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MEASUREMENT OF RELATIVE EFFICIENCY UNDER DIFFERENT SYSTEMS OF IRRIGATION : A PROFIT FUNCTION APPROACH

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ABSTRACT

This study quantitatively assesses the input-output relationship, resource productivity and allocative efficiency of farm inputs under different systems of irrigation through profit function approach using farm level primary cross-section data with respect to sugarcane and wheat of 120 farms from the Meerut district of Western Uttar Pradesh. The study reveals that improvement in water management on private tubewell farms caused a structural break in production relations and shifted the crop production function upwards. The absolute income of all the factors of production by and large was found to be higher under private tubewells as compared to other systems of irrigation. Better water management in terms of assured, timely and adequate water supply led to an improvement in the productivity of land and fertilizer on private tubewell farms as compared to state tubewell and canal irrigated farms for sugarcane and wheat crops. The reallocation of variable inputs had a very limited scope for increasing the yields and returns under all the irrigation systems. However, the horizontal expansion of irrigation especially through private tubewell, will enhance agricultural production and the net income of the farmers at a rapid rate.

The new high yielding agricultural production technology requires judicious management of resources, especially irrigation water which plays a crucial role in increasing the resource productivity. Water management under different systems of irrigation has given rise to many interesting issues in the field of agriculture. This study illustrates the quantitative assessment of various issues through profit function approach using farm level primary cross-section data with respect to sugarcane and wheat of 120 farms from the Meerut district of Western Uttar Pradesh under different systems of irrigation for the year 1980-81. The main objectives of the study are to examine (i) the impact of different systems of irrigation on input-output relationship and (ii) the resource productivity and allocative as well as economic efficiency of farm inputs.

Methodology

Consider the Cobb-Douglas form of production function with usual properties :

$$Y = A\, N^{\alpha_1} I^{\alpha_2} F^{\alpha_3} L^{\beta_1} B^{\beta_2} u \qquad \ldots(1)$$

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where, Y is output, N is the variable human labour input, I is the variable irrigation water input, F is the variable fertilizer input. Land (L) and Plough unit (B) are the fixed inputs and u is the random error variable.

Taking the theory of profit function (Lau and Yotopoulos, 1972) normalized profit function for the production function (1) can be written as :

$$\pi^* = A^* \left(\frac{w}{P}\right)^{\alpha_1^*} \left(\frac{i}{p}\right)^{\alpha_2^*} \left(\frac{r}{p}\right)^{\alpha_3^*} L^{\beta_1^*} C^{\beta_2^*} v \qquad \ldots(2)$$

where,

$$A^* = (1-\lambda)\, A^{\theta}\, \alpha_1^{\alpha_1 \theta}\, \alpha_2^{\alpha_2 \theta}\, \alpha_3^{\alpha_3 \emptyset} \qquad \ldots(3)$$

$$\lambda = \alpha_1 + \alpha_2 + \alpha_3$$

$$\theta = (1-\lambda)^{-1}$$

$$\alpha_1^* = -\alpha_1\, \theta < 0 \qquad \ldots(4)$$

$$\alpha_2^* = -\alpha_2\, \theta < 0 \qquad \ldots(5)$$

$$\alpha_3^* = -\alpha_3\, \theta < 0 \qquad \ldots(6)$$

$$\beta_1^* = \beta_1\, \theta > 0 \qquad \ldots(7)$$

$$\beta_2^* = \beta_2\, \theta > 0 \qquad \ldots(8)$$

$$\pi^* = \frac{\pi}{p} = \text{normalized profit.}$$

π=Profit (current revenues less current total variable input cost).

The relationship in parameters of production function and normalized profit function given above clearly shows that the parameters of production function (1) and the normalized profit function (2) are closely related.

From the estimated parameters of normalized profit function and by using the identities (3) to (8), one can estimate the production elasticities of various factors of production as well as value of intercept of the production function. The negative derivative of the normalized profit function (2) with respect to the normalized wage rate, irrigation water price and fertilizer price, respectively, gives the derived factor demand function.

The above equations have been estimated jointly by using Zellner's Seemingly Unrelated Regression (Arnold Zellner, 1962) which provides asymptotically more efficient estimates than the production function estimated by Ordinary Least Squares.

Since α_1, α_2 and α_3 appear in both sets of profit functions and factor demand equations, a restriction was imposed that α_1, α_2 and α_3 be equal in both equations. Apart fiom this, one can also add the assumption of constant returns to scale, that is $\beta_1+\beta_2=1$ in the normalized profit function (2). Once the normalized profit function is estimated, the parameters of the production function (1) can be obtained indirectly from the identities (3) to (8). These indirect estimates of production elasticities are free from simultaneous bias.

Results and Discussion

The results of restricted joint estimation of Cobb-Douglas normalized profit function and labour, irrigation water and fertilizer demand equations under different systems of irrigation for sugarcane and wheat are presented in Tables 1 and 2 respectively.

Table 1. Results of joint estimation of Cobb-Douglas profit function and labour, irrigation water and fertilizer demand functions under different systems of irrigation with constant returns to scale for sugarcane

Items	Parameter	Restricted sure* estimated value		
		Private tubewell farms	State tubewell farms	Canal irrigated farm
Restricted normalized profit function				
Constant	A^*	248.3768	120.3675	93.4582
Wage rate	α^*_1	—0.0671	—0.0860	—0.0899
Irrigation water price	α^*_2	—0.0766	—0.0341	—0.0270
Fertilizer price	α^*_3	—0.1589	—0.1542	—0.1273
Land	β^*_1	0.9750	0.8587	0.6592
Plough Unit	β^*_2	0.0250	0.1413	0.3408
Labour Demand function	α^*_1	—0.0671	—0.0860	—0.0899
Irrigation water demand function	α^*_2	—0.0766	—0.0331	—0.0270
Fertilizer demand	α^*_3	—0.1589	—0.1542	—0.1273

*Seemingly Unrelated Regressions.

The indirect estimates of Cobb-Douglas production function were obtaned by substituting the estimated parameters of normalized profit function given in Table 1 and 2 into the identities (3) to (8) which are the connecting links between the coefficients of the profit function for sugarcane and wheat crops under different irrigation systems. The results are presented in Tables 3 and 4, respectively.

Sugarcane

Production elasticities of various factors of production under all the systems of irrigation showed that the magnitude of the elasticity of production was highest for

Table 2. Results of joint estimation of Cobb-Douglas profit function and labour, irrigation water and fertilizer demand functions under different systems of irrigation with constant returns to scale for wheat

Items	Parameter	Restricted Sure estimated values		
		Private tubewell farms	State tubewell farms	Canal irrigated farms
Restricted normalized profit function				
Constant	A*	4.5623	1.7299	1.4029
Wage rate	α^*_1	—0.1305	—0.2388	—0.2267
Irrigation water price	α^*_2	—0.0585	—0.1168	—0.0658
Fertilizer price	α^*_3	—0.2877	—0.3689	—0.4883
Land	β^*_1	0.8731	1.0851	0.9325
Plough unit	β^*_2	0.1269	—0.0851	0.0675
Labour demand function	α^*_1	—0.1305	—0.2388	—0.2267
Irrigation water demand	α^*_2	—0.0585	—0.1168	—0.0658
Fertilizer demand function	α_3	—0.2877	—0.3689	—0.4883

Table 3. Indirect estimates of Cobb-Douglas production function under different systems of irrigation with constant returns to scale for sugareane

Items	Parameters	Indirect estimates of production elasticities		
		Private tubewell farms	State tubewell farms	Canal irrigated farms
Constant	A	150.3301	88.5591	75.8424
Human Labour	α_1	0.0515	0.0675	0.0723
Irrigation water	α_2	0.0588	0.0258	0.0217
Fertilizer	α_3	0.1220	0.1210	0.1023
Land	β_1	0.7485	0.6738	0.5298
Plough unit	β_2	0.0192	0.1109	0.2739

Table 4. Indirect estimates of Cobb-Douglas production function under different systems of irrigation with constant returns to scale for wheat

Items	Parameters	Indirect estimates of production elasticities		
		Private tubewell farms	State tubewell farms	Canal irrigated farms
Constant	A	7.0479	4.1367	3.5019
Human labour	α_1	0.0884	0.1385	0.1273
Irrigation water	α_2	0.0396	0.0677	0.0370
Fertilizer	α_3	0.1948	0.2139	0.2742
Land	β_1	0.5913	0.6292	0.5236
Plough unit	β_2	0.0859	—0.0493	0.0379

land followed by fertilizer. It is further observed that the production elasticities with respect to land, fertilizer and irrigation were found to be higher, being 0.75, 0.12 and 0.05, respectively, on private tubewell irrigation system as compared to other systems of irrigation, indicating thereby a relatively greater scope for expanding the area under irrigation and application of fertilizer on private tubewells.

Wheat

The indirect production elasticities revealed that land and fertilizer are the important input factors influencing changes in wheat production. The structural break again showed that the private tubewell irrigation system has shifted the production function upward. This indicates that timely and assured irrigation under this system helped the farmers in increasing the yield of the crop.

Productivity and Resource use Efficiency

For judging the resource use efficiency, the marginal value products of various inputs are compared with the factor prices. Allocative efficiency is measured by the success in maximising profit, that is, equalizing the value of the marginal product of each variable input to its price.

Table 5. Ratio of marginal value products to their factor costs under different systems of irrigation

Irrigation systems	Factors of Production				
	Land	Human labour	Plough unit	Irrigation water	Fertilizer
		Sugarcane			
Private tubewell	4.40	1.09	0.38	1.80	1.44
State tubewell	3.86	1.15	1.37	1.16	1.52
Canal	3.18	1.01	3.66	1.02	1.29
		Wheat			
Private tubewell	3.54	1.02	0.92	1.66	1.48
State tubewell	3.77	1.08	0.34	1.16	1.73
Canal	3.03	1.05	0.34	1.03	1.53

Table 5 indicates that the ratio of marginal value product to its acquisition cost was found to be as high as 4.40 in case of land and that too under private tubewell farms. On the other hand, it was observed to be, by and large, quite close to unity in case of human labour and irrigation water for both the crops indicating thereby tbe optimal use of these input factors in the production proces.

Conclusions

Use of fertilizer, no doubt, gave higher returns under all the three systems of irrigation, since the ratio of marginal value product to its unit price ranged from 1.29 to 1.73 for both the crops, The analysis, thus, revealed that the horizontal expansion of irrigation, especially through private tubewells, coupled with use of fertilizer will enhance agricultural production and net income of the farms at a rapid rate.

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