Institutional Factors behind Effectiveness of Irrigation: A Study in the Brahmaputra Valley in Eastern India

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I. INTRODUCTION:

A significant up-turn in India's food-grain production started in the late 1960s, which was spurred by the technological break through embodied in the high yielding variety (HYV) seeds. Introduction of the new technology was backed by policy of price support and procurement of food-grains for public distribution, and farmers in the Punjab, Haryana and western Uttar Pradesh in North-western India, where developed irrigation infrastructure had already existed, responded promptly by adopting the technology package successfully. During the 1970s and the 1980s the new technology gradually spread to more regions and the growth in food-grain production was sustained, instilling a strong sense of food security in the country. But in the mean time some drawbacks of India's agricultural policy also surfaced. In the 1980s government expenditure in subsidisation of farm inputs swelled, crowding out public investments for expansion of irrigation capacity. Subsidised irrigation water and free electricity to the farm sector resulted in over-exploitation of natural resources leading to adverse environmental consequences such as soil degradation through water logging and salinity and fall in the water table (Government of India, 2001, 2002). Repeated increases in procurement prices, on the other hand, resulted in ballooning of cost of maintaining price support, procurement and public distributions of food-grains. In the 1990s, as India embarked on a process of fiscal correction and market oriented economic reforms, the weaknesses of agricultural policy also attracted attentions of both academics and policy makers. Opening up of the economy as a result of conscious policy change and also due to WTO obligations has brought to fore the questions of efficiency and competitiveness of the economy in general and the farm sector in particular (Radhakrishna, 2002).

The policies of input subsidy and public procurement of food-grains are now gradually giving way to rational pricing of inputs and greater private role in trading and storage of food-grains (Government of India, 2001, 2002). These policy changes, working through changing economic calculations of farmers, are likely to effect significant changes in cropping patterns. There are calls for relocation of production of food grains like rice from large farmers in green revolution areas, where economic and environmental costs of these crops have become prohibitive (Kalra and Singh, 2002; Sidhu, 2002), to small and marginal farmers, and eastern and rain fed areas where returns to both labour and capital are high (Government of India, 2001, 2002).

One of the major factors which has so far restrained full exploitation of existing agricultural technology in Eastern India in general and the state of Assam in it in particular is the paucity of irrigation (Bezbaruah, 1994; Goswami, 1992). Obviously, strengthening of irrigation infrastructure is necessary. However, strengthening of irrigation infrastructure does not end at creating more capacity. Statistics show that the utilization of installed capacity of irrigation in Assam, especially of public sector projects is poor[1] and studies have revealed that the poor utilization rate is due to supply side factors rather than demand related factors (Dutta and Bezbaruah, 2005). It has also been found that these factors are better addressed and hence utilization rate improves when the stake-holding farmers have more control over the operation and management of supply of irrigation. Thus strengthening of irrigation infrastructure should also involve putting in place the necessary institutions to facilitate effective utilization of the installed capacity. The present paper attempts to examine whether farmers' control over management and operation of irrigation system is crucial even in determining their success in effectively using irrigation in terms of level and intensity of productivity increasing practices that are associated with irrigation. Thus the hypothesis to be verified in the following analysis is that greater control of farmers over operation and management of irrigation systems, by reducing uncertainties of water availability, induces more effective utilization of the basic agricultural resources of land and water.

The paper has been organized in four sections. Section two deals with the sample and analytical framework on which the paper is based. While section three pertains to the results and discussion, section four sums up findings and the policy implications of the study.

II. THE SAMPLE AND THE ANALYTICAL FRAMEWORK:

II.1 Location and Sample:

The paper is based on a field study carried out by the authors in 2001 in the Brahmaputra Valley, which constitutes about 70% of the state of Assam in Eastern India. The study covered major, medium and minor irrigation projects of different technical and size specifications located in the three districts of Dibrugarh, Nagaon and Barpeta falling respectively in Upper, Central and Lower Brahmaputra Valley agro-climatic zones. From the point of view of ownership and control of operations, the projects fall in three categories: a) fully owned and managed by government agencies, b) owned by government agencies whose management and operation are largely controlled by stake holding farmers and c) owned and operated by the farmers. The projects in category (a) and (b) are relatively larger, each catering to a group of farmers. In case of category (b), the water using farmers are better organized through their Field Management Committees (locally known as *Pathar Parichalana Samiti*) which provide a ready institution for controlling and managing water release and distribution. The category (c) projects are small, shallow tube well (STW) based each capable of irrigating up to 2 hectares of land and usually owned and used individually by farmers. Of the total sample of 172 farmers, 62 get irrigation from category (a) projects, 43 from category (b) and 67 from category (c) projects.

II. 2 Indicators of Effective Use of Irrigation:

It is well known that irrigation facilitates practice of multiple cropping, use of high yielding varieties (HYVs), and application of fertilizers. Hence, the extent of multiple cropping measured by cropping intensity (CI), use of HYV seeds measured by proportion of HYV area in total rice acreage (HYV_R) and fertilizer consumption in terms of kilograms of N+P+K/hectare of gross cropped area (FC) have been taken as indicators of effectiveness of irrigation. Keeping in view the locational contexts of the present study, yield (Y_R) of rice, the principal crop of the area, has also been included as an additional indicator.

II. 3 Explanatory Factors and Variables:

In the context of the present study, the key factor of interest as a determinant of the above-mentioned indicators of effectiveness of irrigation is the ownership and control of irrigation facility by farmers. To capture the three levels of this factor, two dummy variables have been used. They are:

> I_b which takes the value 1 for cases where the facility is owned by government but farmers have control over its management and operation and 0 for other categories
>
> I_c which takes the value 1 for cases where the facility is privately owned and operated by farmers and 0 for other situations.

Thus the coefficients of I_b and I_c in the regression models will capture the differential effects for category (b) of irrigation systems owned by government agencies but managed by stake holding farmers and (c) fully owned and operated by the farmers respectively over category (a) which are fully owned and operated by government.

Other explanatory factors are: size of farm measured by operational holding of the farm in hectares (OH), tenancy measured by percentage of leased land in the operational holding (T), access to extension service and location.

In the questionnaire used in the field study, six questions related to a farmer's interactions with the extension agency were included. Farmers' responses to these queries were codified into scores. The total score on these questions could vary from 0 to 6 depending on the level of the farmer's interactions with the extension agencies. A farmer's score on these questions has been used as the measure of his access to extension service. This variable representing access to extension service has been denoted by E.

Since the field study was carried out in three districts located in three agro-climatic zones of the state, the difference in location of a sample farm can have some influence on the level of use of the different practices. Since there are three different locations, two dummies namely, L_1 and L_2 had to be taken to capture the effect of the locational factor. The dummy L_1 takes the value 1 for sample farms in Nagaon district and 0 for sample farms in the other two districts. The dummy L_2 takes the value 1 for sample farms in Barpeta district and 0 for others.

In addition to these five common factors, the percentage of area under high yielding rice varieties in gross cropped area, denoted by HYV_G has also been used as an explanatory variable in the analysis of use of fertilizers by sample farmers. Similarly, the variables kgs. of N+P+K per hectare of rice acreage, denoted by F_R and percentage of HYV area in rice acreage (HYV_R) have also been included in the explanatory variables for yield of rice.

II.4 The Models:

As per the above discussion, to explain the variations in cropping intensity (CI), extent of use of high yielding variety seeds (HYV_R), application of fertilizer (FC) and yield of rice (Y_R), the following regression models are used:

$$CI = \alpha_0 + \alpha_1 I_b + \alpha_2 I_c + \alpha_3 OH + \alpha_4 T + \alpha_5 E + \alpha_6 L_1 + \alpha_7 L_2 + u \quad (1)$$

$$HYV_R = \beta_0 + \beta_1 I_b + \beta_2 I_c + \beta_3 OH + \beta_4 T + \beta_5 E + \beta_6 L_1 + \beta_7 L_2 + u \quad (2)$$

$$FC = \chi_0 + \chi_1 I_b + \chi_2 I_c + \chi_3 OH + \chi_4 T + \chi_5 E + \chi_6 L_1 + \chi_7 L_2 + \chi_8 HYV_G + u \quad (3)$$

$$Y_R = \delta_0 + \delta_1 I_b + \delta_2 I_c + \delta_3 OH + \delta_4 T + \delta_5 E + \delta_6 L_1 + \delta_7 L_2 + \delta_8 HYV_R + \delta_9 F_R + u \quad (4)$$

where u is the random disturbance term and α, β, χ and δ are the parameters to be estimated in the respective equations.

The equations have been estimated using ordinary least squares method. It may be noted that the variable HYV_R appears as a dependent variable in equation no. (2) and as an explanatory variable in equation no. (4). In that sense there is an element of simultaneity between equations (2) and (4). However, Y_R, the dependent variable in equation no. (4) is not an explanatory variable in equation (2). Thus the equations (2) and (4) form a recursive system and therefore ordinary least squares (OLS) is still a valid method for estimating the equations.

III. RESULTS AND DISCUSSION:

The results of estimation of the equations are presented in table 1. The R^2 values vary from 0.314 to 0.631 indicating that the models give moderate to good fit. The F-statistic for all the equations is statistically highly significant indicating overall significance of each of the estimated equations. More importantly, at least one of the two variables I_b and I_c representing the key factor of interest in the study, has come out significant in each of the equations. Details of the results are discussed in the following sub-sections.

III.1 Multiple Cropping:

In case of cropping intensity measuring the extent of multiple cropping, the variable I_c is statistically highly significant with a positive coefficient though the variable I_b is not significant. This implies that the farms using private well based irrigation have a higher cropping intensity than farms depending on government irrigation supply. The result can be rationalized in terms of greater control over irrigation facility in case of private irrigation than in situations when the government is the supplier of the service. Fuller control gives farmers freedom and flexibility of irrigating fields often enough for multiple cropping.

The other significant variables explaining cropping intensity are farm size and access to extension services. Farm size has a negative coefficient indicating that smaller farms use land with greater intensity. The obvious explanation is that availability of land being less, this resource is more intensively utilized. The coefficient of extension is expectedly positive showing that access to extension service induces farmers to adopt multiple cropping.

III.2 Use of High Yielding Varieties:

In case of extent of use of high yielding varieties (HYV_R), both the variables I_b and I_c are found significant with positive coefficients. Thus farmers operating with private irrigation and those receiving irrigation from public sector projects but with control over operation and management of the supply use high yielding varieties more extensively than those depending on irrigation from government owned and operated projects. Indeed the variable I_b is more highly significant than I_c and also has a larger coefficient. Thus in case of use of high yielding varieties the farmers using government irrigation but with control over operation and management do better than even the farmers operating with private irrigation.

The other significant variables are access to extension (E) and locational dummy (L_1). The significance of E with a positive coefficient indicates that farmers with a closer contact with extension agencies tend to use HYVs more extensively. The positive and highly significant coefficient of the dummy variable L_1 coupled with non-significance of the other locational dummy L_2 shows that farmers in Nagaon district in Central Brahmaputra Valley put a higher percentage of rice acreage under HYV compared to farmers in the other locations

III.3 Use of Fertilizers:

In case of fertilizer consumption (FC), both the variables I_b and I_c are statistically highly significant with positive coefficients. Clearly farmers using private irrigation as well as those using government irrigation but with control over operation and management of systems tend to use more fertilizer per hectare than the farmers depending on government owned and operated irrigation supply. The fact that coefficient of I_b is more than the double the size of coefficient of I_c shows that the farmers with government irrigation with control over operation and management do much better than farmers operating with private irrigation in terms of use of fertilizer.

Other variables which have come out significant are tenancy (T) and locational dummy L_2

III.4 Yield of Rice:

In case of yield of rice too, the coefficients of the variables I_b and I_c are positive. While the variable I_b is highly significant, I_c is not significant. Thus farmers operating under government irrigation with control over operation and management are able to extract higher yield from their rice crop than the other two categories of farmers. This is to be expected as this category of farmers has been found to be using high yielding varieties and fertilizers to greater extent than the other two categories.

Among the other variables, HYV_R and F_R are expectedly highly significant with positive coefficients. The remaining significant variable is OH representing farm size. Its coefficient is positive implying that rice yield tends to be higher in bigger farms. This finding conforms to Singh and Kalra's (2002) findings for Punjab.

IV. CONCLUSIONS:

The results clearly show that on the whole farmers operating under government supplied irrigation but with control over operation and management of the systems and farmers operating with private irrigation use irrigation water more effectively than those operating under government owned and operated irrigation systems. Thus the hypothesis set up for verification in the study stands validated.

There are, however, significant differences between farmers operating under government irrigation with control in operation and management and farmers operating with tube well based private irrigation in the use of practices, levels of which are taken as indicators of effective use of irrigation. The former category of farmers has utilized HYV seeds-fertilizer technology of food grain production in a fuller way and hence achieved higher yield of rice. The latter group, on the other hand, has achieved higher cropping intensity. It seems that fuller control over irrigation supply from small scale and mostly self-owned tube well based systems give farmers in this category more flexibility in choosing crops and crop seasons, enabling more frequent cropping of their fields. Indeed these farmers have been found to have diversified to non-rice crops to a greater extent than farmers operating with government supplied irrigation with or without control over operation and management of supply.

The findings of the study lead to the following policy suggestions.

(a) To improve effectiveness of public sector irrigation projects and thereby reap higher social returns on public investment on irrigation, the involvement of stake holding farmers in operation and management of irrigation systems should be secured. However, to be able to get involved effectively, farmers need to have the necessary organization among themselves. In situations where such peer organizations among farmers are weak or absent, it is necessary to facilitate emergence of such bodies in a robust manner.

(b) In view of the effectiveness of small scale privately owned tube well based irrigation systems and the ground level conditions in the Brahmaputra valley in the form of relatively small size of holdings[2] and abundance of ground water reserve[3] private investments in such systems can be encouraged so as to add to the total irrigation capacity. However, unrestricted exploitation of the common resource of ground water reserve may be unsustainable in the long term.[4] Thus as the installation of well based irrigation systems picks up, it will be necessary to put suitable regulations in place to ensure sustainable exploitation of the ground water reserves.

NOTES:

1. The utilization rate of government irrigation schemes in the state in 2002-03 was only 15.26% of the total potential created (Government of Assam, 2004).
2. The average size of operational holding in the state was 1.31 hectares in 1985-86, which went down to 1.27 hectares in 1990-91. In 1995-96, the size further went down to 1.17 hectares, which is much lower than the all India average of 1.41 hectares (Government of Assam, 2004)
3. As on 31.03.2003, total replenishable ground water reserve for Assam stood at 24.72 billion cubic meter out of which 21.01 billion cubic meter was available for irrigation. However, only 8.75% of this amount was utilized during 2002-03. (Central Ground Water Board, Ministry of Water Resources, Government of India)
4. For instance, see Guruswami and Kaul (http://www.cpasind.com/reports/04-Looming-Crisis-Indias-Agriculture.pdf)

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Table 1: Results of regression analysis of selected indicators of effectiveness of irrigation

Dependent Variable	Estimated Coefficients of Explanatory Variables										Constant	R^2	F
	I_b	I_c	OH	T	E	L_1	L_2	HYV_G	HYV_R	F_R			
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cropping Intensity (CI)	8.204 (8.241)	49.576*** (8.107)	-4.225** (1.847)	.096 (.125)	3.178* (1.865)	4.376 (8.510)	9.002 (7.733)	–	–	–	151.271*** (8.947)	0.314	10.726*** [7,164]
Extent of HYV seeds (HYV_R)	48.335*** (5.240)	8.521* (5.155)	-1.628 (1.175)	.057 (.080)	2.184* (1.186)	10.036* (5.411)	-1.790 (4.917)	–	–	–	35.785*** (5.689)	0.441	18.487*** [7,164]
Use of Fertilizers (FC)	102.652*** (16.043)	49.783*** (12.923)	3.061 (2.972)	.670*** (.200)	2.327 (2.976)	10.727 (13.864)	29.041** (12.360)	30.240 (24.936)	–	–	-14.104 (16.436)	0.413	14.308*** [8,163]
Yield of Rice (Y_R)	5.320*** (1.386)	1.489 (1.161)	.562** (.239)	-.016 (.016)	-.071 (.243)	-.161 (1.108)	-.868 (1.079)	–	.094*** (.016)	.033*** (.007)	15.577*** (1.318)	0.631	30.762*** [9,162]

Notes: 1. Figures in parentheses ( ) represent standard errors of respective coefficients and within [ ] represent degrees of freedom of F-statistic

2. *,**,*** indicate significant at 0.10, 0.05 and 0.01 respectively