Vol XXXVI
No. 3

JULY-
SEPTEMBER
1981

ISSN 0019-5014

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

ECONOMICS OF IRRIGATION IN CROP PRODUCTION IN HARYANA

F. S. Bagi*

There are two distinct crop seasons in India and the crops need regular supply of moisture throughout their growing period. But almost all of the annual rainfall in India occurs during the monsoon season, and therefore, artificial irrigation plays a crucial role in the nation's agriculture. Irrigation primarily reduces the uncertainty of crop production and consequently increases agricultural productivity in a number of ways. First, it can increase crop yields even without any increased use of agricultural inputs. Second, lower risk and uncertainty of crop production are likely to encourage greater use of inputs. Third, it makes possible to grow crops all year around and hence can increase the cropping intensity. Fourth, cultivation of better quality and high value crops may become feasible. Therefore, the development of irrigation infrastructure is nothing less than an agricultural revolution.

The success of the so-called 'green revolution' is generally attributed to High-Yielding Varieties (HYVs) of wheat and rice. But it is well-known that rice varieties can hardly survive without regular supply of water what to say about high yields, and it is no secret that the *coup d'etat* staged by the HYVs of wheat against the indigenous wheat varieties have miserably failed in the unirrigated wheat growing areas of the world. The Punjab and Haryana States of India are among the few parts of the world where the 'green revolution' has achieved phenomenal success within a few years of its introduction, and irrigation has been a critical factor in this success. While the 'green revolution' has attracted tremendous attention from the economists, and deservingly so, the empirical analysis of the irrigation's contribution to the agricultural production has been largely neglected.

Few studies that exist are primarily descriptive in nature (3, 6, 8). In this study, therefore, an attempt has been made to empirically estimate the economic contribution of irrigation to crop production in Haryana. The plan of the paper is as follows. A brief description of the data used in this study is given in the next section. Section III contains a comparative analysis of the economic efficiencies of the irrigated and unirrigated farms. The input demand and the cost of production for the two groups of farms are compared in section IV, and a brief summary and concluding remarks are given in the last section.

II

DESCRIPTION OF DATA

The HYVs of wheat were introduced in Punjab and Haryana during the early 1960s, and by the 1969-70 crop year, their adoption and hence, the

* Agricultural Economist with the Co-operative Agricultural Research Program and the Department of Rural Development, Tennessee State University, Nashville, Tennessee, U.S.A.
The author would like to thank an anonymous referee of this Journal for his helpful comments on an earlier draft of this paper.

'green revolution' was well underway (7). We have access to farm level data from Haryana in India for the 1969-70 agricultural year. Haryana is one of the agriculturally better off States in India. The data were collected from 119 individual farms. Out of these, 20 farms are fully irrigated, 17 totally unirrigated, and remaining 82 farms are partly irrigated and partly unirrigated. A unique feature of these data is that information about output, and all inputs had been collected separately for irrigated and unirrigated parts of the same 82 farms. Therefore, we divided 82 partly irrigated farms into two subsets of farms; the irrigated area of each farm was treated as an irrigated sub-farm, and the unirrigated area of each farm as an unirrigated sub-farm.

Therefore, there are 102 (=82+20) irrigated farms, and 99 (= 82 +17) unirrigated farms, and hence the total number of observations becomes 201 (=102+99). The irrigated, and the unirrigated sub-farms generated from the same 82 partly irrigated and partly unirrigated farms provide 164 observations. Similarly, when 20 fully irrigated and 17 totally unirrigated farms are pooled together, they generate 37 observations. In this study, we compare the economics of the irrigated and unirrigated farms in the pooled samples of 201, 164, and 37 farms.

III

COMPARATIVE ECONOMIC EFFICIENCY

The economic efficiency has two components: the technical efficiency, and allocative efficiency. The absolute as well as relative allocative efficiency can be analysed in the production function framework. The technical efficiency, however, is sensitive to the specification of the production function. If one just assumes, without testing that the underlying production function is linear homogeneous, he may be led to believe that the differences in allocative efficiency, and in the configuration of input and output prices are responsible for any differences in yields and factor intensities, while actually the answer may lie in the technological differences among the distinct groups of farms (2). In this study, therefore, we first examine the assumptions of linearity and homogeneity of the production function describing the nature of farms in our sample. The assumption of linearity is satisfied if the elasticity of scale is unity. Hence, we estimate the scale elasticity, and test the homogeneity assumption, and only then, we proceed to compare the technical and allocative efficiencies of the irrigated and unirrigated farms.

Returns to Scale

To estimate the returns to scale (*i.e.*, scale elasticity) of various farm samples, the following Cobb-Douglas production function was fitted in the log-linear form[1] (1):

1. This presupposes that the farms in the samples are characterized by a Cobb-Douglas type production function. Cobb-Douglas production function is linear and homogeneous, and therefore, it rules out the possibility of non-homotheticity. A non-homothetic function of the form:

$$\ln V = \ln A + a_1 \ln L + a_2 \ln N + a_3 \ln F + a_4 \ln I + a_5 \ln K + a_6 \ln O + a_7 (\ln L)^2 + u$$

was fitted. But the coefficient a_7 was not significantly different from zero. Furthermore, the samples of irrigated farms are characterized by constant returns to scale. Therefore, we cannot reject the assumption that the observed samples of farms, especially the ones with constant returns to scale, are characterized by the Cobb-Douglas production function.

$$\ln (V/L) = \ln A + h_0 \ln L + a_2 \ln(N/L) + a_3 \ln(F/L) + a_4 \ln(I/L) + a_5 \ln(K/L) + a_6 \ln(O/L) + u \qquad \ldots.(1)$$

where ln A is a constant,

V = the value of crops and crop by-products in rupees, per farm. (The main by-products are wheat straw, maize and sorghum stocks, and cotton sticks, etc.)

L = land area operated in hectares per farm. It includes owned area, cash rented-in, and share-cropped area.

N = number of human labour days used per annum on individual farms. It includes family labour, and permanent and casual hired labour.

F = value (in rupees) of fertilizer and manure used on individual farms.

I = rupee value of the flow of irrigation services on individual farms. It includes depreciation value, interest cost, and operating and repair expenses of tubewells, pumping sets, Persian wheels, plus the payments made for canal irrigation water.

K = the rupee value of the flow of capital services from agricultural machinery, equipment, implements, and tools. This value includes depreciation charges, interest cost, and repair and operating expenses.

O = the rupee value of other production expenses for individual farms. It includes actually paid and imputed value of nursery, seeds, and miscellaneous expenses.

u = a random disturbance term which is assumed to be normally distributed with mean zero, and finite variance.

Equation (1) is estimated using various farm samples, and the Ordinary Least Squares estimates of this analysis are given in Table I. These results show that all the three pooled samples, and unirrigated farms are characterized by decreasing returns to scale, while all irrigated farms are characterized by constant returns to scale. Therefore, it can be concluded that it is the absence of irrigation which causes the decreasing returns to scale.[2]

Technical Efficiency

The main objective in this section is to analyse the relative technical efficiencies of the owner operated and share-cropped farms, and to find out whether the two groups of farms are represented by (*a*) neutral production functions[3] or (*b*) factor-biased production functions.[4] In order to test these differences in the technologies the following log-linear Cobb-Douglas production function has been fitted:[5]

2. It has been suggested that the concept of "returns to scale" is relevant when all inputs are changed in the same proportion. But since irrigation (an important input) is absent from the unirrigated farms, and remains unchanged at zero, the concept of returns to scale is not relevant for the unirrigated farms. While that is true, it does not invalidate the inference that it is the absence of irrigation input which causes decreasing returns to scale, especially on the 82 unirrigated sub-farms where 'potentially' everything else is the same as on 82 irrigated sub-farms, except irrigation.

3. Neutral production functions imply that the two production functions differ only in the intercept, and the slope coefficients are equal in both the production functions.

4. Factor-biased production functions imply that the two production functions differ significantly in one or more of the slope coefficients, whether the intercept terms are the same or not.

5. D has been included without taking its log, since it assumes a value of zero for some of the farms.

TABLE I—ORDINARY LEAST SQUARES ESTIMATES OF RETURNS TO SCALE FOR DIFFERENT SAMPLES

Variables	201 farms			164 farms				37 farms		
	Pooled*	Irrigated	Unirrigated	Pooled*	Irrigated	Unirrigated	Aggregate†	Pooled*	Irrigated	Unirrigated
ln A	5·602 (22·869)	5·616 (19·550)	5·559 (14·418)	5·666 (20·066)	5·891 (19·495)	5·629 (12·756)	5·850 (13·659)	5·488 (9·688)	4·500 (6·097)	5·908 (4·664)
ln L	0·483 (9·170)	0·604 (10·605)	0·398 (3·864)	0·498 (7·834)	0·644 (11·115)	0·434 (3·708)	0·359 (6·142)	0·270 (2·269)	0·524 (9·355)	0·354 (2·497)
ln N	—0·038 —(0·871)	0·072 (1·656)	—0·093 —(1·050)	—0·052 —(1·063)	0·097 (2·120)	—0·129 —(1·564)	0·024 (0·329)	0·118 (1·244)	—0·026 —(1·203)	0·170 (1·305)
ln F	0·044 (2·037)	0·032 (1·595)	0·063 (1·753)	0·026 (1·054)	0·030 (1·459)	0·036 (0·811)	0·084 (3·701)	0·133 (3·609)	0·157 (2·290)	0·135 (2·059)
ln I	0·076 (3·632)	0·101 (3·572)	—	0·087 (3·274)	0·079 (2·421)	—	0·041 (1·447)	0·075 (3·268)	0·124 (2·018)	—
ln K	0·223 (5·318)	0·142 (4·169)	0·269 (3·468)	0·217 (4·429)	0·127 (3·118)	0·279 (3·294)	0·153 (3·155)	0·105 (1·632)	0·153 (2·503)	0·111 (0·448)
ln O	0·142 (3·241)	0·079 (1·867)	0·188 (2·680)	0·146 (2·915)	0·036 (0·788)	0·195 (2·412)	0·136 (3·185)	0·128 (1·838)	0·145 (3·654)	0·008 (0·089)
h_0	0·929 (27·142)	1·030 (36·999)	0·825 (12·837)	0·922 (23·104)	1·012 (33·846)	0·184 (10·780)	0·797 (12·816)	0·829 (10·953)	1·077 (22·568)	0·778 (8·959)
h_1	—0·071 —(2·063)	0·030 (1·080)	—0·175 —(2·727)	—0·078 —(1·966)	0·012 (0·395)	—0·186 —(2·468)	—0·203 —(3·265)	—0·171 —(2·253)	0·077 (1·613)	—0·222 —(2·553)
R^2	0·832	0·939	0·693	0·811	0·942	0·645	0·826	0·871	0·983	0·838
n	201	102	99	164	82	82	82	37	20	17

h_0 is the elasticity of (returns to) scale.

h_1 gives the deviation of the scale elasticity from unity. It can also be calculated directly by estimating a modified equation (1), where ln V is replaced by ln (V/L).

Here the output elasticity of land $= h_0 - \sum_{i=2}^{6} a_i$, and the corresponding t-value of a_1 (*i.e.*, output elasticity of land) from the formula:

$$\text{t-value of } a_1 = a_1/(\mathrm{Var}(h_0 - \sum_{i=2}^{6} a_i))^{\frac{1}{2}}.$$

* Pooled samples include both irrigated and unirrigated farms.

† Aggregate 82 farms are partly irrigated and partly unirrigated, and 82 irrigated sub-farms and 82 unirrigated sub-farms have been created from this aggregate sample.

$$\ln V = \ln A + D + a_1 \ln L + a_2 \ln N + a_3 \ln F + a_4 \ln I + a_5 \ln K + a_6 \ln O + B_1 (\ln L)D + B_2 (\ln N)D + B_3 (\ln F)D + B_4 (\ln I)D + B_5 (\ln K)D + B_6 (\ln O)D + u \quad \ldots.(2)$$

where D is a dummy variable, which assumes the value zero for the irrigated farms, and unity for the unirrigated farms. All other variables are the same as defined before.

In the first step, equation (2) was estimated using Ordinary Least Squares method, in its original form. But in the final analysis only statistically significant dummy variables were included along with all the real variables. The final results are presented in Table II. These results show that the coefficient of the intercept dummy variables for the unirrigated farms is negative and satistically significant in the pooled samples of 201 and 164 farms. However, the two groups of farms are represented by the factor-biased production

TABLE II—COMPARATIVE ESTIMATES OF OUTPUT ELASTICITIES FOR IRRIGATED AND UNIRRIGATED FARMS IN HARYANA: 1969-70

Coefficient of	Total number of irrigated and unirrigated farms in the pooled sample of		
	201 farms	164 farms	37 farms
ln A	5·6623 (12·5403)	5·8165 (11·1852)	5·0829 (9·4496)
D	—0·9164 —(1·7068)	—1·0635 —(1·7045)	—
ln (Land) (hectares)	—0·6018 (6·3848)	0·6237 (5·9015)	0·3464 (3·2587)
ln (Labour) (days)	—0·0167 —(0·4129)	—0·0290 —0·6346	0·0434 (0·4917)
ln (Fertilizer) (Rs.)	0·0279 (1·7231)	0·0295 (1·7327)	0·1271 (1·8555)
ln (Irrigation) (Rs.)	0·1053 (2·3397)	0·0795 (1·7306)	0·1411 (2·1934)
ln (Capital) (Rs.)	0·1379 (3·3249)	0·1368 (2·7983)	0·1265 (1·7988)
ln (Other expenditure) (Rs.)	0·1648 (1·7625)	0·1725 (1·5664)	0·2174 (2·4464)
ln (Land)* (hectares)	—0·3439 —(2·8274)	—0·3748 —(2·6619)	—0·1540 —(1·7648)
ln (Other expenditure)*D (Rs.)	0·2960 (2·5542)	0·2989 (2·1453)	0·2289 (2·9808)
R^2	0·8576	0·8385	0·8937

D is a dummy variable. It assumes value zero on the irrigated farms and unity for the unirrigated farms. The output elasticities for the unirrigated farms can be recovered as the sum of a_i and B_i. The corresponding t-values can be calculated as:

$$\text{t-value } (a_i + B_i) = (a_i + B_i)/(\text{Var}(a_i) + \text{Var}(B_i) + 2\,\text{Cov}(a_i, B_i))^{\frac{1}{2}}.$$

The figures in parentheses are the estimated t-values.

functions (*i.e.*, the functions differ in one or more slope coefficients) in the case of all the three pooled samples. Therefore, in the strict sense, it is not possible to compare technical or allocative efficiencies of the two groups of farms, since here, the two groups of farms are represented by different production functions. However, technical efficiency is alternatively defined as the ability to produce maximum output from the input bundle chosen. The results in Table IV show that per hectare output as well as profits are consistently higher on the irrigated farms as compared to the unirrigated farms in the case of all the three samples. Therefore, there is some evidence that the irrigated farms may have higher technical efficiency than that of the unirrigated farms.

Allocative Efficiency

A rigorous comparison of the allocative efficiencies of any two groups of farms requires that they are (*a*) characterized by constant returns to scale, (*b*) represented by the same or neutral production functions, and (*c*) facing the same configuration of input and output prices. We have found in this study that share-cropped and owner operated farms are represented by factor-biased production functions in all the three pooled samples of 201, 164 and 37 farms. Furthermore, only the samples of 102, 82 and 20 irrigated farms exhibit constant returns to scale. Therefore, it is not possible to attempt a rigorous comparison of the allocative efficiencies of the two groups of farms in every sample.

However, in this case it may still be meaningful to compare them due to at least two reasons. First, the farms are classified on the basis of an input (*i.e.*, irrigation) which is not common to both groups of farms. Furthermore, it looks that decreasing returns to scale prevail primarily due to the absence of irrigation on the unirrigated farms. In this case the constant returns to scale does not remain very restrictive. Second, the configuration of input and output prices facing the two groups are not likely to be very different, because our data are cross-sectional data collected from a single State. The fact that the two groups of farms in all the three samples are represented by factor-biased production functions still remains, and it will have strong impact on the allocative efficiencies of the two groups of farms. Therefore, the results will reflect both technical and allocative efficiencies and not the latter alone.

The tests for the allocative efficiency are performed by deriving the following equation for the Cobb-Douglas production function:

$$MVP_{ij} = a_{ij}(Q_j/X_{ij})P_{oj} = k_{ij}\,P_{ij} \quad i = 1, \text{------}, 6, \text{ and } j = 1, 2 \ldots\ldots (3)$$

where j represents the irrigated and the unirrigated farm groups, MVP_{ij} is the marginal value productivity of ith input, a_{ij} is the output elasticity of ith input, Q_j is the geometric mean of the gross value of farm output, P_{oj} is the geometric mean of the price of output, k_{ij} is the allocative efficiency parameter of the ith input, and P_{ij} is the geometric mean of the input price of ith input.

In this study the dependent variable, the gross value of farm output, is measured in rupees. The inputs other than land and labour are also value concepts measured in rupees.[6] Land is measured in hectares and labour in *days per annum*. Therefore, the marginal value products and marginal products will be equal in this analysis, and provided the two groups of farms face the same configuration of output and input prices, the k_{ij} values for inputs (except land and labour) can be calculated as: $a_{ij}(Q_j/X_{ij})=k_{ij}$. The appropriate a_{ij} values were taken from Table II, and our estimates of marginal (value) productivities and allocative efficiency parameters are presented in Table III.

The input is over-utilized if $k < 1$, and under-utilized if $k > 1$. Absolute allocative efficiency requires that $k_{ij} = 1$, for all inputs. The two groups of farms would have achieved equal allocative efficiency if $k_{i1} = k_{i2}$, for every input. The results in Table III show that (*a*) both irrigated and unirrigated groups of farms make an intensive use of labour, (*b*) the irrigated farms under-utilize and the unirrigated farms over-utilize land, (*c*) the irrigated farms in the samples of 102 and 82 farms almost achieve absolute allocative efficiency in the use of fertilizer, while 20 fully irrigated, and the unirrigated farms (in all the three samples) under-utilize fertilizer, (*d*) irrigated farms under-utilize irrigation resource, and (*e*) both groups of farms under-utilize capital and 'other expenses', but the unirrigated farms under-utilize both of these inputs relatively more as compared to the irrigated farms in the case of all the three samples. Therefore, the irrigated farms deviate relatively less from the absolute allocative efficiency criteria as compared to the unirrigated farms in the use of all inputs, except land.

A part of the allocative efficiency differences among the two groups of farms may be attributed to the differences in the technical efficiency, managerial ability, and output and input prices of the irrigated and the unirrigated farms. However, this explanation does not hold for the 82 irrigated and 82 unirrigated sub-farm groups. These two sub-farm groups are derived from the same 82 partly irrigated and partly unirrigated farms. Therefore, a given farm in both groups has the same technology, technical and managerial know-how, output and input prices, same labour, and same cash to purchase inputs. The only difference is the irrigation; one sub-farm is irrigated while the other sub-farm is unirrigated. Therefore, on these two groups of sub-farms, the differences in technical and allocative efficiencies can not be attributed to any other factor but irrigation. It may not be unreasonable to assume that the same explanation holds for the two groups of farms in the samples of 201 and 37 farms.

There is some evidence from the above analysis that irrigation improves both technical and allocative efficiency of crop production. In other words, irrigation improves the economic efficiency of agricultural production. The next logical questions are (*a*) does irrigation increase the use of the factors of production (*i.e.*, inputs), and (*b*) does irrigation increase the unit cost of production. These questions are examined in the next section.

6. The value measure of output and inputs can be expected to take care of the quality differences among farms to a great extent. The value of gross output is calculated at prices actually received by every farm for its products. Therefore, it takes account of the 'price efficiency' differences across farms.

TABLE III—ALLOCATIVE EFFICIENCY COEFFICIENTS (k_{ij}'s) OF IRRIGATED AND UNIRRIGATED FARMS IN HARYANA: 1969-70

Sample No.	Number of farms in the sample	Irrigated/Unirrigated	Allocative efficiency coefficients (*i.e.*, k_{ij}-values)					
			Land* (hectares)	Labour* (days)	Fertilizer (Rs.)	Irrigation (Rs.)	Capital (Rs.)	Other expenses (Rs.)
1.	201	102 Irrigated	1·98	..	0·95	2·71	2·53	3·02
		99 Unirrigated	0·71	..	14·24		4·03	6·03
2.	164	82 Irrigated	1·60	..	1·02	1·57	2·79	3·39
		82 Unirrigated	0·91	..	21·42		4·27	8·11
3.	37	20 Irrigated	1·38	..	4·16	3·61	1·96	4·68
		17 Unirrigated	0·55	..	11·83		3·70	7·99

The allocative efficiency coefficients (k_{ij}'s) have been calculated from equation (3), which implies: $K_{ij} = MVP_{ij}/P_{ij}$.

* k_{ij}'s for land and labour have been calculated as: $k_{ij} = MVP_{ij}/P_{ij}$, but since the remaining inputs are measured in value (Rs.) terms instead of quantity units, their k_{ij} values are calculated as: $k_{ij} = MVP_{ij}$.

.. indicate that the output elasticity (a_i) associated with this k_{ij} is non-significant even at 10 per cent level.

IV

INPUT DEMAND AND COST OF PRODUCTION

It is widely believed that irrigation increases the use of all variable inputs (1, 3, 4). But it needs to be tested whether or not it leads to higher unit cost of production on the irrigated farms. In this section, an attempt is made to shed some light on these two issues.

The following input demand function can be estimated to test whether the two groups of farms face neutral or factor-biased demand function for any given input:

$$\ln x_i = \ln A + D + \sum_{i=1}^{I} a_i \ln Px_i + \sum_{i=1}^{I} B_i (\ln Px_i) D + u_i \qquad \ldots (4)$$

where x_i is the ith input, Px_i is the price of ith input, ln A is a constant, D is a dummy variable which assumes value zero for one group of farms and unity for the other group, and u_i is a random normal error term with zero mean and constant variance. If the coefficient of D (in the additive form) is zero, and all B_i's are zero, then the two groups of farms face the same demand for a given input. If $B_i = 0$, but coefficient of $D \neq O$, the two groups face neutral demand function, and if at least one of $B_i \neq O$ the two groups of farms are facing factor-biased (non-neutral) input demand functions.

It is obvious that the data on all input prices are necessary to estimate equation (4) for any input. But our data have been collected from a cross-section of farms in Haryana during a single crop year. Therefore, either we do not have detailed price data for every input and every individual farm, or there is not much variation in these prices across farms. Hence, it is not possible to estimate equation (4), compare input demand functions, and input price elasticities (*i.e.*, a_i's and B_i) for the two groups of farms. However, simple analysis of the data presented in Table IV shows that the irrigated farms consistently use larger amounts of all inputs, as compared to the unirrigated farms, assuming the two groups face the same input prices.

The results in Table IV further show that per hectare output value is much higher on the irrigated farms than that on the unirrigated farms, and the former group of farms achieve this by using larger amounts of inputs. But it remains to be tested whether or not they do so at a relatively higher cost of production.

The cost functions for the two groups can be compared as follows. The total cost function corresponding to the Cobb-Douglas production function (2) can be written as (5, 7):

$$\ln C = \ln A + D + a_0 \ln Q + \sum_{i=1}^{I} a_i \ln Px_i + B_0 (\ln Q)D + \sum_{i=1}^{I} B_i (\ln Px_i) D + v_i \qquad \ldots (5)$$

where C is the total cost of production, Q is the physical quantity of output per farm, v_i is the standard normal error term, and all other variables are the same as defined before.

TABLE IV—PER HECTARE VALUES OF IMPORTANT VARIABLES

Variables	102 irrigated	99 unirrigated	82 irrigated	82 unirrigated	20 fully irrigated	17 totally unirrigated
Output values (Rs.)	2,023·99	831·73	1,842·63	792·55	2,545·78	937·21
Human labour (days)	85·26	42·41	83·73	36·33	89·64	58·77
Bullock labour (days)	21·35	14·16	20·36	13·50	25·41	17·33
Fertilizer (Rs.)	94·31	13·04	87·99	10·17	112·50	20·77
Irrigation (Rs.)	99·81	—	89·95	—	128·19	—
Capital flow (Rs.)	134·10	35·13	106·88	36·60	212·41	31·21
Other expenses (Rs.)	114·38	47·63	111·64	43.21	122·26	59·52
Cropping intensity	145·01	137·39	141·31	136·80	160·19	140·24
Output quantity (quintals)* ..	25·78	10·46	23·28	10·01	32·45	11·56
Price of wheat/quintal ..	78·51	79·49	79·15	79·15	78·45	81·10
Cost of production/quintal ..	54·26	47·57	55·48	45·28	53·53	52·67
Profit (Rs.)	625·17	348·42	537·23	336·58	808·73	328·34
Wage (Rs./day)	5·73	5·52	5·49	5·49	6·71	5·68
Land rent (Rs.)	608·76	322·72	613·89	312·49	611·15	372·06
Average farm size (hectares) ..	4·70	5·28	4·34	4·66	6·18	8·33

* It represents the physical quantity of output in quintals. But the farms in our sample are multi-crop farms. Therefore, it is difficult to develop a consistent aggregate quantity measure of output for these farms. However, wheat is the major crop on these farms, and we converted the gross value of farm products and by-products (V) into wheat equivalent quintals, by dividing V with the per quintal price of wheat received by the individual farms.

The total cost function as written above would have another problem, because it does not consider the differences in the farm sizes of the irrigated and unirrigated farms. But this problem can be easily solved by estimating a per hectare or per quintal cost of production. The main problem is that equation (5) can not be estimated due to inadequate data for input prices (Px_i's) for individual farms. Therefore, in this study it is not possible to estimate and compare the cost price elasticities of the two groups of farms. However, a simple analysis of the data presented in Table IV shows that the per quintal cost of production is relatively higher on the irrigated farms as compared to the unirrigated farms. In other words, the irrigated farms produce higher quantities of output at relatively higher unit cost of production. But the per hectare profit (*i.e.*, net income) is much higher on the irrigated farms. Consequently, irrigation increases the profit margin.

V

SUMMARY AND CONCLUSIONS

In this study, an attempt has been made, using simple models based on the neo-classical theory of production, to empirically estimate the economic contribution of irrigation to crop production. The results show that the technical change introduced by irrigation is non-neutral (*i.e.*, factor-biased) and there is some evidence that technical efficiency is higher on the irrigated farms. Irrigation significantly improves the relative allocative efficiency of all variable inputs, and the irrigated farms use larger quantities of all variable inputs.

The study also shows that the irrigated farms under-utilize all inputs, except labour. Therefore, there is scope to further increase the use of these inputs. The study further shows that the output per hectare is much higher on the irrigated farms, and so is the per quintal cost of production. But the per hectare profit margin remains much higher on these farms. Therefore, irrigation can significantly increase agricultural production, which the country needs to support its growing population. The increased profits can enable the farmers to purchase larger quantities of inputs which are likely to improve both allocative and technical efficiencies, and consequently to increase output even further.

It is encouraging to know that irrigation increases the labour absorption capability of the agricultural sector, since it is crucial for a nation like India, whose urban industrial sector is generating the demand for labour at a rather slow rate. In brief, the availability of irrigation is nothing less than an agricultural revolution. It is true that improving the country's irrigation infrastructure will have to compete with other national priorities for the scarce resources, but it seems to be a very vital alternative.

APPENDIX

GEOMETRIC MEANS OF OUTPUTS AND INPUTS FOR DIFFERENT FARM SAMPLES

Sample No.	Number of farms in the sample	Irrigated/ Unirrigated	Land (hectares)	Labour (days)	Fertilizer (Rs.)
1.	201 ..	.. 102 irrigated	3·295	292·160	194·377
		99 unirrigated	3·515	126·419	6·106
2.	164 ..	.. 82 irrigated	2·919	260·161	162·748
		82 unirrigated	3·064	99·137	3·604
3.	37 ..	.. 20 irrigated	5·416	470·126	402·663
		17 unirrigated	6·812	399·095	77·626

(*Contd.*)

APPENDIX (*Concld.*)

Sample No.	Number of farms in the sample	Irrigated Unirrigated	Irrigation (Rs.)	Capital (Rs.)	Other expenditure (Rs.)	Output (Rs.)
1.	201	102 irrigated	257·856	361·369	361·948	6,631·59
		99 unirrigated		106·517	238·150	3,115·36
2.	164	82 irrigated	217·870	293·331	424·792	5,610·53
		82 unirrigated		89·452	193·388	2,616·78
3.	37	20 irrigated	514·394	850·139	611·246	13,164·78
		17 unirrigated		247·300	403·348	7,225·704

REFERENCES

1. P. K. Bardhan, "Size, Productivity, and Returns to Scale: An Analysis of Farm-Level Data in Indian Agriculture", *Journal of Political Economy*, Vol. 81, No. 6, December 1973, pp. 1370-86.

2. H. N. Barnum and L. Squire, "Technology and Relative Economic Efficiency", Unpublished paper, World Bank, August 1976.

3. Krishna Bharadwaj: Production Conditions in Indian Agriculture: A Study Based on Farm Management Surveys, Cambridge University Press, Cambridge, 1974.

4. S. Ishikawa: Economic Development in Asian Perspective, Kinokuniya Bookstore, Tokyo, 1967.

5. Marc Nerlove: Estimation and Identification of Cobb-Douglas Production Function, Rand McNally and Company, Chicago, 1965.

6. C. H. Hanumantha Rao, "Farm Mechanization in a Labour-Abundant Economy", *Economic and Political Weekly*, Vol. VII, Nos. 5, 6 and 7, Annual Number, February 1972.

7. S. S. Sidhu, "Economics of Technical Change in Wheat Production in the Indian Punjab", *American Journal of Agricultural Economics*, Vol. 56, No. 2, May 1974, pp. 217-226.

8. E. Whitcombe: Agrarian Conditions in North India, Vol. 1, University of California Press, Berkeley, 1971.