Seed	β_2	-0.461*	0.109	0.359 *	0.106
Manures+Fertilizers	β_3	0.087*	0.027	-0.057***	0.043
Family labour	β_4	-0.060	0.079	-0.061***	0.056
Hired labour	β_5	0.017	0.024	0.044**	0.025
R^2		0.90		0.87	

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

Table 3. Maximum likelihood estimates (MLE) of parameters of stochastic frontier production function in dryland and irrigated wheat crop in Jammu district

Variable	Parameters	Wheat dry		Wheat irrigated	
		Coefficient/ elasticity	Standard error	Coefficient/ elasticity	Standard error
Intercept	β_0	5.574	0.292	3.757	0.423
Area (X_1)	β_1	1.358 *	0.127	0.618*	0.168
Seed (X_2)	β_2	-0.461*	0.087	0.373*	0.136
Manures + Fertilizers (X_3)	β_3	0.087*	0.011	- 0.076***	0.074
Familylabour (X_4)	β_4	-0.060	0.090	-0.072	0.064
Hired labour (X_5)	β_5	0.017	0.020	0.059**	0.035
RTS		0.941	0.902		
Variance parameters					
σ^2_u		0.01385		0.0113	
σ^2_v		0.00012		0.0014	
σ^2		0.1181		0.1131	
λ		10.8175		2.7800	
γ		0.9919		0.8852	
log likelihood		83.8645		122.3071	

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

were having negative returns to scale. The sum total of elasticities of different inputs was less than one in both dryland (0.941) and irrigated land (0.902), indicating diminishing returns to scale. This indicated that if use of the inputs specified in the function were increased by one per cent, it would increase the output, but less than 1 per cent.

The γ parameter associated with variances in the stochastic frontier was significant under both the conditions. It indicated that there were inefficiency effects in the wheat crop production and the random component of the inefficiency effects made a significant contribution in wheat production. The value of γ was 0.9919 in dryland and 0.8852 in irrigated conditions, which meant that about 99 per cent and 88 per cent of the differences, respectively between the observed and the maximum production frontier outputs were due to the factors which were under farmers' control. The stochastic frontier analysis further showed that 99 per cent under dry and 88 per cent under irrigated condition of the observed inefficiency was due to farmers' inefficiency in decision making and only 1 per cent and 12 per cent of it was due to random factors outside their control. These results are in conformity with those of Shanmugam and Venkataramani (2006) and Ogundari *et al.* (2007). The estimated value of λ was 10.8175 for dry and 2.7800 for irrigated conditions; these values were significantly different from zero, indicating a good fit and the correctness of the distributional assumptions specified. The value of λ was more than one, implying the dominance of one-sided component u_i in E_i and thus indicated high degree of technical inefficiency. In other words, the inefficiency component was not dominated by the random factors. The variance ratio γ showed that the farm-specific variability contributed more to the variation in yield, which meant that variation in output from frontier was attributed to technical inefficiency. The estimate of σ^2 was 0.1181 for dry and 0.1131 for irrigated conditions and both were significant. These suggested that the technical inefficiency effects were a momentous component to the total variability in the yield of wheat crop. The log likelihood functions of dryland (83.8645) and irrigated (122.3071) conditions were large and significantly different from zero, indicating a good fit and the correctness of the specific distribution assumption.

Efficiency Scores of the Farmers for Dryland and Irrigated Wheat Crop

A perusal of Table 4 revealed that mean technical efficiencies were 0.84 per cent for dry condition and 0.88 per cent for irrigated condition. This indicated that the farmers were about 4 per cent more efficient technically under irrigated condition than under dry condition. The study implied that the wheat output of the "average farmer" could be increased by 16 per cent in the case of dryland and 12 per cent in irrigated condition by adopting technology properly. Table 4 further indicated that maximum number of sample wheat growers were in the minimum efficiency level of 80-85 per cent under dryland and 85-90 per cent under irrigated conditions. The level of technical efficiency observed in this study appeared to be more than that reported by Bravo-Ureta and Evenson (1994) for farmers in eastern Peru (58-59%), Anupama *et al.* (2005) among the maize producers in Madhya Pradesh (77%) and Wadud and White (2000) for rice farmers in Bangladesh (75%).

Input Use and Technical Efficiency of Wheat Crop under Dryland and Irrigated Farmings

The details about input-use across different levels of technical efficiency (Table 5) showed that the technically most efficient producers (95-100% efficiency level) who had the highest average yield of 19.04 q/ha, used the following combination of inputs: 52.23 kg/ha fertilizers, 78.36 kg/ha seed and 38.52 humandays/ha. However, though efficient among the sampled wheat growers, they still used inputs below the recommended rates, viz. seed (100 kg/ha), N (60-80 kg/ha), P (40 kg/ha) and K (20 kg/ha). In comparison, the least-efficient producers (80-85%) who had the yield of merely 10.95 q/ha, were using the inputs far less than the recommended dosages (29.96 kg/ha fertilizers, 52.16 kg/ha seed, and 75.56 humandays/ha). The labour used by this cluster was more than that of the most efficient producers. Table 5 has further revealed that under irrigated wheat farming, the technically most efficient-producers (95-100% efficiency level), who had the highest average yield of 37.02 q/ha, used the following combination of inputs: 100.52 kg/ha fertilizers, 99.58 kg/ha seed and 52.23 humandays/ha. However, though efficient among the sampled wheat growers, they still used inputs below the recommended rates, viz. seed (125 kg/ha), N (80-120 kg/ha), P (40-60 kg/ha) and K (40 kg/ha). In comparison, the least-efficient producers (80-85%) who

Table 4. Distribution of wheat growers under different levels of technical efficiency in Jammu district

Efficiency level	Wheat dry		Wheat irrigated	
(%)	Number of farms	Percentage of total farms	Number of farms	Percentage of total farms
80-85	35	35.00	28	28.00
85-90	23	23.00	32	32.00
90-95	18	18.00	15	25.00
95-100	24	24.00	25	15.00
Total farmers	100	100	100	100
Mean efficiency	0.84	0.88		

Table 5. Input use of wheat growers under different levels of technical efficiency in Jammu district

Categorized technical efficiency (%)	Yield (q/ha)	Fertilizers (kg/ha)	Seed (kg/ha)	Labour (humandays/ha)
		Dryland wheat		
80-85	10.95	29.96	52.16	75.56
85-90	13.65	35.63	58.35	54.74
90-95	16.20	43.32	65.58	43.07
95-100	19.04	52.23	78.36	38.52
Overall mean	100	40.28	63.61	52.97
		Irrigated wheat		
80-85	25.58	80.29	80.28	75.56
85-90	29.38	84.54	83.25	64.74
90-95	33.96	89.89	88.32	53.07
95-100	37.02	100.52	99.58	52.23
Overall mean	100	88.81	87.85	61.40

had the yield of merely 25.58 q/ha, were using the input far less than the recommended dosages (80.29 kg/ha fertilizers, 80.28 kg/ha seed and 75.56 humandays/ha). Similar findings were reported by Kibaara (2005) for the technical efficiency in Kenyan maize production.

Estimated Potential Yield under Dryland and Irrigated Wheat Farmings

The potential yield was calculated for each farm and the range of technical efficiency presented the results:

Potential yield= 100/TE* actual yield

Under different efficiency levels, the estimated average potential yield for the sampled farmers was 19.37 q/ha and average actual yield was 14.96 q/ha, this could go up to 25.32 q/ha among the most-efficient farms having the technical efficiency level of 95-100 per cent. However, there was a range of actual yield between 10.95 q/ha and 14.96 q/ha (technically most-inefficient and technically most-efficient farmers, respectively). This showed that there was intra-variation in yield among farmers in the same region. The farmers having efficiency level of 80-85 per cent showed the actual yield of 10.95 q/ha, 13.65 q/ha in the efficiency level of 85-90 per cent, 16.20 q/ha in 90-95 per cent, and 19.04 q/ha for the farmers under the efficiency level of 95-100 per cent. The potential yield showed that the actual yield could go up to 14.68 q/ha (for 80-85% range), to 17.26 q/ha (for 85-90% range), to 20.25 q/ha (for 90-95% range), and to 25.32 q/ha (for 95-100% range), if the farmers were technically most efficient or used the resources properly. Thus, the difference between the potential and actual yields was 3.73 q/ha, 3.61 q/ha, 4.05 q/ha, 6.28 q/ha, respectively for the above mentioned efficiency levels.

Under different efficiency levels, the estimated average potential yield for the farmers was 34.96 q/ha and the average actual yield was 31.48 q/ha, this could go up to 40.32 q/ha among the most-efficient farms having the technical efficiency level of 95-100 per cent under the irrigated conditions. However, the actual yield ranged between 25.58 q/ha and 37.02 q/ha for technically most-inefficient and technically most-efficient farmers, respectively. The potential yield showed that this actual yield could go up to 30.36 q/ha (for 80-85% range), to 33.25 q/ha (for 85-90% range), to 35.91 q/ha (for 90-95% range), and to 40.32 q/ha (for 95-100% range), if the farmers were technically most efficient or used the resources properly. The difference between the potential and actual yields was 4.78 q/ha, 3.87 q/ha, 1.95q/ha, 3.3 q/ha, respectively in the above mentioned efficiency levels. These results are in conformity with those of Kibaara (2005) and Ingosi (2005).

Factors Affecting Technical Efficiency

A perusal of Table 7 indicated that the coefficient of estimated value for male workers in dryland condition was positive and significant, which meant that male workers were more efficient. The coefficient of estimated value of education in irrigated condition was negative but significant at 5 per cent level of

Table 6. Estimated potential yield under dryland and irrigated wheat farmings in Jammu district

Categorized technical efficiency (%)	Percentage of total farms	Technical efficiency	Yield (q/ha)	Potential yield (q/ha)
		Dryland wheat		
80-85	35	81.56	10.95	14.68
85-90	23	86.13	13.65	17.26
90-95	18	92.56	16.20	20.25
95-100	24	96.32	19.04	25.32
Overall mean	100	89.14	14.96	19.37
		Irrigated wheat		
80-85	28	84.23	25.58	30.36
85-90	32	88.36	29.38	33.25
90-95	15	94.56	33.96	35.91
95-100	25	97.77	37.02	40.32
Overall mean	100	91.23	31.48	34.96

Table 7. Determinants of technical efficiency in wheat farms in Jammu district

Variables	Parameters	Dryland wheat		Irrigated wheat	
		Co-efficient	Standard error	Co-efficient	Standard error
Intercept	δ_0	99.502	0.630	22.306	0.919
Farm size (Z_1)	δ_1	-0.031*	0.086	1.673**	1.497
Male (Z_2)	δ_2	0.276***	0.202	0.012*	0.150
Female (Z_3)	δ_3	-0.103**	0.216	0.030**	0.088
Children (Z_4)	δ_4	0.032	0.115	-9.861	4.406
Education (Z_5)	δ_5	-0.024*	0.050	-8.536**	8.985

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

significance, which indicated an inverse relationship between technical efficiency and level of education. The negative sign on the coefficients of farm size, female workers and education indicated that the technical efficiency of farmers under dryland conditions decreased with the increase of these inputs and the positive sign on the proportion of children though non-significant indicated that the technical efficiency could increase with increase in number of children as helpers. As far as irrigated wheat farming was concerned, the coefficient for children (-9.861) as helpers and education (-8.536) were inversely related with technical efficiency, whereas the farm-size, male workers and female workers were positively related with technical efficiency.

Conclusions

The present study has confirmed that the farmers under irrigated conditions are technically more efficient than those under dryland conditions. The mean technical efficiency has been found as 0.84 per cent for dryland condition and 0.88 per cent for irrigated condition, which indicates that on an average, the realized output could be raised by 16 per cent under dryland and 12 per cent under irrigated wheat farming systems without any additional resources. Technical inefficiency has been attributed to the functioning of the farmers under both irrigated and rainfed conditions and not by the random factors, which are beyond the control of farmers. Education under both the farming systems is contributing negatively to the technical efficiency. It has been observed that education up to middle level contributes positively to the technical efficiency, but beyond that level, a negative relationship appears between the two. The technical efficiency of wheat growers in the Jammu district of J&K state can be improved by the use of proper technology.

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