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ECONOMIC IMPACTS OF INCREASED WATER SUPPLY ON SMALL FARMS IN IRAN

The poverty of small farmers has become a more serious problem in developing countries.[1] The strategies which have been used to deal with the problem of small farmers can be classified into different categories including the strategy which has emphasized the development of new technologies and production services to increase the productivity and profitability of the resources used in agriculture.[2] Introduction of new technologies and production services, although might not be sufficient to deal with the small farmers' problem, has been recognized as one of the effective ones.[3] Larson and Hu introduced the expansion of off-farm work as another strategy to deal with the problem.[4] Meyer and Larson, without rejecting the potentials of new technologies for increasing the income of poor small farmers, suggest the possibility of off-farm jobs as a strategy which can generate additional income, when the biological technologies and expansion of farm size are fully exploited.[5]

The relevance of the strategy of introducing new technologies, therefore, depends to a great extent upon whether or not the possibilities of production increase through new technologies are exhausted. Although the answer varies with the country and the region, there are many countries which still could gain a tremendous production increase through the adoption of new technologies.

Supply of additional irrigation water in the countries where their agriculture is suffering from shortage of water could have a large impact on the state of production and growth. More knowledge about the impacts of increased supply of water on the production behaviour of small farmers would help the public decision-makers with regard to their decisions on the amount of additional water which should be allocated to their small farmers.

The objectives of this paper are (*i*) to analyse the changes in the production function of small farmers as a result of increased supply of water; and (*ii*) to show the nature of input allocation adjustment as they face with new state of production. That is, how efficiently the inputs have been allocated before and after the increase in water supply. Small rice producing farms in Ram-

1. For the magnitude of poverty of small farmers in the developing countries, see Robert S. McNamara: One Hundred Countries, Two Billion People, Praeger Publisher, New York, 1973, pp. 102-116.
2. For an excellent review of literature on schools of thought and strategies for small farm development, see Marcelino Avila and Melvin G. Blase, "The School of Thought on Small-Farm Development in Developing Countries", a contributed paper presented at the annual meeting of American Agricultural Economic Association, August 1976, *American Journal of Agricultural Economics*, Vol. 58, No. 5, December 1976, Proceedings, p. 1025.
3. For the significant role of new technology in agricultural development, see Yujiro Hayami and Vernon W. Ruttan, Agricultural Development: An International Perspective, The Johns Hopkins Press, Baltimore, 1971.
4. Donald W. Larson and Hung Yu Hu, "Factors Affecting the Supply of Off-Farm Labour among Small Farmers in Taiwan", *American Journal of Agricultural Economics*, Vol. 59, No. 3, August 1977, p. 549.
5. Richard L. Meyer and Donald W. Larson, "Rural Non-farm Employment: The Recent East Asian Experience", *Journal of Economic Development*, Vol. 3, No. 1, July 1978 (forthcoming).

jerd and Abarj are considered in our analysis. The size of land under cultivation for these small farms averages less than ten hectares.

THE REGIONS AND THE DATA

Ramjerd and Abarj are two rice producing regions located north-west of the city of Shiraz in Fars Province, Iran. Rice production of small farms in Ramjerd which was affected by an increase in water supply from the Darius Dam, is studied for two-crop years. Abarj, which was not affected, was studied as the control region. Irrigation water in these regions, where average rainfall is about 370 millimetres per annum, is very important—especially for rice production, which requires intensive irrigation as well as managerial skills. Prior to the construction of the Dam, Ramjerd received irrigation water mainly from rivers. In the few years of the Dam construction, the Ramjerd agriculture has been subjected to irregularity of avilable water resulting from construction of the Dam. Abarj always has ample water supply from rivers, ghanats,[6] and springs.

The data for this study were collected through interviews with 232 small farmers who were chosen on the basis of a stratified random sample of farms in about 30 villages.[7] Information on farm size and crop combinations for the two regions in two-crop years is presented in Table I. Before the utilization of water from the Dam, in 1971-72, only 3 per cent of all cultivated land was allocated to rice cultivation in Ramjerd, compared to 16 per cent in 1973-74.[8]

In both the regions, the farms had already reached a certain degree of mechanization in 1971-72. Ploughing and most of the other activities to prepare the land were accomplished by tractors, and harvesting of a large portion of wheat and barley was also mechanized.

THE MODEL

A Cobb-Douglas production function is used to estimate the production coefficients of rice in the two regions before and after an increase in irrigation water supply to small farms. The Cobb-Douglas model is as follows:[9]

6. A ghanat brings underground water to the surface on gentle slopes by gravity force.
7. The data were originally collected for a descriptive research on the Darius Dam project area carried out by the Department of Agricultural Economics and supported by the Research Centre of the College of Agriculture, Pahlavi University.

Some of the farmers operated their farms individually while others operated in groups or partnerships. The 1973-74 data used in this study are from the first category.

Along with the utilization of water from the Darius Dam in Ramjerd, farm corporations started to expand rather quickly. By 1977 these corporations embodied almost all of the small farms in the region. However, the data for this study were collected from farms which were not yet affected by corporations. Abarj, on the other hand, was not affected by any farm corporation. For a discussion on farm corporations and other farming organizations in Iran, see Reza Doroudian, "Modernization of Rural Economy in Iran", in Jone W. Jacqz (Ed.): Iran: Past, Present and Future, Aspen Institute for Humanistic Studies, 1976, pp. 157-168.

8. Some farmers started to use water from the Dam in 1971-72 but they are not included in the 1971-72 observations used in this study.
9. Due to lack of data, especially for 1971-72, the inputs considered are limited to land, seed and chemical fertilizers. For the inputs which are not included in the model, it is assumed that they are highly correlated with land and their effects on the output are picked up by land productivity coefficient.

TABLE I—CROP COMBINATIONS IN THE RAMJERD AND ABARJ REGIONS FOR 1971-72 AND 1973-74

(*hectares per farm*)[a]

Crops	1971-72				1973-74			
	Ramjerd		Abarj		Ramjerd		Abarj	
	Hectare	Per cent	Hectare	Per cent	Hectare	Per cent	Hectare	Per-cent
Irrigated								
Wheat	3.50	59	2.20	47	4.27	58	1.74	50
Barley	.44	7	.82	18	1.79	24	.79	23
Rice	.19	3	.77	17	1.17	16	.80	23
Sugar beets	.20	3	.15	3	.01	*	—	—
Others	.57	10	.29	6	.12	2	.02	1
Non-irrigated								
Wheat	.30	5	.28	6	—	—	—	—
Barley	.78	13	.15	3	.03	*	.09	3
Total cultivated ..	5.98	100	4.66	100	7.39	100	3.44	100
Fallow	5.87		3.82		4.63		2.85	
Total farm	11.85		8.48		12.02		6.29[b]	

a. Calculated at arithmetic means.
b. Average size of farms interviewed in 1973-74 is smaller than in 1971-72.
* Less than 0.5 per cent.

$$(1) \quad Y = A X_1^{\alpha 1} X_2^{\alpha 2} X_3^{\alpha 3} \exp(\delta_j + U)$$

where

$Y =$ Physical output measured in kilograms (kg.) per farm.
$X_1 =$ Land input measured in hectares of the crop grown per farm.
$X_2 =$ Seed measured in kg. per farm.
$X_3 =$ Chemical fertilizers applied to the crop measured in kg. per farm.

δ_j denotes the coefficient of dummy variable with a value of one for 1971-72 (before the increase in water supply) and zero for 1973-74 (after the increase in water supply). The dummy variable is used to measure the shifts in the intercepts from 1971-72 to 1973-74, that is, the shift in the production function other than those explained by the variable X_1 to X_3.

U is the random disturbance term, independently distributed with zero mean and finite variance.

RESULTS

A. *Change in Production Functions as a Result of Increased Supply of Water*

Although the elasticities of production estimated by the Cobb-Douglas model fitted to farm level data sometimes give unexpected results[10] (negative or larger than one), the results of this study are quite satisfactory. The output elasticities of land, seed, and chemical fertilizers in all regressions, with the exception of land in regression (1), are between zero and one (Table II). That is, these inputs are used in Stage Two of production functions. The negative sign for output elasticity of land in regression (1) for Ramjerd in 1971-72 is surprising. One explanation could be that in that year the farmers had less than the normal amount of water supply. Moreover, they might have planted rice in a larger area in anticipation of additional water supply from the Dam. Thus, the land input is in Stage Three of the rice production function in Ramjerd for that year.

Differences between the production coefficients for 1971-72 and for 1973-74 can be seen as we compare regressions (1) and (2) of Ramjerd to the pooled regression (3) and regressions (5) and (6) of Abarj to pooled regression (7) in Table II. A Chow Test[11] is used to test if output elasticities with respect to various inputs are the same in every regression before and after the increase of water supply. The analysis of variance for the Ramjerd regressions gives an F-ratio of 5.90 with 3 and 147 degrees of freedom which is significant at 1 per cent level. Therefore, the hypothesis that the output elasticities are the same in separate regressions is rejected for Ramjerd. The analysis of variance for Abarj, however, gives an F-ratio of 0.46 with 3 and 69 degrees of freedom which is not significant even at 10 per cent level. Therefore, one cannot reject the hypothesis that output elasticities in separate regressions are the same for Abarj.

The sum of productivity coefficients for Ramjerd increases from 0.5847 in 1971-72 to 0.9870 in 1973-74 [regressions (1) and (2), Table II]. We may deduce that this increase is the result of the additional water supplied by the Darius Dam. Because land and water are highly complementary inputs in rice production, most of the productivity increase is embodied in land.

The estimated dummy variables and intercepts of regressions (4) and (8) show that the intercept term for Ramjerd in 1971-72 increased by 11 per cent in 1973-74, and for Abarj the increase is only by 3 per cent. A change in the intercept implies a neutral shift in the production function. Here, the larger percentage of the upward shift in the rice production intercept for Ramjerd indicates the impact of the change in the amount of water supplied to this region.

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10. See S. Roy Chowdhury, Vishnuprasad Nagadevara and Earl O. Heady, "A Bayesian Application on Cobb-Douglas Production Function," *American Journal of Agricultural Economics*, Vol. 57, No. 2, May 1975, pp. 361-363.

11. Gregory C. Chow, "Test of Equality Between Sets of Coefficients in Two Linear Regressions," *Econometrica*, Vol. 28, No. 3, July 1960, pp. 591-605.

TABLE II—ESTIMATES OF PRODUCTION FUNCTIONS FOR RICE IN RAMJERD AND ABARJ: 1971-72 AND 1973-74[a]

Regression number	Region and year	Number of observations	Constant term (in $\log_{10}$) A	Coefficients of $D°$	Coefficients of X_1	Coefficients of X_2	Coefficients of X_3	R^2	SEE[b]	Sum of coefficients	F-ratio[c]
	Ramjerd										
(1)	1971-72	60	1.6352		—0.1610 (0.3016)	0.7140 (0.2663)	0.0317 (0.0104)	0.509	0.1544	0.5847	19.36
(2)	1973-74	95	2.0621		0.3438 (0.1692)	0.4381 (0.1338)	0.2051 (0.0747)	0.636	0.1083	0.9870	52.91
(3)	Pooled	155	1.4785		0.1074 (0.1721)	0.8695 (0.1370)	0.0447 (0.0097)	0.818	0.1490	1.0216	266.27
(4)	Pooled (with dummy)	155	2.2658	—0.2300 (0.0354)	0.1887 (0.1531)	0.5336 (0.1320)	0.0349 0.0088)	0.858	0.1321	0.7572	226.54
	Abarj										
(5)	1971-72	34	2.6514		0.5530 (0.3861)	0.3709 (0.4021)	0.0212 (0.1587)	0.630	0.1656	0.9451	17.00
(6)	1973-74	43	3.1913		(0.8557 (0.1749)	0.0754 (0.1372)	0.0916 (0.0258)	0.861	0.0328	1.0227	80.85
(7)	Pooled	77	2.3167		0.4423 (0.2203)	0.5509 (0.2049)	0.0286 (0.0658)	0.723	0.1137	1.0218	63.24
(8)	Pooled (with dummy)	77	2.8211	—0.0764 (0.0309)	0.6231 (0.2252)	0.2882 (0.2248)	0.0575 (0.0647)	0.744	0.1099	0.9688	52.42

a. Linear regressions in logarithmic terms are estimated where Y, dependent variables, are the outputs of rice in physical units. $D°$ is dummy variable with value of one for 1971-72, and zero for 1973-74. X_1, X_2 and X_3 are land, seed and chemical fertilizers (physical units) per farm. Standard errors of coefficients are in parentheses.

b. Standard errors of estimates in $\log_{10}$ output are measured in kg.

c. Significant at 1 per cent level for all regressions.

B. Sum of Coefficient Results

The sum of coefficients for the Ramjerd rice in 1971-72 is 0.5847, indicating that the farmers were using inputs for rice beyond the optimum scale of production. This was, as explained before, an unexpected situation where the amount of water available for the rice irrigation was less than what the farmers anticipated at planting time. In 1973-74, when a regular and greater quantity of water became available, the farmers were operating very close to the optimum scale (the sum of coefficients is 0.9870). The increase in the amount of water supply raised the optimum scale of rice production to a higher level of output. The farmers adjusted to the new optimum scale by allocating more amount of land, seed, and fertilizers to this crop. The sum of coefficients for rice production in Abarj is close to unity in each period.

In short, the above comparison indicates that first, the regularity and quantity of irrigation water is one of the major determinants of the optimum size for rice cultivation in both the regions, and secondly, under normal conditions, the small farms will operate very closely to the optimum scale of production.[12]

C. Input Allocation Adjustment

A relevant question is how efficiently small farms allocate the input to rice production in the two periods. In order to examine the efficiency of allocation, marginal value produts (MVPs) of the inputs, presented in Table III, can be compared with the prices of these inputs. Among the inputs considered, seed and especially chemical fertilizers are variable inputs in the sense that their acquisition prices equal their respective salvage values.[13] Hence, the MVPs of these two inputs are compared with their prices. The MVP of land, however, is not compared with its price for two reasons. First, land is relatively fixed at the farm level and its allocation efficiency should be judged on the basis of its on farm opportunity cost.[14] Secondly, owing to its potential for other uses, it is difficult to estimate the price of land for agricultural purposes in these regions.

The comparison of MVPs for seed and chemical fertilizer with their prices indicates a proper adjustment by the farmers for the level of application of these inputs—proper in the sense that the adjustments were toward profit maximization level where the MVP of input equals its prices. The increase in the application of fertilizer from 28 kg. per hectare (5 kg. per farm) in 1971-72 to 192 kg. per hectare (217 kg. per farm) in 1973-74 shows an appro-

12. This is consistent with the results of Surjit S. Sidhu, "Economics of Technical Change in Wheat Production in the Indian Punjab," *American Journal of Agricultural Economics*, Vol. 56, No. 2, May 1974, p. 226.

13. See Glenn L. Johnson and C. Leroy Quance: The Over-production Trap in U.S. Agriculture—A Study of Resource Allocation from World War I to the Late 1960's, The Johns Hopkins University Press, Baltimore and London, 1972, pp. 27-32.

14. See W. David Hopper, "Allocation Efficiency in a Traditional Indian Agriculture," *Journal of Farm Economics*, Vol. 47, No. 3, August 1965, pp. 611-624.

TABLE III—MARGINAL VALUE PRODUCTS FOR DIFFERENT INPUTS IN THE PRODUCTION OF RICE IN RAMJERD AND ABARJ; 1971-72 AND 1973-74

Region and year	Output			Land			Seed					Chemical fertilizer				
	Y^a (kg. per farm)	APP (kg. per hectare)	Price (Rials[b] per kg.)	X_1^a (hectare per farm)	MPP (kg.)	MVP[c] (Rials)[b]	X_2^a (kg. per farm)	Kg. per hectare	MPP (kg.)	MVP[c] (Rials)[b]	Price per kg. (Rials)[b]	X_3^a (kg. per farm)	Kg. per hectare	MPP (kg.)	MVP[c] (Rials)[b]	Price per kg. (Rials)[b]
Ramjerd																
1971-72	289	1,606	15	0.18	—258	—3,870	17	94	12.0	182	33	5	28	1.8	27	9
1973-74	3,281	2,904	33	1.13	997	32,901	148	131	9.7	320	35	217	192	3.1	102	11
Abarj																
1971-72	2,000	2,778	15	0.72	1,536	23,042	71	99	10.5	157	33	84	117	0.5	8	9
1973-74	2,662	3,370	33	0.79	2,883	95,139	89	113	2.3	76	35	77	98	3.2	106	11

a. Geometric means of the samples.

b. 70 Rials equal one dollar. The indicated prices of seed and fertilizer do not include the cost of transportation and labour; they are the arithmetic means of the samples.

c. MVPs are calculated as MPPs multiplied by the price of output, and MPPs are calculated as α (Y/X). See Vernon W. Ruttan: The Economic Demand for Irrigated Acreage—New Methodology and Some Projections, 1954-1980, The Johns Hopkins Press, Baltimore and Maryland, 1965, p. 20. αs are shown in Table II.

priate adjustment by these farmers.[15] Using relatively low amounts of inputs for rice in 1973-74, as compared to the optimum level, is partly due to the fact that the MVPs had sharp rise as a result of unexpected increase in the price of output.[16]

CONCLUSION AND IMPLICATIONS

The impact of additional water supplied by the Darius Dam on rice production of small farms is as follows: the production function shifts upward, indicating an increase in the productivity coefficients and the value of the intercept.

Owing to the upward shift in the production function, a greater area of land per farm and more intensive use of seed and especially chemical fertilizers per hectare are possible. The increase in the price of rice magnifies the profitability of these inputs. The farmers' response to new technology shows that they adjust their input allocation properly—that is, they increase the amount of resources used for rice production and move toward the level of profit maximization determined by the new technology. In fact, they move along the metaproduction functions.[17] The results indicate that small farm holders in Iran are rational and efficient in allocating resources, provided that they have adequate information on the availability of resources.

The study also shows that the amount of water available for irrigation is one of the major determinants of the optimum size for rice production. Moreover, under normal conditions and given production techniques, the small farms would operate at the optimum size of production.

One of the questions in agricultural development is whether governments should decide upon the size of farms. The sum of coefficient results of this paper indicates that instead of forcing a policy on farm size, governments should focus on the provision of scarce inputs such as irrigation water and the size of farm will adjust automatically to reach the optimum.

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15. It should be explained that the increase in fertilizer application has been mainly for profit maximization and is not due to availability of fertilizer. Consider Abarj which is further away from the fertilizer factory and suffers from worse roads. It has generally less access to chemical fertilizer than Ramjerd, yet in 1971-72 when Ramjerd was using only 28 kg. of fertilizer per hectare, Abarj was applying 117 kg. per hectare. However in 1973-74, when a greater amount of water became available to Ramjerd, the rate of fertilizer application increased more than six-fold and exceeded the rate for Abarj.

16. The increase of more than 100 per cent in the price of rice, from 15 Rials per kg. in 1971-72 to 33 Rials per kg. in 1973-74, was unexpected by the farmers.

17. Moving along the metaproduction function, which is important for agricultural development, is the result of additional water supply to the Ramjerd small farms. For the importance of movement along the metaproduction function, see Yujiro Hayami and Vernon W. Ruttan; *op cit.*, pp. 82-85 and 192-196.

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