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SUBJECT III
RURAL INFRASTRUCTURE AND GROWTH

**Rural Infrastructure and Agricultural Output Linkages:
A Study of 256 Indian Districts**

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I

INTRODUCTION

The linkages between infrastructure development and sustained output growth have been documented by many global empirical studies (Aschauer, 1989; Canning, 1998; Calderon and Chong, 2004) and worldwide reviews (Sawada, 2000; ADB *et al.*, 2005; Estache *et al.*, 2005; Pinstруп-Andersen and Shimokawa, 2006). Cross-country analyses have also documented strong linkages between infrastructure and agricultural output growth. For example, using cross-sectional data for 47 less developed countries including India, Antle (1983) found a strong and positive relationship between infrastructure development and aggregate agricultural productivity. Using annual data for 58 countries Binswanger *et al.*, (1987) reported a positive and significant correlation between road development and aggregate crop output. These views have been substantiated by many Asian studies (Ruttan, 2002; Mundlak *et al.*, 2004).

Studies from Indian settings also document evidence of positive linkages between various types of infrastructure and agricultural output growth (Antle, 1984). Rural infrastructure (both physical and institutional) such as irrigation, watershed development, rural electrification, roads, markets, credit institutions, rural literacy, agricultural research and extension, etc., together play a key role in determining the agricultural output in India. For instance, irrigation infrastructure increases the land use intensity and cropping intensity, and provides incentives to farmers to use yield increasing inputs, and thus results in higher agricultural output (Dhawan, 1988; Shah, 1993; Vaidyanathan, 1999; Narayanamoorthy and Deshpande, 2005). Rural electrification increases the energisation of pumpsets, which helps to increase the

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The data used in this study was originally collected for the larger study on “Impact of Irrigation in India: Aggregate Level Analysis” sponsored by the International Water Management Institute (IWMI), Colombo, Sri Lanka, under the theme *Comprehensive Assessment of Water Management in Agriculture*. While taking full responsibility for any remaining errors, the authors would like to thank R. Maria Saleth and V. Ratna Reddy for useful comments on the paper and Queenie Rodrigues and Ashwini Phadnis for compiling and processing the data.

irrigated area using groundwater; the output of crops cultivated under groundwater irrigation is always higher than those under canal or tank irrigation, because of its better reliability and controllability (Barnes and Binswanger, 1986; Dhawan, 1988; Vaidyanathan *et al.*, 1994; Shah *et al.* 2006). Rural road increases the diffusion of agricultural technology by improving access to markets, enhances more efficient allocation of resources, reduces the transaction costs as well as helps the farmers to realise better input and output prices (Ahmed and Donovan, 1992; ESCAP, 2000; van de Walle, 2002). Improved road infrastructure also increases the transport facility through which the rural farm households are able to get better health care, education and credit facility. Rural-urban linkages are developed through road development, which also helps strengthening the backward and forward linkages in agricultural sector.

Institutional infrastructure such as markets and credit facility also play a pivotal role in the growth of agricultural sector (Binswanger *et al.*, 1993). Better access to institutional credit reduces the cost of borrowings (Ramachandran and Swaminathan, 2002) and increases farmer's investments in production durables such as bullocks, tractors and implements (Rosenzweig and Wolpin, 1993). Better access to markets bolsters farm productivity and profitability (Ahmed and Hossain, 1990; Ali and Pernia, 2003). However, as pointed out by Binswanger *et al.* (1993), the rural infrastructure package as a whole matters, some elements being more important than the others; and the overall impact of infrastructure on output is more pronounced in a better endowed region than in a poorly endowed region.

The above stance is corroborated by other Indian studies, which document evidence of strong complementarities between various forms of rural infrastructure and their linkages to output growth. For example, using Indian state-level time-series data for 1957-1991, Datt and Ravallion (1998) show that states with better initial endowments of physical and human infrastructure (towards the early 1960s) achieved higher rates of agricultural output growth than poorly endowed states; higher initial irrigation, higher initial literacy, and lower initial infant mortality, all contributed to higher long-term growth rates. 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).

A classic study by Bhatia (1999) shows that, Indian states with highest rural infrastructure index (a composite measure for rural electrification, roads, transport, health, irrigation, farm credit, fertiliser, and agricultural marketing, research and extension) such as Punjab, Haryana, and Tamil Nadu have the highest foodgrain productivity per hectare (ha); and the states with lowest index such as Rajasthan, Bihar, and Madhya Pradesh have lowest foodgrains productivity per ha; the rural infrastructure index explains about 68 per cent of the variability in the yield in different states; and 10 per cent improvement in rural infrastructure index in states with lower score would increase their foodgrains productivity by about 470 kg per ha on an average. This study thus establishes a strong relationship between the level of rural infrastructure development and the level of agricultural output.

The linkages between the Green Revolution technology package (irrigation, research and extension, improved varieties and fertilisers) and other rural infrastructure and agricultural output/ growth are well accepted, for India and elsewhere (Evenson and Gollin, 2003; Murgai *et al.* 2001; Hussain and Hanjra, 2003, 2004; Saleth *et al.*, 2003). Similar evidence distills from studies conducted at various spatial scales, such as the all India level (Datt and Ravallion, 1998; Fan *et al.*, (1999, 2000), state-level (Ghosh, 2002; Bhatia, 1999), project/scheme level (Nayyar, 2002) taluka/sub-district level (Gidwani, 2002; Shah and Singh, 2004), and village level (Barnes and Binswanger, 1986; Ballabh and Pandey, 1999). Likewise, studies using agro-ecological zones (AEZ) typology also provide further evidence on varied contribution of infrastructure to agricultural output growth in India (Fan *et al.*, 2000b; Palmer-Jones, 2003; Saleth *et al.* 2003). Such studies typically divide the whole country into 14-19 or at best 45 zones. These studies are highly insightful, but both the level of aggregation involved as well as non-correspondence of National Sample Survey data used to the AEZ remain problematic. India-wide studies on the infrastructure-output nexus, at lower spatial scale are fewer. In particular, studies at the district level – the basic administrative unit – are none or few at best. Building on our earlier work (Bhattarai and Narayanamoorthy, 2003) and armed with comprehensive dataset, we set out to better understand the linkages between rural infrastructure and agricultural output levels for 256 districts in India, for three time-points. This framework offers several advantages.

Though the empirical studies have clearly demonstrated the nexus between the infrastructure development and agricultural growth, not many studies are available covering different times points as well as using large number of districts in recent times in the Indian context. One can understand whether the effect of infrastructure factors on agricultural output is increasing or decreasing over time only by covering different time points. The impact of infrastructure development (such as irrigation, road, rural electrification, schools/literacy, etc.) on output cannot materialise 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 infrastructure development with the agricultural output, one must give

enough time lag for infrastructure variables so that its impact can be clearly measured. But, unfortunately, most of the available studies have analysed the impact of infrastructure factors on the agricultural growth/output without giving any time lag. This study covers these caveats and attempts to better understand the nexus between infrastructure development and the agricultural output across 256 districts at three points of time, namely 1970-71, 1980-81 and 1990-91. The overall goal of the study is to better understand the pattern of rural infrastructure development in India over the years, to help identify the future priorities. The main objectives of the study are: (a) to analyse the infrastructure and other characteristics of the districts having above and below average agricultural output, to help account for the differences in output, (b) to measure the independent relationship between infrastructure factors (irrigation, road, rural electrification and rural literacy) and agricultural output (measured in terms of Rs./hectare), and (c) to analyse the contribution of infrastructure and other factors to agricultural output over time.

The paper is structured into six sections. Section Two explains the data, variables and methodology used in this study. The infrastructure and other characteristics of the districts are discussed in Section Three. The independent relationship between different infrastructure variables and agricultural output is discussed in Section Four, while the contribution of infrastructure and other factors to agricultural output is analysed in Section Five. The conclusions and implications are presented in the final section.

II

DATA, VARIABLES AND METHOD

The whole analysis of the study is based on secondary data. The study covers 256 districts drawn from 13 states in India.¹ These districts together account for nearly 93 per cent of the rural population in 1999-2000 and for more than 80 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 (in 1990-93 prices)², fertiliser use per ha (FERT) and cropping intensity (CI) have been compiled from Bhalla and Singh (2001). Data on rural literacy (LITE), schooling facility (SCHOOL), availability of pucca road (ROAD) and villages electrified (ELEC) have been compiled/computed from various issues of *Census of India*, for the years 1971, 1981 and 1991.

The agricultural output is determined by a number of infrastructure and other growth related factors. However, due to data constraint, the study uses in total eight variables for the analysis (Table 1). Of these, five are treated as infrastructure variables (IRRI, ROAD, ELEC, LITE and SCHOOL), while the remaining three are treated as growth related variables (FERT, CI and VAO). The rationale for using these variables is as follows.

TABLE 1. DESCRIPTIVE STATISTICS OF VARIABLES USED IN THE STUDY

Variable (1)	Description (2)	Unit (3)	Averages (N = 256)		
			1970-71 (4)	1980-81 (5)	1990-91 (6)
VAO	Value of output (in 1990-93 prices)*	Rs./ha	3997.18 (3392.61)	5239.37 (2591.58)	6990.84 (3482.49)
IRRI	Ratio of irrigated area to cropped area [@]	Per cent	23.51 (20.92)	30.15 (23.09)	37.03 (25.14)
ROAD	Road facility [†]	Per cent	28.72 (13.19)	37.92 (22.40)	45.95 (23.70)
ELEC	Villages electrified [†]	Per cent	23.25 (23.58)	53.28 (27.46)	80.38 (21.90)
SCHOOL	Villages having school facility [†]	Per cent	60.12 (18.86)	74.79 (17.75)	80.63 (14.96)
LITE	Rural literacy [†]	Per cent	21.23 (8.01)	27.42 (11.73)	41.95 (12.52)
FERT	Fertiliser use*	kg/ha	17.36 (18.08)	39.18 (44.87)	76.25 (66.40)
CI	Cropping intensity [@]	Per cent	119.26 (18.45)	126.28 (19.08)	131.99 (23.07)

Sources: *Bhalla and Singh (2001); †Census of India, *Primary Census Abstract*, India (various years); @Government of India, *Indian Agricultural Statistics*, Ministry of Agriculture, New Delhi.

Note: Figures in parentheses are standard deviation.

The VAO, defined as the value of output in rupees per hectare, is the dependent variable in the analysis. All the variables used in the study (both infrastructure and other growth variables) are expected to positively influence VAO, for all three time-points. The variable IRRI, defined as the percentage of irrigated area to cropped area, is one of the key infrastructure variables for increasing the crop output and thus, IRRI is used along with other variables in the regression analysis.³ Also, ROAD (percentage of villages having pucca road in each district) is another important infrastructure variable, expected to increase the growth of agriculture through improved transport facility as well as via forward and backward linkages between agriculture and other sectors. Likewise, 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 variables, SCHOOL (per cent of villages having school facility) and LITE (per cent of rural literacy) are 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 (Narayanamoorthy, 2000). Yield increasing inputs such as fertiliser, improved seeds, pesticides as well as use of machines such as tractors, etc., all play a key role in increasing the agricultural output. However, due to data constraints, all of the yield increasing inputs could not be included in the analysis, except fertiliser (FERT). The inclusion of fertiliser is a reasonable proxy, since the other input factors tend to move in tandem with fertiliser use. Cropping intensity, defined as the ratio of gross cropped area to net cropped area in percentage term, explains how intensively crops are

cultivated in a year. Since agricultural output is determined by the intensity of crop cultivation, CI has also been included for the analysis along with other defined variables.

In order to study the relationship between infrastructure development and agricultural output, both descriptive and regression analyses have been carried out. To understand the characteristics of the districts, all the 256 districts have been divided into two groups, namely: the districts above the average (AA districts) value of output; and the districts below the average (BA districts) VAO, at each time-point. This analysis is expected to show how the districts rank in terms of their agricultural output, fertiliser use, cropping intensity and other characteristics of interest, at each time point. In order to study the independent linkages between various infrastructure factors and agricultural output, the following eight univariate regressions are estimated, taking the VAO as the dependent variable and irrigation, road, literacy rate and rural electrification as independent variables separately, with and without time lags, for all three time points.

$$\begin{aligned} \text{VAO} &= a + b1 \text{IRRI} && \dots(1) \\ \text{VAO} &= a + b1 \text{IRRI}_{t-10} && \dots(2) \\ \text{VAO} &= a + b1 \text{ROAD} && \dots(3) \\ \text{VAO} &= a + b1 \text{ROAD}_{t-10} && \dots(4) \\ \text{VAO} &= a + b1 \text{ELEC} && \dots(5) \\ \text{VAO} &= a + b1 \text{ELEC}_{t-10} && \dots(6) \\ \text{VAO} &= a + b1 \text{LITE} && \dots(7) \\ \text{VAO} &= a + b1 \text{LITE}_{t-10} && \dots(8) \end{aligned}$$

The equations (1), (3), (5), (7) explore the independent relationship between VAO and infrastructure variable without giving any time lag, while equations (2), (4), (6) and (8) are estimated treating infrastructure as lagged variables (by giving 10 years time lag). As mentioned earlier, since the impact of infrastructure development cannot be seen instantaneously after providing it, infrastructure is used as lagged variable to capture the real impact of it on the value of agricultural output.

$$\text{VAO} = a + b1 \text{ROAD} + b2 \text{LITE} + b3 \text{ELEC} + b4 \text{IRRI} + b5 \text{FERT} + b6 \text{CI} \quad \dots(9)$$

$$\text{VAO} = a + b1 \text{ROAD}_{t-10} + b2 \text{LITE}_{t-10} + b3 \text{ELEC}_{t-10} + b4 \text{IRRI}_{t-10} + b5 \text{FERT} + b6 \text{CI} \quad \dots(10)$$

Besides studying the independent relationship between each infrastructure variable and the agricultural output, the above-mentioned two multivariate regressions (equation 9 and 10) are also estimated to know the contribution of each variable factor to the agricultural output, wherein fertiliser⁴ and CI are included along with other variables. Again equation (9) is estimated without any lagged variable, while equation (10) is estimated treating all infrastructures as lagged variables, but

not the technology variables FERT and CI. It is expected that the impact of infrastructure variables on agricultural output would be stronger when using them as lagged variables in the regression analysis.

III

INFRASTRUCTURAL CHARACTERISTICS OF THE DISTRICTS

How the AA and BA districts rank in terms of infrastructural parameters over time is evident from data presented in Table 2. It is clear that there has been an appreciable improvement in the infrastructure development such as irrigation, school facility including literacy rate, road and rural electrification across the districts between 1970-71 and 1990-91. While the coverage of irrigation (IRRI) increased from 23.51 per cent in 1970-71 to 37.03 per cent in 1990-91, villages having pucca road facility increased from 28.72 per cent to around 46 per cent during the same period. Similarly, the rural literacy rate (LITE) increased from 21.23 per cent to 42 per cent and the coverage of rural electrification (ELEC) increased from 23.25 per cent to 80.38 per cent during this period. Along with the infrastructural development, output determining factors such as fertiliser and cropping intensity have also substantially increased between 1970-71 and 1990-91. All these amply suggest that the rural infrastructures have expanded considerably between 1970s and 1990s in India.

TABLE 2. CHARACTERISTICS OF THE DISTRICTS CLASSIFIED BASED ON VALUE OF AGRICULTURAL OUTPUT

Classification (1)	No. of districts (2)	VAO (Rs./ha) (3)	IRRI (per cent) (4)	SCHOOL (per cent) (5)	ROAD (per cent) (6)	ELEC (per cent) (7)	LITE (per cent) (8)	FERT (kg/ha) (9)	CI (per cent) (10)
1970-71:									
AA Districts	105	6099 (4419)	36.39 (23.46)	64.84 (17.92)	36.02 (13.95)	33.21 (26.55)	24.65 (8.17)	28.04 (20.01)	126.07 (20.31)
BA Districts	151	2535 (885)	14.56 (12.86)	56.84 (18.86)	23.65 (9.87)	16.32 (18.39)	18.85 (7.01)	9.94 (11.97)	114.52 (15.41)
All Average	256	3997 (3393)	23.51 (20.92)	60.12 (18.86)	28.72 (13.19)	23.25 (23.57)	21.23 (8.02)	17.36 (18.08)	119.26 (18.44)
1980-81:									
AA Districts	110	10099 (2854)	47.30 (22.19)	76.70 (19.68)	53.17 (22.94)	68.18 (24.63)	31.67 (13.62)	65.08 (33.87)	135.72 (20.28)
BA Districts	146	3472 (1016)	17.23 (13.27)	73.23 (13.27)	26.52 (13.39)	42.05 (23.98)	24.22 (8.87)	19.67 (42.26)	119.16 (14.58)
All Average	256	5239 (2592)	30.15 (23.09)	74.79 (17.75)	37.97 (22.40)	53.28 (27.46)	27.42 (11.73)	39.18 (44.87)	126.28 (19.08)
1990-91:									
AA Districts	108	10291 (2679)	55.70 (24.62)	80.85 (16.29)	60.44 (24.20)	84.92 (20.33)	45.54 (12.99)	114.51 (47.65)	143.19 (24.85)
BA Districts	148	4583 (1405)	23.40 (14.55)	80.47 (13.95)	35.36 (16.75)	77.07 (22.47)	39.22 (11.52)	48.33 (64.31)	123.83 (17.74)
All Average	256	6991 (3482)	37.03 (25.13)	80.63 (14.95)	45.94 (23.70)	80.38 (21.90)	41.94 (12.52)	76.25 (66.40)	131.99 (23.07)

Sources: Same as in Table 1.

Notes: AA – above average; BA – below average; Figures in parentheses are standard deviation.

As regards the characteristics of the districts, a distinct difference in all the parameters between the AA and BA districts across all three time points is evident. Among the five infrastructure variables namely IRRI, SCHOOL, ROAD, ELEC and LITE, the difference between AA and BA districts is more pronounced in IRRI, for all the three time-points. While the difference between AA and BA districts in IRRI was 21.83 percentage points in 1970-71, the same increased to 32.30 per cent in 1990-91. This suggests that districts having higher agricultural output invariably have higher irrigation coverage as well. Following irrigation, the difference is found to be relatively large in road infrastructure, which is empirically proven to be a crucial factor in determining the agricultural output (see, Binswanger *et al.*, 1993; Fan *et al.*, 1999; van de Walle, 2002). However, in the case of school facility and literacy rate, the difference between AA and BA districts are minimum, suggesting that the human development infrastructure has not very much changed between the districts having higher and lower VAO. Apart from variation in infrastructural development, significant difference is also noticed in fertiliser use between the AA and BA districts at all three time-points, suggesting the fact that value of agricultural output is highly related to the use of fertiliser.⁵ On the whole, though the infrastructure and other characteristics of the districts having above the average VOA are better than those districts having output below the average, one may not be able to judge decisively whether infrastructure plays greater role than other factors from this descriptive analysis. Therefore, the independent relationship between infrastructure variables and agricultural output using univariate regression analysis is investigated in the following section.

IV

INFRASTRUCTURE AND AGRICULTURAL OUTPUT NEXUS

The impact of infrastructure development on the agricultural output is likely to vary for each of the infrastructural variables because the role played by each infrastructure is different. It is expected that the role played by the irrigation infrastructure will be totally different from the role of roads on the agricultural output. Irrigation directly helps to increase the crop output by reducing moisture stress, whereas roads help to increase the value of output by providing transport and market accessibility as well as enhancing more efficient allocation of resources. Therefore, the independent relationship between each infrastructural variable and agricultural output is investigated, using eight univariate regression equations mentioned above. As noted elsewhere in the paper, the impact of infrastructure development on output cannot materialise instantaneously after making it available to the farmers, because of the time lag involved for making adjustments to the factors of production. Generally farmers take certain time to respond to the available infrastructure because of resource and other constraints. Therefore, in order to capture

the real effect of infrastructure variable on agricultural output, univariate regression is estimated both with and without time lag for infrastructural variables.

The results of regression presented in Table 3 clearly show that among the four infrastructure variables, the impact of irrigation (IRRI) on agricultural output appears to be stronger than the remaining three variables namely ROAD, LITE and ELEC. Interestingly, only in the case of IRRI, both the R^2 as well as the regression coefficients have consistently increased from 1970-71 to 1990-91. For instance, the regression coefficient increased from 71.57 in 1970-71 to 97.69 in 1990-91, while the R^2 of the same improved from 0.20 to 0.50. This higher level of R^2 (0.50) arrived from 1990-91 data suggests that 50 per cent of variation in agricultural output is due to variation in the level of irrigation. The regression estimated treating ROAD as an independent variable also turns out to be significant in impacting VAO, but its impact (coefficient) on VAO has not improved over time. This implies that the impact of ROAD on VAO is not consistently higher as in the case of irrigation, which is plausible because the inter-district variation in ROAD might have increased over the years. The regression results of other two infrastructure variables (namely, ELEC and LITE) estimated separately show a weak relationship with VAO. The R^2 of regression estimated using ELEC as independent variable explains only six and seven per cent of the variation in agricultural output in 1970-71 and 1990-91, respectively. Similarly, the value of R^2 is also relatively low for regression treating literacy as an independent variable, which suggest that literacy independently (without other determining factors) will have only limited role in impacting the agricultural output.

The regression results estimated treating infrastructure as lagged variable appear to be better than the results arrived without giving time lag, in all cases (see, Table 3). In the case of IRRI, the magnitude of regression coefficient (along with R^2) increased from 97.69 (when irrigation is not used as lagged variable) to 108.86 when IRRI is used as lagged variable in 1990-91. Similarly, the coefficient of ROAD also increased from 87.63 to 97.56 while estimating regression with ten years of time lag in 1990-91 [see the results of equation (3) and (4) in Table 3]. Similar results are also arrived at while estimating regression by treating ELEC and LITE as a lagged variable. This was expected because the impact of any infrastructure development on the agricultural output would reflect only after certain time lag. On the whole, the univariate regression results suggest that irrigation and road infrastructure independently play a greater role in impacting the value of output than the other infrastructure variables taken for the analysis—all matter, *albeit* differently.

TABLE 3. AGRICULTURAL OUTPUT AND INFRASTRUCTURE DEVELOPMENT NEXUS:
UNIVARIATE REGRESSION RESULTS

Year (1)	Constant (2)	Coefficient (3)	R ² (4)	Adjusted R ² (5)	F-value (6)	D-W stat (7)
		VAO = a + b1 IRRI		Equation (1)		
1970-71	2314.37 (8.06)	71.57 (7.84) ^a	0.20	0.19	61.41 ^a	1.85
1980-81	2888.09 (15.02)	77.98 (15.39) ^a	0.48	0.48	236.97 ^a	1.34
1990-91	3373.87 (12.23)	97.69 (15.84) ^a	0.50	0.50	250.95 ^a	1.36
		VAO = a + b1 IRRI _{t-10}		Equation (2)		
1980-81	3146.22 (18.51)	89.03 (16.46) ^a	0.52	0.51	271.07 ^a	1.44
1990-91	3708.60 (14.92)	108.86 (16.62) ^a	0.52	0.52	276.10 ^a	1.42
		VAO = a + b1 ROAD		Equation (3)		
1970-71	1112.30 (2.37)	100.44 (6.76) ^a	0.15	0.15	45.70 ^a	1.81
1980-81	2321.44 (9.71)	76.84 (14.16) ^a	0.44	0.44	200.55 ^a	1.44
1990-91	2964.81 (7.75)	87.63 (11.84) ^a	0.37	0.35	140.17 ^a	1.22
		VAO = a + b1 ROAD _{t-10}		Equation (4)		
1980-81	1769.65 (5.82)	119.86 (12.27) ^a	0.37	0.37	150.55 ^a	1.46
1990-91	3286.17 (9.82)	97.56 (12.85) ^a	0.39	0.39	165.04 ^a	1.31
		VAO = a + b1 ELEC		Equation (5)		
1970-71	3141.69 (10.88)	36.79 (4.22) ^a	0.07	0.07	17.76 ^a	1.67
1980-81	2533.64 (8.47)	50.79 (10.18) ^a	0.29	0.29	103.53 ^a	1.32
1990-91	3900.44 (4.84)	38.45 (3.97)	0.06	0.06	15.78 ^a	0.981
		VAO = a + b1 ELEC _{t-10}		Equation (6)		
1980-81	3888.41 (20.08)	58.10 (9.92) ^a	0.28	0.28	98.47 ^a	1.15
1990-91	3678.82 (8.85)	62.17 (8.96) ^a	0.24	0.24	80.34 ^a	1.12
		VAO = a + b1 LITE		Equation (7)		
1970-71	1485.77 (2.57)	118.28 (4.64) ^a	0.08	0.07	21.53 ^a	1.61
1980-81	2661.09 (7.12)	94.02 (7.50) ^a	0.18	0.18	56.20 ^a	1.25
1990-91	2874.01 (4.02)	98.15 (6.01) ^a	0.13	0.13	36.13 ^a	1.04
		VAO = a + b1 LITE _{t-10}		Equation (8)		
1980-81	1974.32 (4.88)	153.78 (8.62) ^a	0.23	0.22	74.29 ^a	1.16
1990-91	4088.64 (7.88)	105.83 (6.08) ^a	0.13	0.12	36.99 ^a	1.08

Source: Computed using sources referred in Table 1.

Notes: a – Significant at 1 per cent level; figures in parentheses are 't' values.

V

INFRASTRUCTURE AND OTHER FACTORS CONTRIBUTION TO OUTPUT

Having studied the independent linkages between the agricultural output and rural infrastructure development, an attempt is made to study the contribution of infrastructure and other factors to agricultural output, using multivariate regression analysis. Here, since the agricultural output is also determined by yield determining factors such as fertiliser and cropping intensity, these two factors are included along with four infrastructure variables in the regression model so as to capture the impact of each variable on the agricultural output. Specifically the following four questions are probed using the multivariate regression analysis: (a) what is the role of infrastructure factors vis-à-vis other factors in determining the agricultural output?, (b) whether the role of infrastructure factors in impacting the value of output increases over time?, (c) which is the most important infrastructure variable in determining the value of output? and (d) how does the impact on the agricultural output change when lagged infrastructure variables are used in the regression analysis?

The results of the multivariate regression model estimated using both infrastructure and other yield determining factors are presented in Table 4. The coefficients of regression suggest that except rural electrification variable,⁶ all other infrastructure variables do significantly influence the value of output at all three time-points taken for the analysis. Though the coefficient of fertiliser is also highly significant in determining the output especially in 1980-81 and 1990-91, its magnitude is relatively small than the infrastructure variables in all three time points.

TABLE 4. INFRASTRUCTURE AND OTHER FACTORS CONTRIBUTION TO AGRICULTURAL OUTPUT: MULTIVARIATE REGRESSION RESULTS

Independent Variables (1)	Without lagged infrastructure variables			With lagged infrastructure variables	
	1970-71 (2)	1980-81 (3)	1990-91 (4)	1980-81 (5)	1990-91 (6)
CI	5.24 (0.42)	4.13 (0.56)	8.71 (1.13)	9.53 (1.35)	7.26 (0.96)
FERT	2.73 (0.17)	11.91 (4.48) ^a	9.43 (3.80) ^a	11.78 (4.63) ^a	9.10 (3.64) ^a
ELEC	-34.87 (-2.83) ^a	-4.79 (-0.76)	-11.42 (-1.42)	-	-
IRRI	58.15 (3.94) ^a	43.29 (5.86) ^a	61.95 (7.55) ^a	-	-
LITE	61.67 (2.26) ^b	45.63 (4.67) ^a	43.56 (3.45) ^a	-	-
ROAD	81.01 (3.70) ^a	32.65 (4.06) ^a	37.36 (4.38) ^a	-	-
ELEC _{t-10}	-	-	-	-9.53 (-1.52)	-9.00 (-1.05)
IRRI _{t-10}	-	-	-	46.02 (6.66) ^a	61.82(7.68) ^a
ROAD _{t-10}	-	-	-	51.99 (4.68) ^a	45.72 (4.21) ^a
LITE _{t-10}	-	-	-	84.30 (6.09) ^a	42.51 (3.16) ^a
Constant	-868.17(-0.59)	709.61 (0.80)	203.38 (0.80)	-875.53(1.01)	627.93 (0.67)
R ²	0.27	0.65	0.63	0.68	0.64
Adjusted R ²	0.25	0.64	0.62	0.67	0.63
F – value	15.47 ^a	77.33 ^a	71.58 ^a	86.69 ^a	74.43 ^a
D-W stat	1.99	1.78	1.95	1.98	1.85
N	256	256	256	256	256

Source: Same as in Table 1.

Note: Figures in parentheses are 't' values; a and b are significant at 1 and 5 percent level.

The regression results pertaining to the year 1990-91 suggest that one percent increase in irrigation (IRRI) coverage would increase nearly Rs. 62 in the value of output, but in the case of LITE (literacy) and ROAD the output would increase only by Rs. 43 and Rs. 37 respectively. In contrast, the regression coefficient of fertiliser suggests that one unit increase in fertiliser use would increase the agricultural output only by about Rs. 9, during the year 1990-91. This trend is almost the same in all the three time-points. The significant regression coefficient of infrastructure variables seems to suggest that infrastructure development remains important for increasing the agricultural output.

Whether the role of infrastructure variables in determining the output increases over time is another question studied using regression analysis. The regression coefficients of infrastructure variables do not show any clear picture on this. Though the coefficients of IRRI improved over time from 58.15 in 1970-71 to 61.95 in 1990-91, the same trend is not seen with other infrastructure variables namely LITE and ROAD. In fact, the magnitude of regression coefficients of LITE and ROAD variables have reduced considerably over time. For example, the coefficients of ROAD declined from 81.01 to 37.36 between 1970-71 and 1990-91, while the coefficient of LITE declined from 61.67 to 43.56 during the same period. This could be due to two reasons. First, since the value of output is also determined by seasonal variation (supply and demand factors) and other associated factors, the contribution of ROAD and LITE may have been affected by them. Second, the agricultural sector has been changing at a rapid pace since 1970-71, owing to the adoption of green revolution technologies and therefore, one may not be able to see the same level of contribution by infrastructure factors to agricultural output at different time points. The impact could have been mediated by technology factors such as irrigation and modern varieties over time.

As mentioned earlier, the impact of each infrastructure variable on the agricultural output is expected to be different. Therefore, it is interesting to identify the most crucial variable that determines the agricultural output. The regression results reveal that the role played by each infrastructure variable considerably changes over time. During 1970-71, ROAD factor impacted the output more significantly followed by LITE and IRRI, but the trend is changed during 1990-91, where IRRI turns out to be the most dominant factor followed by LITE and ROAD. This means that the road factor played a dominant role in determining the value of output at the initial stage of the green revolution (during 1970-71), whereas IRRI played a dominant role during the second phase of the green revolution (during 1990-91). Similarly, rural literacy must have played greater role during the initial period of Green Revolution (GR) because of relatively less development of extension services, but its role might have changed in the recent years because of significant development in extension network in Indian agriculture. Another explanation could be that during the first phase of GR, a larger subset of school goers were farm households, whereas during the second phase, the landless households subset became

larger, which may not have made any impact on VAO. This suggests that the role played by the infrastructure factors tend to vary over time because of simultaneous changes that are taking place in other factors determining the agricultural output. The role of infrastructure factors also changes between different time-points even when they are treated as lagged variables in the regression model, which further reinforces the point that the contribution of each infrastructure variable to agricultural output tends to change over time.

VI

CONCLUSION AND POLICY IMPLICATIONS

It is widely believed that provision of rural infrastructure remains poor in most parts of India and this constrains agricultural output growth. The precise linkages between infrastructure and output growth however remain debatable. Against this backdrop, this paper attempted to better understand the linkages between rural infrastructure development and agricultural output, using cross-sectional data for 256 Indian districts, drawn from 13 states at three time points: 1970-71, 1980-81 and 1990-91. Both descriptive and regression analyses were used to study the relationship. Descriptive analysis show that the districts having value of agricultural output above the average are better placed in terms of rural infrastructure development (irrigation, road, literacy, school facility, rural electrification, fertiliser) than the other districts. The univariate regression analysis carried out to investigate the independent relationship between each infrastructure variable and the value of agricultural output shows that except rural electrification, the remaining three infrastructure factors (irrigation, roads, and literacy) appear to significantly explain the variation in output, for all three time-points. And, the impact of irrigation infrastructure on the value of output appears to have increased over time. Multivariate regression analysis suggests that rural roads play a dominant role in increasing the value of output, followed by literacy and irrigation during 1970-71, whereas irrigation played a dominant role in 1990-91. That is, while the regression coefficient of irrigation increased from 58.15 in 1970-71 to 61.95 in 1990-91, the coefficients of road and literacy declined considerably between the two time-points. This also suggests that the role played by each infrastructure type changes over time. The impact of infrastructure variables on the value of output turns out to be stronger when they are used as lagged variables in the regression analysis.

The study thus established strong linkages between rural infrastructure development and value of agricultural output. It also noted that large inequities in rural infrastructure exist among the districts studied. This implies significant scope for increasing agricultural output by improving rural infrastructure such as irrigation, roads, education, electrification etc. While a mega-scale step up in India's rural infrastructure remains warranted for almost all districts, "one size fits all" solutions are unlikely to be optimal, rather a targeted approach might be more promising for

enhancing agricultural output and growth. The right infrastructure-mix for the backward districts however remains unknown. Though the study does reveal the close nexus between different rural infrastructure and the value of agricultural output, the level of aggregation used (district level data) enabled the determination of only broad infrastructural priorities for various areas. While irrigation emerges as a critical infrastructural priority, due to its key role in agricultural output growth in all areas, some areas may not be simply reachable or suitable for large scale irrigation in future. Without irrigation, other infrastructures may perform poorly; watershed development and land and water conservation interventions, rainwater harvesting, no tillage method, mulching, etc., may offer a promising alternative to irrigation development for such settings. To that end, studies using more disaggregated or micro-level data might be useful. Further research is needed for identifying the water conservation alternatives and for selecting the right mix of complementary rural infrastructure suited to areas with limited scope for traditional irrigation.

NOTES

1. These 256 districts have been selected without any specific reasons. We could get comparable data only for these districts for all three-time points and therefore, the remaining districts could not be included in the analysis. These districts have been selected from 13 states namely Andhra Pradesh (16), Bihar (12), Gujarat (18), Haryana (7), Karnataka (18), Madhya Pradesh (43), Maharashtra (24), Orissa (10), Punjab (11), Rajasthan (26), Tamil Nadu (11), Uttar Pradesh (47) and West Bengal (13).

2. As mentioned by Bhalla and Singh (2001), the value of output (1990-93 prices) has been estimated by covering the production of 35 important crops, which accounted for over 95 per cent of the gross value of output at the country level. The detailed method followed for estimating the value of output including the data sources is systematically presented in Bhalla and Singh (2001).

3. The importance of irrigation infrastructure in increasing the crop output has been corroborated by a number of studies using micro as well as macro-level data in India at different time points. Readers are requested to see Dhawan (1988) and Vaidyanathan *et al.* (1994) for more details on this.

4. The contribution of fertiliser to the agricultural output at different time points is clearly analysed by Vaidyanathan (1993).

5. As a part of the analysis, we have computed correlation matrix for all the variables so as to understand their interrelationship at different time points. We have observed significant correlation between value of agricultural output and the use of fertiliser at all the three time points. However, for brevity the correlation matrix results are omitted here.

6. The coefficient of rural electrification variable turned out to be negative, but not significant (except for 1970-71) in our analysis. Some of the earlier studies have also found negative relationship between rural electrification and value of agricultural output (see, Evenson, 1986). This could probably be due to two reasons. First, the effect of rural electrification might have been captured by IRR and CI due to endogeneity problem. Second, rural electrification is basically used as a proxy variable for energisation of pumpsets but the vague definition of rural electrification followed in India may not have captured the complete effect of it. Instead of rural electrification, if one uses electricity availability for agricultural purpose in terms of hours as well as the intensity of pumpsets in each district, the relationship might turn out to be significant in impacting the value of agricultural output. Unfortunately, we could not use these variables in the analysis because of data constraints.

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