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Whether Source of Irrigation Make Difference in Technical Efficiency of Wheat Growers in Canal Command Areas? A Stochastic Frontier Approach

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ABSTRACT

This paper analyses farm level efficiencies using Stochastic Frontier Production Function in two major wheat producing states of India: Uttar Pradesh and Haryana for the period 2015-16. For this empirical study, a total of 603 farmers were intensively surveyed using stratified random sampling in the study domain covering 8 villages and from each village at least 75 wheat growers were selected. The frontier production function was estimated using inputs like, labour (hour/ha), tractor use (hour/ha), quantity of seed (kg), fertiliser (kg/ha), and water usage (cum/ha), water market regimes, consumptive use of water etc. Overall, Technical Efficiency (TE) of the sample farmers in states was estimated to be 90 per cent, and TE of Haryana is only 2 per cent higher in comparison to Uttar Pradesh. This higher TE may be attributed to the consumptive irrigation. The result shows that majority of wheat farms attained TE more than70 per cent and other efficiency majors corresponding to these firms were higher. However, about 45per cent farms were at low lever level of TE. Thus, there is scope of improving the efficiency of these farms. The irrigation does influence the TE for both the states positively but it had significantly high impact on consumptive users as compared to ground water users. The farmers located in Haryana were found to be marginally more efficient than was Uttar Pradesh. The farm level innovations or new technology breakthrough can shift frontier production on the higher side to improve productivity and resource use efficiency of wheat growers.

Keywords: Wheat, Irrigation, Efficiency, Stochastic Frontier Production.

JEL.: C73, D24, Q15, Q25

I

INTRODUCTION

The prime objectives of irrigation investment are to have socio-economic development, inclusive economic growth and environmental protection. However, in the recent past the decline in spending on irrigation can be attributed to extraneous forces, such as escalating irrigation costs, the impact of the environmental movement, and inter-state river disputes (Shetty, 1990; Mishra and Chand, 1995, Bathla *et al.*. 2018). India's irrigation potential has been estimated about 139.8 mha. Surface irrigation was a major source of irrigation for both the cropping seasons. Agriculture consumes about 78 per cent Sharma (2018) and FAO, 2019 estimated it to be 90 per cent. The efficiency in wheat production is the major challenge due to high input cost

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including irrigation. Since wheat is the most important cereal crop and staple food for majority of the human population in northern India and it has been predominant particularly in states like Punjab, Haryana and western Uttar Pradesh. The economic factors - farm type (tenure or ownership), farm size, farm machinery and socio-environmental factors- infrastructure, markets, government policies and international trade contribute directly or indirectly to efficient wheat production (Passel *et al*., 2006; Hashmi *et al*. 2015). Wheat crop is grown in nearly 30 million hectares area producing 93.5 million tonnes with productivity of 3.1 tonnes/ha and India's share in world wheat production is 12.43 per cent. However, in recent times, the major wheat producing states like Punjab, Haryana, UP and Bihar have shown decline in the yield (Kaur *et al*., 2010)..

This may be attributed to low availability of irrigation water for the proper growth at critical stages of crops. The current estimates indicate that in India around 13.5 million hectares of wheat is heat stressed (Joshi *et al*., 2007). The other inputs like seed, chemicals and fertiliser, labour, machines and managerial efforts are becoming very expensive. The most efficient farmers would be those who choose from the input bundle which contributes to a maximum feasible output. It is very important to identify the bundles of inputs which improve the efficiency of crop production. The scope for expansion of area under wheat cultivation is limited; therefore, the growth in production is the only way of enhancing wheat productivity in India. The improvement in efficiency through canal and ground water irrigation can be the most important pathways in this endeavour. In this backdrop, efficient use of factors of production and their allocation need to be studied. There have been very limited studies specifically looking at wheat production amongst individual farmers, or what opportunities exist for them to improve their efficiency. Whether, irrigation affect the efficiency?, The efficiency analysis, in general, focuses on the possibility if producing a certain level of output at the lowest cost or producing an optimal level of output from a given resources (Russell and Young, 1983). Therefore, this study aims to analyse the technical efficiency and to identify the determinants of inefficiencies in wheat growing Indian states: UP and Haryana and in seeking the answer, does irrigation influence the efficiency of wheat farms.

The land fragmentation and divisions lead to decline in technical efficiency due to underutilisation of the existing resources. The estimation of technical efficiency to understand the status and policy options has become essential. Technical inefficiency tends to decline with increase in family size and access to canal and tube-well irrigation in wheat cultivation. There was a positive relationship between the educational level, contacts with extension agencies, and farmers experiences (Kalra *et al*. 2015). Several studies focus on the technical efficiency estimation using frontier production function approach which has been reviewed.

The importance of groundwater development is increasing rapidly on account of the inherent weaknesses (maintenance and operational inefficiencies) in the canal (surface water) irrigation system. Water conveyance loss in canal irrigation is twice

(40-50 per cent) than that of well irrigation and about 20 per cent of canal-irrigated area currently is seriously affected by waterlogging and salinity problems. However, it is not easy to establish water rights trading markets in India due to various reasons, i.e., political, legal, administrative, technical, cultural and physiography vary from country to country. As per Indian Act of 1872, groundwater rights are appurtenant to a landowner *de jure*. But *de facto*, these rights are ambiguous, as small farmers cannot afford to invest on construction of water extraction structure for irrigating their small landholdings. Judicious utilisation and excessive reliance on this precious natural resource has resulted into emergence of a groundwater crisis, especially in North-West region of the country (Srivastava *et al*. 2014). Agriculture sector being the largest user of groundwater resources bears the prime responsibility in averting the groundwater crisis (CGWB, 2014). Many studies have elucidated several hydrological (Srivastava *et al*. 2014), socio-economic, institutional and policy related aspects of groundwater management.

There are studies focused on the functioning and associated benefits on technical efficiency of ground water use. The equity in water resource distribution and management favour of water markets for making them competitive and efficient on the ground of equity in resource distribution. The researchers have stated that the water markets amount to favouring the rich over the poor by monopoly rents, leading to worsening of income distribution. In canal commands of UP and HR also it was observed that use of ground water increased even in high water availability areas due to the fact that canal system has been defunct, encroached and fractured by various socio and political reasons (Chand and Kishore, 2020).

Efficiency can be described in different terms such as technical efficiency (TE), scale efficiency (SE) and allocative efficiency (AE). TE is a comparison between observed and optimal values of inputs and outputs of a production unit (Sadoulet and Janvry, 1995). Therefore, this comparison gives the ratio of observed to that of maximum potential output which is attainable from the given inputs, or it is the ratio of minimum potential to that of observe d input(s) which are required to produce given amount of output(s), or it may be the combination of the two. A production unit is technically not efficient when it is unable to produce maximum possible output(s). Triuneh *et al*., 2016, in Ethiopia studied that TE was 57 per cent and herd, farm size, education had positive influence on TE while distance of farms from the residence of respondents have significantly negative influence. The lack of formal or informal property rights (Ward and Dillon, 2012; Skurray and Pannell, 2012) a general failure to develop institutional rules and enforceable sanctions to coordinate and extractions of individual well owners to meet hydrological limits has focused attention on irrigator communities, nominally the village level, crafting their own institutional arrangements (Ostrom, 2003; Meinzen-Dick *et al*., 2002; Syme *et al*., 2012; Steenbergen, 2006; Maheshwari *et al*., 2014).. Participatory processes at the village level, by targeting specific factors likely to jointly improve aquifer sustainability and household wellbeing (Ward *et al*.2016).The technical efficiency is an indicator of the productivity of the firm and the variation in technical efficiency reflect the productivity difference across firms. Singh, 2007 argued that wheat-cultivating farms in the Haryana state can increase their production by 27 per cent without increasing the quantity of inputs if they take rational decisions and Rahman *et al*. 2002 found out the TE varies from 86 per cent to 89 per cent in Bangladesh. The education and experience have significant positive effect on the level of efficiency, and in some cases these two variables can be treated as substitutes in explaining the farm performance (Stefanou and Saxena, 1988). Thus, identification of those factors, which influence the technical efficiency of farming, is undoubtedly very significant for policy decisions. With this background, this study aims to study the efficiencies among different water users for wheat cultivation and to determine the factors affecting it.

II

DATA AND METHODOLOGY

Description of Study Area: The selected states Haryana and Uttar Pradesh significantly contribute to wheat production in the country**.** Food grains are cultivated in about 69 per cent of gross cropped area; with rice and wheat alone accounting for 49 per cent. In particular, Haryana is a major producer of food grains in the country, accounting for about 12 per cent of national wheat production. Haryana is highly dependent on electric pumps for extracting ground water, while the use of diesel pumps is more limited. The density of electric pumps in Haryana is 68 units per 1000 ha, while the ratio of electric to diesel pumps was about 2:1. Wheat accounted for the highest share being 37.90 per cent followed by 22.83 per cent, 3.57 per cent, 2.68 per cent, 0.69 per cent and 0.64 per cent of rice, bajra, maize, sorghum and barley respectively. The availability of groundwater in Uttar Pradesh was 68575 million cubic meters of which 72.18 per cent has been utilised (MoA, India 2016-17). The net irrigated area of both the districts by source was analysed from 2000 to 2015 and the same is presented in Figures 1 and 2. The share of canal irrigation indicated that over a period of time its coverage was decreasing in both the states. This trend was more volatile for Rohtak as compared to Saharanpur district.

*Sampling Framework***:** This study was conducted in Haryana and UP, for study two districts from each state were selected in canal command area in 2015-16 agricultural years. Two blocks from each district and from each blocks two villages were selected randomly. The selected study area is predominantly irrigated by canal as the Saharanpur district of UP falls under Eastern Yamuna Canal Command area and Rohtak district of Haryana feed with Western Yamuna Canal Command area. The irrigation water sourced either from canals (42 per cent) or groundwater (58 per cent) in wheat cultivation.

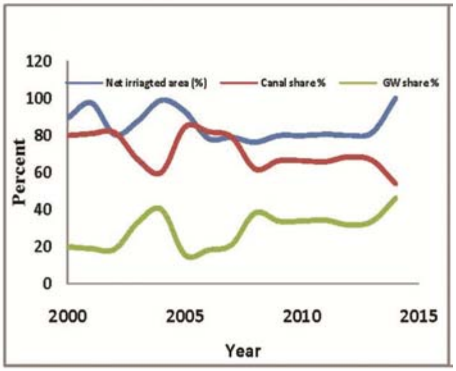

Figure 1. Irrigated Area by Source in Rohtak District.

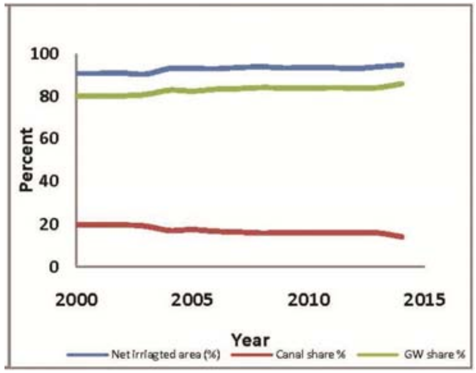

Figure 2. Irrigated Area by Source in Saharanpur District.

A total of 603 respondents were surveyed using structured and pretested schedule with the intention that at least 75 farmers of heterogeneous group could be selected for detailed study. The data were collected on the socio-economic characteristics like age, gender, family size, education level, landholding size, livestock, farm and non-farm income, possession of farm implements etc. and input use in farm production system like cropped area, seed, fertilisers, machines and equipment used, number of irrigation, sources of power used and their charges, informal water marketing system existing in the study area, etc. Finally, the data set were analysed as descriptive statistics and econometric model for better interpretation and logical conclusions.

Empirical Framework: Descriptive statistics has been used to compare the difference between the socio-economic aspects of two selected districts Saharanpur (UP) and Rohtak (Haryana). Since, this study was conducted in canal command area, we need to differentiate the canal water irrigation dominated and ground water dominated farmers. Therefore, those farmers who use both canal and ground water in the ratio of 60:40 and who use ground water and canal in the 40:60 were classified into two groups. Further, two states represented by districts in each state within the canal command area were analysed with the hypothesis that canal irrigation dominated district Rohtak (Haryana) may be better-off as compared to ground water irrigation dominated area Saharanpur (UP). The different efficiency measures were estimated using both Data Envelop Analysis (DEA) and Frontier Production Function approaches. Further, farmers were classified into four groups based on technical efficiency attained, i.e., TE>90 per cent, 80-90 per cent, 70-80 per cent, 60-70 per cent and <60 per cent. We use the empirical model as follows.

The empirical model specified for the wheat crop is as follow:

$$\ln yield = \beta_0 + \beta_1 (\ln croparea) + \beta_2 (\ln labour) + \beta_4 (\ln machine) + \beta_4 (\ln seed) + \beta_4 (\ln fertilizer) + \beta_5 (\ln water) + d1 + d2 + d3 + vi - ui \quad \ldots (1)$$

where, *yield* is the wheat production quintal per ha; *area* is the area sown under wheat, *labour* is the number of man-days used per ha; *machine* is the machine hour used per; *seed* is seeds used kg per ha; fertiliser is amount of fertiliser applied kg per ha*; water* is the total quantity of water used cubic meter per ha in wheat production. Whereas the values of *vi* represent the occurrences that cannot be controlled by the farmer and the values of *ui* represent the technical inefficiency of the wheat growing farmers. d1 is state dummy (d=0 if Haryana state, otherwise 0); d2 is irrigation dummy (d=0 if canal irrigated, otherwise 0) and d3 is water regime dummy (d=0 if tubewell owner, otherwise 0). The vector of coefficients (β) represents the parameters to be estimated.

The maximum likelihood estimate of the parameters of the model was obtained using the computer programme*, FRONTIER version 4.1* that was written by Tim Coelli (1996). This is used to obtain technical efficiencies of the firm for our study. This version assumes a linear functional form. Cobb-Douglas production function gave the best fit for our results, so all input and output data were converted into their log form before creating data file. Output elasticity for each explanatory variable is calculated at its mean are of basic importance in the study (Awudu and Eberlin, 2001).

Technical inefficiency model employed by author based on model developed by Coelli and Battesse (1996):

$$\begin{aligned} U_i = \delta_0 + \delta_1 age + \delta_2 education + \delta_3 familysize + \delta_4 numberoftractor \\ + \delta_5 gender \\ + \delta_6 landholdingsize + \delta_7 croparea + \delta_8 d\_waterregime \\ + \delta_9 d\_subsidies + \delta_{10} d\_irrigation \end{aligned} \quad \text{…. (2)}$$

where Ui=Technical inefficiency

Tobit regression analysis was done as technically this model is designed to estimate linear relationships between variables when there is either left or right censoring in the dependent variable and here technical inefficiency vary from 0 to 100.

III

RESULTS AND DISCUSSION

Socio-Economic Features of Sample Households: The general socio-economic features of the selected respondents of both states were statistically tested with mean difference. The average age of the respondent was around 49 years, but this did not significantly differ across the selected states. The level of education was higher among Haryana farmers indicating that they had better level of education than in Uttar Pradesh. At overall basis the number of schooling years were 7.7 indicating all the farmers were educated at middle class and above. The common features of respondents of both states were keeping livestock along with crop cultivation and on an average herd size was 3.0 animals reared by each family. The family size was found to be significantly different in both the states and indicated that bigger family size for Haryana as compared to Uttar Pradesh (Table 1). In farm assets, tractors were used for multiple purposes and the number of tractors possessed by UP farmers were higher (0.39) as compared to farmers in HR (0.20 No.) and this difference was found to be significant.

TABLE 1. CHARACTERISTICS OF WHEAT GROWING FARMER IN UTTAR PRADESH AND HARYANA

Variables specification (1)	Units (2)	Pooled data (3)	Canal dominated irrigation (4)	Groundwater dominated irrigation (5)
Age of head of farm households	No of Years	48.89	49.47	48.30
Education level of head of farm household	No of schooling years	7.73	9.15*	6.30
Average family size of farm household	No.	5.01	5.26*	4.76
Average land holding size	Ha.	1.65	1.99*	1.32
Average livestock possessed	No.	3.18	3.73*	2.63
Average Tube Wells ownership	No.	0.67	0.59*	0.75
Average Tractors ownership	No.	0.29	0.20*	0.39
Total Annual farm Income#	INR In 100 K (lakh)/HH	1.57	2.02*	1.13
Average wheat yield	Kg / ha.	3928	4144 *	3712
Average Cropped area under wheat	Ha.	1.36	1.86*	0.85
Cropping intensity	Per cent	171.86	176.51*	168.18
Seed (kg/ ha)	Kg/ha	127.69	116.15***	139.25
Fertiliser uses (NPK)	Kg/ha	178.30	182.08***	174.51
Total Machinery uses	Hour/ha	30.04	27.83***	32.26
Number of labour use	Hour/ha	218.82	182.18***	155.59
Water used for irrigation	Cum/ha	3475.32	3330.21***	3620.93
Land lease charges	Rs./ha	30000.50	33000.00**	28500.00
No of farm visit by extension agent	During crop season	3.50	4.13***	1.05
Access to credit (per cent)	Yes=1 No=0	76	80**	73
Off farm Income	Per cent	7.96	8.94***	6.98
Subsidies	Yes=1 No=0	0.75	0.78**	0.71
Food secure farmers	Yes=1 No=0	0.92	0.95**	0.89
Wheat crop area per farm household	Ha/farmer	1.36	1.86***	0.85
Water self-sufficient farmers	No.	310 (51.20)	152 (50.33)	158 (52.49)
Water surplus and deficit farmers	No.	132 (21.89)	101(33.44)	31 (10.30)
Water buyer	No.	161 (26.70)	49 (16.22)	112(37.21)
Consumptive users	No.	121 (20.06)	109 (36.09)	2 (0.66)
Ground water users	No.	482 (79.94)	193 (63.91)	299 (99.34)

Note: ***,**,*- 1 per cent,5 per cent,10 per cent level of significance respectively, "#"- income is estimated both from crop production and livestock rearing, figures in parentheses per cent to total number of respondents, respectively.

HR farmers have significantly larger land holding size in comparison to UP farmers. Similar trend was observed in the case of total income of households. The yield of wheat was significantly higher for HR farmers as compared to UP farmers by 11 per cent. The cropped area under wheat was found to be significantly higher for HR farmers as compared to UP farmers. The labour used wheat cultivation was found to be significantly different and indicated that HR farmers used a greater number of labours (182.18 hrs/ha) as compared to UP (156 hrs/ha). This indicated that human labour and machine are interchangeably used in wheat production system and there is vast scope of mechanisation. Similar mean difference was also noticed for seed application. However, fertiliser application was significantly higher for Rohtak (HR). The quantum of water application for wheat cultivation was found to be higher in canal users' area as compared to ground water users. The cropping intensity was found to be significantly higher for canal water users. Out of 1000 ha areas operated by sample as whole about 13 per cent, 31 per cent and 56 per cent were operated by small, medium and large categories of farmers respectively.

The farmers leased out and leased in the land and the rate is generally fixed on an annual basis. Though, crop sharing system is also practiced the average land leased rate was higher for Haryana respondents (Rs.33000/ha) followed by Uttar Pradesh farmers (Rs.28500/-). Therefore, descriptive statistics of farmers clearly indicate that the socio-economic features of the farmers were significantly different across the states in selected districts under the study. The visits made by extension agencies, i.e., agriculture departments, research institutions and NGOs for educating the farmers were found to be more for Haryana and on an average 3.0 visits made in the wheat season while it was only 1.03 visits for Uttar Pradesh. This indicates that Haryana farmers are more aware about the latest agricultural technological development and this might be the one of the reasons for attaining higher technical efficiency (Kalra *et al.,* 2015).

The accessibility to credit institutions was higher (80 per cent) for Haryana farmers while the access of UP farmers was about 73 per cent. The off-farm income also encouraged the farmers to have better farm implements and technology due to strong financial position. We found that HR farmer had more than 9 per cent income from off farm sources like government jobs, business and by other means while for the UP farmers this was only for 7 per cent farmers. The selected respondents were food secure (>90 per cent) in both the states. The area devoted to wheat crop was higher by Haryana farmer as compared to UP farmers. This may be due to the fact that UP farmers planted more of annual crops like sugarcane and mango plantations. Though, both the districts had better canal networks Haryana farmers had better accessibility to canal water. Mostly UP farmers were using ground water for irrigation of wheat crop. This may be because Haryana farmers faced problems of high salinity in ground water and regular supply of water in canal. Thus, in general it can be inferred that HR is in a much better position and significantly different in comparison to Uttar Pradesh as far as the general socio-economic characteristics of respondents are concerned.

Estimation of Technical, Allocative and Economic Efficiency: Improving Water Use Efficiency (WUE) in agriculture requires an increase in crop water productivity (an increase in marketable crop yield per unit of water used by plant) and a reduction in water losses from the crop root zone. The amount of water required for food production depends on the quantity of agricultural commodities produced. Hence, enhancing WUE in agriculture may also require some socio-economic adjustment to encourage and develop more water efficient enterprises. The result shows that majority of the wheat farms attained TE more than 70 per cent and other efficiency majors corresponding to these firms were higher. However, about 45 per cent farms were at low lever level of TE. Thus, there is scope of improving the efficiency of these farms (Table 2). The estimates the technical efficiency of various crops/ enterprises in different states/regions of India were attempted by [Shanmugam, 2003; Rama Rao *et al*., 2003; Saha and Jain, 2004; Goyal *et al*., 2006; Kalirajan and Bhende, 2007, Battese and Corra (1977].

TABLE 2. DISTRIBUTION OF TECHNICAL EFFICIENCY OF HARYANA AND UTTAR PRADESH

	Efficiency	Canal dominated irrigation			Ground water dominated irrigation		
Range TE	measure	No of firm	Mean	Std. Dev.	No of firm	Mean	Std. Dev.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
> 0.9	TE		0.96	0.04		0.98	0.02
	AE	74	0.45	0.22	15	0.39	0.21
	EE		0.43	0.22		0.39	0.21
0.8-0.9	TE		0.85	0.03		0.85	0.03
	AE	71	0.39	0.17	26	0.38	0.20
	EE		0.33	0.15		0.32	0.17
0.7-0.8	TE		0.76	0.03		0.75	0.02
	AE	80	0.33	0.13	65	0.26	0.08
	EE		0.25	0.10		0.19	0.06
0.6-0.7	TE		0.66	0.03		0.64	0.03
	AE	48	0.30	0.13	94	0.34	0.16
	EE		0.20	0.09		0.21	0.10
< 0.6	TE		0.56	0.03		0.54	0.04
	AE	28	0.27	0.08	102	0.29	0.09
	EE		0.15	0.05		0.16	0.06

Note: TE-Technical efficiency, AE- Allocative efficiency, EE- Economic efficiency.

Economic efficiency takes on to increase output without using inputs that are more conventional. The study suggests that >60 per cent farmer were cultivating wheat in the study area at economies of scale and EE range was 21 per cent to 43 per cent. Similarly, allocative efficiencies also were found to be in the line of economic efficiency, since, AE and EE are related.

Parameter Estimates of Stochastic Production Function: The maximum likelihood estimates (MLE) of stochastic frontier production model obtained from the pooled data and for states where the study was conducted (Table 3). The coefficient of input variables like labour, machine, seed, fertiliser and water quantity applied were found to have positive impact on wheat yield and test statistics indicated it to be significant. Area of the crop, which is considered to be the important factor in production system came out to be insignificant for pooled and state estimates. Quantity of water and fertiliser applied were major input factor contributing to yield response. Estimate at individual farmer of canal dominated area were significantly more productive than ground water irrigating farmers. Estimate for canal irrigation dummy used in model, turned out to be significant for pooled data indicating that canal users are better off that their counterpart and will have positive and better impact on yield in comparison to ground water user. However, in totality India draws more ground water as its consumption is more than that of China and USA put together. The state dummy turned out to be negative and significant indicating that Haryana farmers are obtaining better yield than UP farmers. This study was undertaken in canal command area which could be one of the reasons for the significance of canal users. However, labour utilisation coefficient was also negative and significant. This indicates that more use of labour result in decrease in yield by about 1.2 per cent. It may due to the fact that farmers of the study area already are using higher number of labours in the wheat cultivation. Similar observation made by Bakh and Islam, 2005 in Bangladesh.

TABLE 3. PARAMETER ESTIMATES OF STOCHASTIC FRONTIER ANALYSIS IN HARYANA AND UTTAR PRADESH

Variables used (1)	Pooled data (2)	Canal dominated irrigation (3)	Ground water dominated irrigation (4)
Ln(yield in quintal/hectare)	0.13093**	0.07361**	0.16155***
Ln(crop area in hectares)	0.01094	-0.01201	0.01641
Ln(labour used man-days/hectare)	0.03743**	-0.02409	0.04941**
Ln(machine used hours/hectare)	0.15094**	0.08372**	0.17274***
Ln(seed quantity kg/hectare)	0.14309***	0.02203	0.18933**
Ln(fertiliser quantity kg/hectare)	0.23940***	0.28009***	0.22842***
Ln(water applied cubic meter/hectare)	0.45172**	0.56777**	0.42802**
State dummy (d=0 if state=Haryana, otherwise 1)	-0.04445***	-0.00198	-0.04577***
Irrigation dummy (d=0 if canal irrigated otherwise 0)	0.00133	-0.03373**	0.00595
Water regime dummy (d=0 if tube well owner otherwise 0)	-0.00282	-	-
_cons	-1.05530**	-1.06144***	-1.09946***
/lnsig2v	-5.50845***	-5.75048**	-5.44370**
/lnsig2u	-4.94938***	-5.06759***	-5.06907***

Notes: "***", "**" and "*", 1,5 and 10 per cent level of significance respectively, and ns= non-significant.

Determinants of Technical Inefficiency of Wheat Farms: It was noticed from the analysis that coefficients like age of head of family, gender and level of education, water regimes canal water users had significant and negative relationships with technical inefficiency. This has given the insight that age and farming experience of household head is positively correlated and with increase in framing experiences farmers are able to allocate farm resources more efficiently, hence reducing its inefficiencies. Similarly, farmers who are educated take rational decisions regarding input use that might be leading to higher efficiency. The results supports the findings of Singh (2007) and Saha and Jain (2004), Dung *et al*. (2011), Kachroo *et al* (2010) who have also reported positive relationship with the age and technical inefficiency of the wheat farmers in Haryana and argued that as the age increases, farmers tends to be more risk averters and hesitate to adopt new technologies making the production process inefficient. However, the results contradict the findings of Coelli and Battese (1996), who reported from a study of two villages in India that older farmers are relatively more efficient. However, state dummy turned to be negative, indicated that canal users (HR) are more efficient than UP, in terms of getting negative sign, with respect to inefficiency however, it was non-significant. The variable total number of tractors possessed was positive but turned out to be non-significant. The farmers who buy water for wheat cultivation found to have negative sign for UP, indicating that net buyers are efficient. However, it was positive for HR. The farmers who cultivate wheat and had landholdings more than marginal farmers, store food grains for their home consumption were considered food secure and entered in the analysis. This indicates that these farmers are likely to move to attain the higher efficiency in wheat production. The coefficient of subsidies in installation of ground water devices and for other inputs leads to inefficiency as the coefficient was positive and significant (Table 4). This may be due to the fact that farmers want to avail more and more subsidies for financial gain without considering its impact on ground water extractions.

TABLE 4. DETERMINANTS OF TECHNICAL INEFFICIENCY OF WHEAT FARMS

Inefficiency (1)	Pooled data (2)	Canal dominated irrigation (HR) (3)	Groundwater dominated irrigation (UP) (4)
Age	-0.00101	0.022905	-0.00463
Educational	-0.07459***	-0.03429	-0.08134**
Family size	0.000762	-0.3206*	0.087821
Total tractors	0.571329*	-0.53685	0.631196*
d_gender (d=0 if gender=female otherwise 1)	-0.89234**	0.899329	-1.25064***
Land holdings	-0.79561***	-0.95804	-0.83809***
Crop area	0.743615***	0.859571	0.812955***
d_regime (d=0 if tube well owner otherwise 0)	-0.26568	1.15743	-0.5958*
Subsidies (d=1 if Yes availed otherwise No=0)	0.066185	-0.16597	0.156339
d_irr (d=0 if canal irrigated otherwise 0)	-0.18077		
_cons	8.453881***	6.325817***	8.364233***
/sigma	3.231717	3.158756	3.195665

Notes: "***", "**" and "*", 1,5 and 10 per cent level of significance respectively, and ^{ns} = not statistically significant.

IV

CONCLUSIONS AND POLICY IMPLICATIONS

The prices of farm production factor like seeds, fertiliser, rental rate of irrigation and hired machinery, agricultural wage rate, have been increasing and resulting in high cost of production. Due to small and marginalised size of holdings many farmers are unable to access the irrigation facilities. However, there is well established canal network in both the districts for surface irrigation but irregular supply and insufficient quantity forced the farmers to go for ground water pumping. Ground water pumping needs higher investment which is beyond the reach of these small and marginal farmers. It was observed in this study that in canal irrigated area attained higher yield than ground water irrigated areas. The possible reasons may be prolonged moisture in the wheat through flood irrigation. The study empirically analysed the data and results indicated that canal irrigated farms attain higher (HR) technical efficiency as compared to ground water (UP) irrigated farms. This may be because flood canal irrigation provides more water and time of moisture availability to the crop which might have resulted in higher efficiency. However, about 45 per cent farms were at low level of TE. The technical efficiency was worked out using stochastic frontier production function and found to vary in the range of <60 per cent to >95 per cent. Coefficients like age of head of family, gender, food secure farmers, subsidies and level of education had significant and negative relationships with technical inefficiency. This has given us the insight that higher aged farmer who is expected to be the head of the family is more experienced and allocate his resources to get higher efficiency. Similarly, in the case of higher educated farmers take rational decision to get higher efficiency and reduce the chance of getting into the trap of inefficiency. The result shows that majority of the wheat farms attained TE more than 70 per cent and other efficiency measures corresponding to these firms were also higher. Thus, there is scope of improving the efficiency of these farms. Therefore, efforts should be made in terms of providing quality and timely inputs, including irrigation, and combined with farm level innovations to enhance efficiency sustainably and more precisely.

The extension agents and agricultural economists need to educate the farmers through mass media about their rational decisions by taking into account owned labour wage and land rent in decision making. Further, varieties of wheat may be promoted which require less water in the study area. A participatory water management may be promoted so that pressure on ground water can be minimised. The strengthening of surface irrigation network will provide high efficiency and productivity of wheat cultivation will be improved.

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