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Is the Role of Irrigation in Agricultural Output Declining in India?: A District-Wise Study at Six Time Points

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ABSTRACT

The significant role of irrigation development in land use pattern, cropping pattern, cropping intensity, production and productivity of crops has been well documented by various studies in India. However, the contributions of irrigation to agricultural output and related parameters are fervently questioned in the recent years. Since the role of irrigation in increasing the value of agricultural output has not been studied by many scholars especially using disaggregated data covering different time points, an attempt has been made in this study to fill this gap by using cross-sectional data for 235 Indian districts, drawn from 13 states at six time points: 1962-65, 1970-73, 1980-83, 1990-93, 2003-05 and 2005-08. Both descriptive and regression analyses have been carried out to study the relationship. Descriptive analysis shows that the difference in value of agricultural output per hectare has narrowed down between less (<30 per cent), medium (30-50 per cent) and high (>50 per cent) irrigated districts over the years, especially after 1990-93. The univariate regression analysis carried out treating irrigation (with and without dummy as well as with and without time lag) as an independent variable and the value of agricultural output per hectare as dependent variable shows that the impact of irrigation on the value of output has declined (both irrigation coefficient and R^2) over time. During 1980-83 and 1990-93, irrigation alone has explained around 50 per cent of variation in agricultural output, but the same declined to about 24 per cent during 2003-05 and 2005-08. Multivariate regression analysis carried out by using different yield increasing and infrastructure variables suggests that although irrigation still plays a dominant role in increasing the value of output, its value of coefficients has been declining over time. Although both univariate and multivariate regression results show a declining trend of irrigation coefficient over time, one may not be able to firmly say that the role of irrigation in determining the value of agricultural output has reduced over time, as this could have happened due to acceleration in the productivity of crops cultivated in the rainfed/less irrigated districts.

Keywords: Farm profitability, Irrigated area and crops, Rainfed crops, Value of agricultural output

JEL: Q11, Q12, Q13, Q15

I

INTRODUCTION

Irrigation is often considered as the engine of agricultural growth as it plays an important complementary role in the process of crop cultivation. It has been corroborated by various studies in India and elsewhere in the world that irrigation facility makes significant difference in productivity of crop/crop output (Dhawan, 1988 and 1991; Vaidyanathan *et al*., 1994; Vaidyanathan, 1999; Hussain and Hanjra, 2004; Narayanamoorthy, 2004, 2005; Narayanamoorthy and Deshpande, 2005; Narayanamoorthy and Hanjra, 2006;). This happens because of various reasons. First, irrigation facility encourages the farmers to use better varieties and other bio-

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chemical technologies which obviously lead to increased productivity. Second, the cropping pattern followed in the irrigated area is superior to that of un-irrigated area and therefore, the output of crop is invariably higher under irrigated land. Third, irrigation facility allows the farmers to use the land more intensively throughout the year with higher level of cropping intensity, which is not possible under un-irrigated land (for details see, Dhawan, 1991). Fourth, the risk in getting the assured output from the crops cultivated due to moisture stress is very high under un-irrigated land while it is much less in irrigated land (Vaidyanathan *et al*., 1994). Importantly, given the highly inelastic supply of land and reduced net sown area, the future growth of agriculture will have to heavily rely on irrigation facility as it allows for multiple cropping on the same piece of land.

However, the contribution of irrigation on agricultural output and related parameters are fervently questioned in the recent years. While attempting to estimate the various categories of public investment in rural areas with state level data from 1970-1993, Fan *et al*., (1999) have reported that the returns in rupees for every rupee spent in rural areas was only Rs. 1.36 for irrigation which is much lower than the return generated by the research and development (Rs. 13.45) and rural roads (Rs.5.31) in India (also see, Fan and Hazell, 1999; Thorat and Fan, 2007). In spite of voluminous literature on the impact of irrigation on various parameters including the value of crop output, the report on World Commission on Dam (WCD, 2000) has reported that there are no reliable estimates available on the marginal impact of irrigation from that of other policy and technology factors. The incremental effect of irrigation on agricultural growth versus others inputs (technology and other related rural infrastructure) has also been debated by various studies in the literature on irrigation especially in the recent years (Fan *et al*., 1999; Dhawan, 1986; Evenson *et al*., 1999; Shah, 2001; Bhalla and Singh, 2001).

The linkages between irrigation and agricultural growth or crop output have been studied by various scholars using different types of data of various points of time in India (Ray, 1977; Vaidyanathan, 1980 and 1987; Abbie *et al*., 1982; Dhawan, 1988; Mahendra Dev, 1992; Vaidyanathan *et al*., 1994; Narayanamoorthy *et al*., 2014). Some studies have analysed the source-wise (tanks, canals and groundwater) impact of irrigation on the agricultural output (Dhawan, 1988), while some other studies have looked into the role of irrigation by following 'before' and 'after' approach (for instance, Gadgil, 1948). By utilising state-level time-series data from 1957 to 1991, Datt and Ravallion (1998) showed that states with better initial (towards early 1960s) irrigation facility achieved higher rates of agricultural output growth than poorly endowed states. Using state level data for 1970-93 in India, Fan *et al*. (1999, 2000) studied the relationship between government expenditures on agricultural research and development, irrigation, roads, education, power, soil and water conservation, rural development spending on agricultural growth and rural poverty. The study concludes that improved rural infrastructure and technology have all contributed to agricultural growth, but their impacts have varied by settings. "Government expenditures on roads and R&D have by far the largest impact on poverty reduction and growth in agricultural productivity; they are attractive win-win strategies. Government spending on education has the third largest impact on rural poverty and productivity growth. Irrigation investment has had only modest impacts on growth in agricultural productivity and rural poverty reduction, even after allowing for trickle-down benefits" (Fan *et al*., 2000: p.1050).

In a very detailed study on the impact of irrigation on productivity of land, Vaidyanathan *et al*., (1994) have analysed the role of irrigation by utilising three times point data namely 1962-65, 1970-73 and 1980-83 with the use of regression estimates. This study found no consistent relationship between irrigation and agricultural output across all the three time points; especially irrigation influence on value of output was found to be very low in high rainfall regions. Similarly, with the use of district level data from India, Fan and Hazell (2000) have studied the issue of whether developed countries should invest more in less favoured areas with the help of regression analysis. It concluded that irrigated areas played a key role in agricultural growth during the green revolution era, but now the rainfed areas including many less favoured areas give higher output growth for an additional unit of investment.

Though several attempts have been made to study the impact of irrigation development on land productivity or agricultural output, not many studies are available covering different time points as well as using large number of districts in recent times in the Indian context. One can understand whether the effect of irrigation development on agricultural output is increasing or decreasing over time only by covering different time points. The impact of irrigation development on output cannot take place instantaneously after making it available to the farmers, because of the time lag involved for making adjustments to the factors of production. Therefore, while linking the irrigation development with the agricultural output, one must also give enough time lag for irrigation variable so that its impact can be clearly measured. But, unfortunately, most of the available studies have analysed the impact of irrigation on the agricultural growth/output without giving any time lag to it. Keeping these caveats in view, an attempt has been made in this study to measure the role of irrigation on agricultural output across 235 districts at six time-points starting from 1962-65 to 2005-08. While the major objective of the study is to understand the role of irrigation on agricultural output in India over the years, the specific objectives of the study are: (a) to measure the independent relationship between irrigation and agricultural output (measured in terms of Rs./ha), and (b) to analyse the contribution of irrigation and other factors to agricultural output over time.

II

DATA AND METHODOLOGY

Secondary data pertaining to 235 Indian districts covering six time points namely 1962-65, 1970-73, 1980-83, 1990-93, 2003-05 and 2005-08 have been used for the entire analysis of the study.[1] As per the data of 2007-08, these 235 districts together accounted for about 82 per cent of the cropped area in India. The data for this study has been compiled from various sources. Data on irrigated area (IRRI) has been compiled from various issues of *Indian Agricultural Statistics*, published by the Ministry of Agriculture, Government of India, New Delhi. District-wise data on value of agricultural output (VAO) of 35 crops (at 1990-93 prices),[2] fertiliser use per hectare (FERT) and cropping intensity (CI) have been compiled from Bhalla and Singh (2001 and 2012). Data on rural literacy (LITE), availability of pucca road (ROAD) and villages electrified (ELEC) have been compiled and computed from various issues of *Census of India*.

It is known fact that the productivity of crop or agricultural output in value terms is determined by various factors; bio-chemical, growth related factors, infrastructure and other factors. But, due to data constraint, the study has utilised in total eight variables for the analysis which are presented in Table 1. Of these, three variables (ROAD, ELEC, LITE) have been treated as infrastructure variables, while the remaining five have been treated as growth related variables [IRRI, IrD (irrigation dummy), FERT, CI and VAO].

TABLE 1. DESCRIPTIVE STATISTICS OF VARIABLES USED IN THE STUDY

			Average of 235 Districts				
Variable (1)	Description (2)	Unit (3)	1970-73 (4)	1980-83 (5)	1990-93 (6)	2003-06 (7)	2005-08 (8)
VAO	Value of output (in 1990 -93 prices)*	Rs./ha	3977.48 (3775.89)	5286.72 (2621.15)	7032.99 (3492.76)	7693.07 (3734.76)	8167.13 (3975.20)
IRRI	Ratio of irrigated area to cropped area*	Per cent	23.78 (20.98)	30.59 (23.23)	37.61 (25.40)	43.81 (25.73)	48.54 (27.70)
IrD	Irrigation dummy	<30 per cent = 0; >30 per cent = 1	<30 per cent = 158 >30 per cent = 77	<30 per cent = 134 >30 per cent = 101	<30 per cent = 113 >30 per cent = 122	<30 per cent = 81 >30 per cent = 154	<30 per cent = 72 >30 per cent = 163
ROAD	Road facility†	Per cent	29.05 (13.20)	38.84 (22.48)	46.88 (23.80)	62.32 (22.88)	62.32 (22.88)
ELEC	Villages electrified†	Per cent	23.60 (23.38)	54.46 (26.89)	81.41 (21.02)	88.00 (16.50)	88.00 (16.50)
LITE	Rural literacy†	Per cent	21.43 (8.09)	27.72 (11.95)	42.30 (12.53)	56.64 (13.85)	56.64 (13.85)
FERT	Fertiliser use*	Kg/ha	17.06 (16.64)	40.00 (45.45)	77.59 (67.45)	103.82 (66.17)	119.25 (72.33)
CI	Cropping intensity*	Per cent	119.37 (17.33)	126.33 (19.27)	132.34 (23.34)	139.96 (27.55)	143.34 (33.91)

Sources: *Bhalla and Singh (2001); †Census of India, *Primary Census Abstract*, India (various years).
Note: Figures in parentheses are standard deviation; DNA- data not available.

There are underlying principles for using these variables in the analysis. The study tries to find out whether or not the role of irrigation in influencing the agricultural output is declining over the years. Therefore, the dependent variable in the analysis is VAO, defined as the value of output in rupees per hectare at constant prices. All the variables used in the study (bio-chemical, infrastructure and other growth variables) are expected to positively influence VAO. The key variable in the analysis is IRRI, defined as the percentage of irrigated area to cropped area. Irrigation is known factor in influencing the productivity of crop and therefore, IRRI is used along with other variables in the regression analysis. Alternatively, since minimum level of irrigation coverage is needed to influence the agricultural output in any given district, the irrigation variable is also used as dummy variable (<30 per cent = 0; > 30 per cent = 1) which is abbreviated as IrD for the purpose of analysis.

Inputs such as fertilisers, HYV seeds, pesticides as well as use of machineries (tractors, etc.) also play a key role in increasing the agricultural output. However, except fertilisers (FERT), all other yield increasing inputs could not be included in the analysis mainly due to data constraints. Since most yield enhancing factors tend to move in tandem with fertiliser use, the inclusion of fertiliser can be treated as reasonable proxy for other yield increasing inputs.[3] Cropping intensity (CI), defined as the ratio of gross cropped area to net cropped area in percentage term, explains the intensity of crops cultivation in the same piece of land in a year. CI has also been included for analysis along with other defined variables as agricultural output per hectare is expected to increase along with it.

Most infrastructure variables are expected to indirectly influence the agricultural output (Antle, 1983; Binswanger *et al.*, 1993; Bhatia, 1999; Ruttan, 2002; van de Walle, 2002). ROAD (percentage of villages having pucca road in each district) is one among three important infrastructure variables considered for the analysis. This is expected to increase the growth of agriculture through improved transport facility and also through forward and backward linkages between agriculture and other sectors. Equally, ELEC (percentage of villages electrified) is expected to increase the energisation of pumpsets through which irrigated area under groundwater can be increased, which is again an important factor for increasing agricultural output. Human capital variable, LITE (per cent of rural literacy) is expected to improve the knowledge of the farmers' households and enhance the diffusion of improved agricultural technology, both of which are essential to increase the agricultural output (see, Foster and Rosenzweig, 1996; Narayanamoorthy, 2000).

Although this study mainly utilises regression for its most part of the analysis, a small piece of descriptive analysis has also been carried out to study the relationship between irrigation development and agricultural output. To find out whether VAO increases along with irrigation facility over time, the value of output has been worked out by classifying all the 235 districts into three groups, namely low irrigation (<30 per cent), medium (30-50 per cent) and high (>50 per cent). This analysis is expected to explain the direction of change in value of output by level of irrigation across all six time points.

In order to study the simple relationship between irrigation development and agricultural output, the following four univariate regressions are estimated, taking

VAO as the dependent variable and irrigation as the independent variable separately, with and without time lags, for all six time points:

$$VAO = a + b_1IRRI + u \quad ....(1)$$

$$VAO= a + b_1IrD + u \quad ....(2)$$

$$VAO=a+b_1IRRI_{t-10} + u \quad ....(3)$$

$$VAO = a + b_1IrD_{t-10}+ u \quad ....(4)$$

The equations (1) and (2) explore the independent relationship between VAO and irrigation variable without giving any time lag, while equations (3) and (4) are estimated treating irrigation as lagged variables (by giving 10 years time lag). The impact of irrigation development cannot always be seen instantaneously on output and therefore, alternatively irrigation is also used as lagged variable to capture the real impact of it on the value of agricultural output.

$$VAO = a + b_1CI + b_2FERT + b_3ELEC + b_4IRRI + b_5LITE + b_6ROAD \quad ....(5)$$

$$VAO = a + b_1CI + b_2FERT + b_3ELEC + b_4IrD + b_5LITE+ b_6ROAD \quad ....(6)$$

We are fully aware of the fact that irrigation is not the only factor determining the value of agricultural output. In addition to irrigation, many other factors are also determining the output. Therefore, after studying the independent relationship between irrigation variable and the agricultural output, the above-mentioned two multivariate regressions (equations 5 and 6) are estimated to know the contribution of each factor to the agricultural output. The only difference between equations (5) and (6) is that the former model is estimated treating irrigation as normal variable (percentage of irrigated area), whereas the latter model treats irrigation as a dummy variable (<30 per cent = 0; >30 per cent=1).

III

VAO BY LEVEL OF IRRIGATION

Irrigation significantly increases the productivity of crop is well corroborated. But, one does not know whether the crop output would increase along with the level of irrigation coverage, because it depends upon the quality of irrigation (source of water) available to the farmers. Therefore, before getting into the results of regression analysis, let us study whether the increased coverage of irrigation augments the agricultural output across the districts in all six points of time considered for the analysis. To study this, the value of output has been worked out by classifying all the 235 districts into three categories namely low (<30 per cent), medium (30-50 per cent) and high (> 50 per cent) level irrigation, as mentioned in the methodology section. As one can see from Table 2, the value of agricultural output (at 1990-93 prices) has increased considerably from about Rs. 3358/ha in 1962-65 to about Rs. 8167/ha in 2005-08, an increase of about 2.43 times. But, our aim is not to study the overall increase in value of output but to study VAO by level of irrigation. As expected, there are considerable differences in VAO among the districts having low, medium and high level irrigation coverage. During 1962-65, the average output of the districts having irrigation coverage < 30 per cent was about Rs. 2932/ha, but the same was about Rs. 4359/ha for the districts having irrigation in the range of 30-50 per cent and about Rs. 5016/ha for those districts with irrigation > 50 per cent. This gap has widened further till the year 1990-93, but thereafter it started narrowing down. For instance, during 1990-93, the value output of those districts with irrigation coverage above 50 per cent was 2.06 times of that districts with less than 30 per cent of irrigation. But, this same ratio reduced to 1.93 during 2003-05 and to 1.61 during 2005-08. It suggests that although the amount of agricultural output is considerably higher among the districts having high level of irrigation as compared to their counterparts low irrigation districts till early nineties, this has narrowed down especially after 2003-05 mainly because of substantial improvement in the value of output among the districts having less irrigation facility.

TABLE 2. VALUE OF AGRICULTURAL OUTPUT BY IRRIGATION LEVEL

(*Rs./ha*)

	Level of irrigation										
	< 30 per cent		30-50 per cent		> 50 per cent		All				
	No. of		No. of		No. of		No. of		Ratio		
Period	districts	VAO	districts	VAO	districts	VAO	districts	VAO	(5/3)	(7/5)	(7/3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1962-65	176	2932.97	35	4359.29	24	5016.83	235	3358.22	1.49	1.15	1.71
		(1123.42)		(1259.48)		(1363.16)		(1387.46)			
1970-73	158	3068.93	51	4880.44	26	7727.46	235	3977.48	1.59	1.58	2.51
		(1497.91)		(2070.38)		(8301.61)		(3475.89)			
1980-83	134	4068.66	57	5946.07	44	8142.10	235	5286.72	1.46	1.37	2.00
		(1869.95)		(2301.71)		(2475.96)		(2621.15)			
1990-93	113	4932.70	56	7665.99	65	10157.85	235	7032.99	1.55	1.32	2.06
		(2365.89)		(3142.35)		(2870.96)		(3492.76)			
2003-05	81	5096.46	76	8262.97	78	9834.26	235	7693.07	1.62	1.19	1.93
		(2564.44)		(3927.74)		(2910.71)		(3734.76)			
2005-08	72	6302.60	67	7323.51	96	10154.31	235	8167.13	1.16	1.39	1.61
		(3752.02)		(3651.90)		(3465.51)		(3975.20)			

Sources: Computed using sources referred on Table 1.
Note: Figures in parentheses are standard deviation.

IV

IRRIGATION AND AGRICULTURAL OUTPUT NEXUS – UNIVARIATE REGRESSION ANALYSIS

The descriptive analysis presented above shows that the difference in value of agricultural output between the high and low irrigated districts has been narrowing down especially in the recent years. In order to probe this further, we have employed univariate regression analysis where the percentage of irrigation to cropped area is used as an independent variable and VAO as dependent variable. As mentioned earlier, the impact of irrigation development on output of crop cannot occur instantaneously (immediately after providing to the farmers), because of the time lag involved for making adjustments to the factors of production. Based on the certainty and controllability of irrigation supply, farmers take certain time to change their cropping pattern – from low value to high value crops and from seasonal crop to annual crops. All these changes involve time and thus, base level irrigation is also an important element in determining the value of agricultural output. Keeping this in view and to capture the real effect of irrigation variable on agricultural output, univariate regression is estimated with and without time lag.

Another important point to be underlined here is that the total irrigation coverage *per se* cannot capture its entire impact on the value of agricultural output. Many studies have unequivocally proved that the crop output tends to change substantially depending upon the source of water used for its cultivation (for details on this, see Dhawan, 1988; Vaidyanathan, 1987, Shah, 1993; Vaidyanathan *et al*., 1994). Groundwater irrigated crop generally gives more output per unit of area followed by canal and tank irrigated crop. Therefore, the source of irrigation water needs to be considered to capture the real impact of irrigation on the value of crop output. But, unfortunately, district-wise data on source of irrigated area is not readily available for the analysis and therefore, the percentage irrigation to cropped area is used as a single variable in the analysis.

Let us now study the results of regression. The results of univariate regression estimated treating irrigation as a normal continuous variable show that IRRI impact on agricultural output appears to be inverted `U' shape curve over the years (see, Table 3). The values of both R^2 as well as the regression coefficients of IRRI have

TABLE 3. IRRIGATION (PERCENTAGE) IMPACT ON VAO - LINER REGRESSION RESULTS

Year	Model (1): $VAO = a + b_1\ IRRI$			Model (3): $VAO = a + b_1\ IRRI_{t-10}$		
	Constant	Coefficients	R^2	Constant	Coefficients	R^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1962-65	2445.34 (23.43)***	46.43 (11.98)***	0.381	--	--	--
1970-73	2311.57 (7.42)***	70.07 (7.13)***	0.179	2519.57 (8.24)***	74.16 (6.54)***	0.16
1980-83	2928.86 (14.14)***	77.09 (14.28)***	0.467	3182.71 (17.39)***	88.49 (15.32)***	0.50
1990-93	3424.03 (11.70)***	95.95 (14.87)***	0.487	3770.04 (14.15)***	106.68 (15.37)***	0.50
2003-06	4619.70 (10.93)***	70.15 (8.43)***	0.234	4472.29 (12.59)***	85.63 (10.94)***	0.34
2005-08	4751.82 (10.38)***	70.36 (8.59)***	0.240	5392.09 (11.50)***	63.34 (6.86)***	0.17

Sources: Computed using sources referred on Table 1.
Notes: ***-significant at 1 per cent level; Figures in parentheses are ‘t’ values.

increased from 1962-65 to 1990-93, but declined sharply during 2003-06 and 2005-08. For instance, the value of regression coefficient of irrigation increased from 46.43 in 1962-65 to 95.95 in 1990-93 and then declined to around 70 during 2003-06 and 2005-08. The same trend is also noticed in the value of R^2. This higher level of R^2 (around 0.50) arrived from 1980-83 and 1990-93 data suggests that as much as around 50 per cent of variation in agricultural output is due to variation in the level of irrigation, but this has reduced to 24 per cent during 2005-08, which is very surprising result. The regression results estimated treating percentage of irrigation as lagged variable also show similar results. The magnitude of irrigation coefficient (along with R^2) increased from 74.16 in 1970-73 to 106.68 in 1990-93, but declined to 85.63 in 2003-06 and further to 63.34 in 2005-08.

Without threshold level of irrigation, it is difficult to augment the crop output in any given region. Therefore, it is not prudent to treat all the types of irrigated areas/districts under a single category/group. For instance, it is not prudent to equate the districts with <30 per cent of irrigation with those districts having irrigation >50 per cent, because the cropping pattern and the cropping intensity followed might be totally different in the latter category of districts as compared to the former districts. The Union Ministry of Agriculture also classifies the districts having irrigation facility < 30 per cent as rainfed areas and > 30 per cent as irrigated areas for the purpose of implementing watershed development programme. In view of this, alternatively, we have estimated regression by treating irrigation as dummy variable instead of continuous variable, as reported in equation (2) and (4). This is done specifically to see whether the impact of irrigation on influencing VAO is in anyway better than the results estimated earlier using irrigation as a continuous variable. But to our surprise, the regression results (see, Table 4) estimated by using irrigation as dummy variable turned out to be almost similar to that of the results estimated from

TABLE 4. IRRIGATION (DUMMY) IMPACT ON VAO - LINER REGRESSION RESULTS

	Model (2): $VAO = a + b_1 IrD + u$			Model (4): $VAO = a + b_1 IrD_{t-10} + u$		
Year (1)	Constant (2)	Coefficients (3)	R^2 (4)	Constant (5)	Coefficients (6)	R^2 (7)
1962-65	2932.97 (33.01)***	1693.79 (9.55)***	0.281	--	--	--
1970-73	3068.93 (11.95)***	2772.85 (6.18)***	0.141	3242.79 (13.27)***	2926.28 (6.00)***	0.13
1980-83	4068.66 (21.25)***	2834.10 (9.70)***	0.288	4181.72 (25.14)***	3372.39 (11.60)***	0.37
1990-93	4932.70 (18.39)***	4045.63 (10.87)***	0.336	5300.99 (21.38)***	4029.89 (10.66)***	0.33
2003-06	5096.46 (14.20)***	3962.36 (8.94)***	0.255	5879.11 (18.90)***	3493.93 (8.09)***	0.22
2005-08	6302.60 (14.13)***	2688.13 (5.02)***	0.098	5884.10 (14.63)***	3483.84 (7.01)***	0.17

Sources: Computed using sources referred on Table 1.
Notes: *** - significant at 1 per cent level; Figures in parentheses are ‘t’ values.

equation (1) and (3). That is, the magnitude of regression coefficients has increased up to the year 1990-93, but thereafter it started declining. The value of R^2 also showed the same trend. Does it mean that the role of irrigation has declined in the recent years? Or whether the role of irrigation is declining due to fast increase in agricultural output in rainfed areas? We will answer these questions after studying the results of multiple regression where irrigation is used as one of the variables along with other determinant factors.

V

IRRIGATION AND OTHER FACTORS CONTRIBUTION TO AGRICULTURAL OUTPUT

Besides irrigation factor, many other yield increasing and infrastructural factors would also influence the agricultural output. One must study the role of irrigation on VAO along with other influencing factors to find out its real impact. Therefore, after having studied the independent relationship between the agricultural output and irrigation development, we have made an attempt to study the contribution of irrigation and other factors to agricultural output with the help of multivariate regression analysis. While studying the role of irrigation in VAO, some of the earlier studies (for example, Vaidyanathan *et al*., 1994) have considered only those variables that can directly influence the crop output (irrigation, fertiliser, rainfall) and ignored the infrastructural variables that are indirectly determining the crop output (Antle, 1983; Binswanger *et al*., 1993; Ruttan, 2002). Here, since the agricultural output is determined not only by yield determining factors such as irrigation, fertiliser and cropping intensity, we have included three infrastructural variables (electricity, road and literacy) in the regression model so as to capture the impact of each variable on the agricultural output, as reported in equation (5) and (6). Here, the main focus of the analysis is to find out whether the role of irrigation is increasing over the time when holding other variables fixed?

As followed in the univariate regression, two multivariate regression models have been estimated separately using irrigation as continuous variable (IRR) and also as dummy variable (IrD). The results of the multivariate regression model estimated using irrigation (IRR) and other determining factors for five time points[4] are presented in Table 5. The regression results seem to be satisfactory from a statistical perspective as the values of R^2 estimated from all the models are reasonably high. Among the six variables used in the regression model, variables such as IRR, FERT, LITE and ROAD have turned out to be significant in most time points considered for the analysis which is expected. Specifically, IRR and ROAD have consistently and significantly influenced the agricultural output at all time points. The coefficient of irrigation which is the main focus of the analysis has declined sharply in the recent years, as observed in the univariate regression analysis. The irrigation coefficient explains that one per cent increase in irrigation, given all other variables constant, has increased by about Rs. 60 in the value of output during the year 1970-73 and this has further increased to Rs. 62 during 1990-93. However, the influence of irrigation in increasing the value of output declined sharply during 2003-06 and 2005-08; the regression coefficients varied only from 23.28 to 27.01. The influence of fertiliser and literacy rate on the value of agricultural output seems to have increased in the recent years which are obvious and plausible.

TABLE 5. IRRIGATION AND OTHER DETERMINANTS OF VAO - MULTIPLE REGRESSION RESULTS

Independent variables	Model (5): Dependent variable: VAO in Rs./ha				
	1970-73	1980-83	1990-93	2003-06	2005-08
(1)	(2)	(3)	(4)	(5)	(6)
CI	8.39	3.04	8.72	7.12	1.31
	(0.60)^{ns}	(0.38)^{ns}	(1.070)^{ns}	(1.00)^{ns}	(0.19)^{ns}
FERT	-4.42	11.54	9.01	30.64	24.98
	(-0.23)^{ns}	(4.19)***	(3.53)***	(8.12)***	(6.28)***
ELEC	-36.68	-4.27	-12.01	15.33	10.62
	(-2.78)***	(-0.64)^{ns}	(-1.37)^{ns}	(1.22)^{ns}	(0.75)^{ns}
IRRI	59.81	44.45	62.26	23.27	27.01
	(3.78)***	(5.73)***	(7.29)***	(2.56)**	(2.51)**
LITE	69.57	46.45	44.19	34.28	48.21
	(2.39)**	(4.55)***	(3.34)***	(2.44)**	(2.99)***
ROAD	83.24	32.72	37.22	4.65	8.77
	(3.62)***	(3.88)***	(4.11)***	(0.50)^{ns}	(0.82)^{ns}
Constant	-1414.12	756.35	202.63	-1087.34	-524.23
	(-0.85)^{ns}	(0.80)^{ns}	(0.16)^{ns}	(-0.77)^{ns}	(-0.37)^{ns}
R^2	0.26	0.64	0.62	0.54	0.48
Adjusted R^2	0.24	0.63	0.61	0.53	0.46
F-Value	13.38***	68.00***	62.87***	44.52***	34.27***
D-W	2.02	1.70	1.60	1.68	1.64
N	235	235	235	235	235

Sources: Computed using sources referred on Table 1.

Notes: *** and ** are significant at 1 and 5 per cent level respectively; ns-not significant; Figures in parentheses are ‘t’ values.

Minimum threshold level of irrigation coverage is required to influence the agricultural output in any given district. As reported earlier, districts having irrigation less than 30 per cent are treated as rainfed and all those districts with irrigation coverage more than 30 per cent are treated as irrigated area by the Union Ministry of Agriculture for implementing watershed development programme. Taking clue from this, alternatively, multivariate regressions are estimated (equation 6) treating irrigation as dummy variable (<30 per cent of irrigation = 0; >30 per cent of irrigation = 1) along with other variables that are used in equation (5). This analysis is carried out specifically to see whether the influence of irrigation in increasing the value of agricultural output changes from that of the results estimated using equation (5). The regression results estimated using irrigation as a dummy variable are presented in Table 6, which are almost similar to the results arrived from equation (5). Not only the values of R^2 are almost similar, but even the significant rate of coefficients of different variables are also almost identical. Leaving other variables from the discussion, one can vividly see a sharp decline in the value of irrigation coefficients especially after 1990-93. The coefficient of irrigation (IrD) explains that when a district moved from less than 30 per cent to over 30 per cent of irrigation coverage, the value of agricultural output increased by about Rs. 1718/ha during 1970-73 and this further increased to about Rs. 2235/ha during 1990-93. But, the influence of IrD variable on the output declined to Rs. 1873/ha during 2003-06 and further to about Rs. 966/ha during 2005-08. These results of multivariate regression are also matching with the results that are estimated from univariate regression model and also from descriptive analysis.

TABLE 6. IRRIGATION (DUMMY) AND OTHER DETERMINANTS OF VAO – MULTIPLE REGRESSION RESULTS

Independent variables	Model (5): Dependent variable: VAO in Rs./ha				
	1970-73	1980-83	1990-93	2003-06	2005-08
(1)	(2)	(3)	(4)	(5)	(6)
CI	22.48	22.07	23.84	5.72	7.33
	(1.74)*	(3.08)***	(3.18)***	(0.85)^{ns}	(1.22)^{ns}
FERT	16.06	14.47	11.03	29.02	28.08
	(0.91)^{ns}	(5.15)***	(4.30)***	(8.34)***	(7.97)***
ELEC	-33.91	0.15	-8.26	13.27	7.60
	(-2.55)**	(0.02)^{ns}	(-0.91)^{ns}	(1.12)^{ns}	(0.54)^{ns}
IrD	1718.03	903.87	2235.10	1873.11	965.87
	(2.94)***	(3.09)***	(6.26)***	(4.44)***	(1.98)**
LITE	68.52	41.19	35.10	36.20	47.36
	(2.31)**	(3.88)***	(2.62)***	(2.65)***	(2.92)***
ROAD	79.02	38.10	49.48	6.43	11.94
	(3.39)***	(4.46)***	(5.71)***	(0.70)^{ns}	(1.11)^{ns}
Constant	-2506.51	-1134.00	-1270.03	-969.97	-999.96
	(-1.55)	(-1.26)^{ns}	(-1.03)^{ns}	(-0.72)^{ns}	(-0.68)
R^2	0.243	0.61	0.60	0.57	0.47
Adjusted R^2	0.22	0.60	0.59	0.55	0.46
F-Value	12.18***	58.53***	57.87***	49.14***	33.54***
D-W	1.96	1.78	1.63	1.70	1.66
N	235	235	235	235	235

Sources: Computed using sources referred on Table 1.

Notes: ***, ** and * are significant at 1, 5 and10 per cent level respectively; ns-not significant; Figures in parentheses are 't' values.

From these results, can we say that the role of irrigation in increasing the value of agricultural output is declining in India over the years? It is difficult to say that the role of irrigation has been declining over the years. This decline could have happened because of various reasons, not necessarily due to role of irrigation. First, the value of output of crops cultivated in the rainfed districts may have increased at a faster pace in the recent years because of various moisture conservation and yield augmenting programmes introduced by the state and central governments. Huge amount of investment has been made on the watershed development programmes to improve the condition of rainfed areas especially after eighth five year plan. According to the report of the working group on Minor Irrigation and Watershed Management for the Twelfth Five-Year-Plan (2012-17), till March 2011 a total of 71.58 million hectares has been 'treated' through watershed programmes run by various Ministries, with an investment of Rs 31,964.57 crore. Over 15 years since 1995 (when the watershed programme got a real boost), the average expenditure works out to Rs. 2,130 crore per annum and about Rs. 4,500 per hectare of treated area (Government of India, 2012, p.44). This intervention programme might have made significant impact on the yield of crops in different regions in India and reduced the gap in the value of output between the irrigated and less irrigated districts (for details on this see, Deshpande and Reddy,1991; Deshpande and Narayanamoorthy, 1999). In fact, the Eleventh Five-Year Plan (2007-12) document reported that under the watershed development programme, the productivity of rainfed crops increased considerably and the net returns also increased up to 63 per cent (Government of India, 2007, p. 26).

Second, the minimum support price (MSP) offered to crops such as pulses, oilseeds, cotton, etc., have increased mani-fold because of increased demand for these crops, which are predominantly cultivated in the less irrigated regions (see, Narayanamoorthy and Suresh, 2013). The massive increase in MSP for these crops might have increased the overall value of crop output in the rainfed areas which might have reduced the role of irrigation, in spite of increased productivity in the irrigated tracks. Third, the groundwater boom in the rainfed districts has taken place over the last two decades or so have helped the farmers to cultivate high value crops which could have increased the value of output in rainfed districts. Four, many rainfed districts (for example, Jalgaon district in Maharashtra state) have also been increasingly adopting the micro-irrigation specifically to cultivate high value crops such as banana, sugarcane, cotton, fruit and vegetable crops. This rapid adoption of micro-irrigation in the rainfed districts could have also increased their average value of crop output per unit of land. Five, the rapid development in the cultivation of horticulture crops in the rainfed areas might have also added to the increased value of output in agriculture (see, Chand *et al*., 2015). All these positive changes that are taking place in the rainfed districts especially after early nineties could have accelerated the per hectare crop output which may have dampened the magnitude of irrigation coefficient. Although the coefficient of irrigation has been declining over the years, its significant regression coefficient seems to suggest that irrigation development still remains paramount in increasing the value of agricultural output.

VI

CONCLUSION AND POLICY POINTERS

The impact of irrigation development on land use pattern, cropping pattern, cropping intensity, production and productivity of crops has been well documented by various studies in India. However, the role of irrigation in increasing the value of agricultural output has not been studied by many scholars especially using disaggregated data covering different time points. An attempt has been made in this study to understand the relationship between irrigation development and the value of agricultural output, using cross-sectional data for 235 Indian districts, drawn from 13 states at six time points: 1962-65, 1970-73, 1980-83, 1990-93, 2003-05 and 2005-08. Descriptive and regression analyses have been carried out to study the relationship.

Descriptive analysis shows that the difference in value of agricultural output per hectare has narrowed down between less (<30 per cent), medium (30-50 per cent) and high (>50 per cent) irrigated districts over the years, more particularly after 1990-93.

The univariate regression analysis has been carried out (with and without dummy as well as with and without time lag) to study the independent relationship between irrigation coverage and the value of agricultural output. It shows that irrigation is significant factor in explaining the variation in output across all six time points. But, the impact of irrigation on the value of output has declined (both irrigation coefficient and R^2) over time. During 1980-83 and 1990-93, irrigation alone has explained around 50 per cent of variation in agricultural output, but the same declined to about 24 per cent during 2003-05 and 2005-08. Multivariate regression estimated by using yield increasing and infrastructure variables suggests that irrigation plays a dominant role in increasing the value of output, but its value of coefficients has been declining over time. Although both univariate and multivariate regression results show declining coefficient of irrigation over time, one may not be able to firmly say that the role of irrigation in determining the value of agricultural output has reduced. This could have happened due to acceleration in the productivity of crops cultivated in the rainfed districts.

Although the intensive crop cultivation with bio-chemical inputs followed in the irrigated districts has reportedly decelerated the productivity of crops in different regions in recent years, one cannot ignore the huge progress that is taking place in the rainfed areas especially since 1990s. Because of comprehensive soil and water conservation programmes (watershed and other similar programmes), farmers have changed their cropping pattern from low value to high value crops and also started cultivating multiple crops in the same piece of land. This has not only increased the cropping intensity but the value of output generated per hectare of land in the rainfed/less irrigated areas. Therefore, more disaggregated studies need to be carried out by including the variables that can capture the changing nature of cropping pattern, level of soil and water conservation activities carried out in each district, etc., along with the variables included in this study to find out the role irrigation.

Apart from the positive changes that are taking place in the rainfed districts, slow growth in crop output in the irrigated districts may have weakened the role of irrigation over the years. Studies based on cost of cultivation survey data show that the difference in value of output of various crops is not very significant between high and low irrigated states in India (see, Narayanamoorthy *et al*., 2014). Mono-crop rotation and intensive use of bio-chemical inputs may have created technology fatigue in the irrigated districts that could have resulted in deceleration in agricultural output. More studies needed to find out whether the incremental output in irrigated area is tapering-off due to intensive agriculture followed with the use of bio-chemical inputs over the years. Most irrigated tracts in India have been following foodgrains dominated cropping pattern (crops like paddy and wheat) over the years, where the output prices have not increased much as compared to the less irrigated crops like pulses, oilseeds, cotton, etc. This could also be one of the reasons for declining role of irrigation in agricultural output. In any case, if the declining role of irrigation is explained by the increased output in less irrigated districts, one should not worry about this study results. But, if the role of irrigation declines due to poor crop output in the irrigated districts, then the policy makers must look at these results seriously and take necessary remedial measures to increase the crop output.

NOTES

1. We wanted to include as many districts as possible in the analysis, but we could get comparable data only for these 235 districts for all six time points and therefore, the remaining districts could not be included in the analysis. These districts have been selected form 13 states namely Andhra Pradesh (15), Bihar (7), Gujarat (16), Haryana (7), Karnataka (18), Madhya Pradesh (37), Maharashtra (24), Orissa (10), Punjab (11), Rajasthan (26), Tamil Nadu (8), Uttar Pradesh (44) and West Bengal (12).

2. This data has been compiled from Bhalla and Singh (2001 and 2012), who have estimated the value of output (at 1990-93 prices) by covering the production of 35 important crops that accounted for over 95 per cent of the gross value of output at the country level. For more details about the methodology followed for estimating the value of output, readers are suggested to refer Bhalla and Singh (2001).

3. Fertiliser has synergy with almost all the yield augmenting factors. Therefore, fertiliser can be used as a proxy variable to reflect the adoption of other factors determining the crop output. Vaidyanathan (1993) has provided a systematic exposition about the importance and contribution of fertiliser to the agricultural output at different time points.

4. Though the study has covered data of six time points for its analysis, the analysis on multiple regression has been carried out only by covering data of five time points due to non-availability of infrastructure related data for the year 1962-65.

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