DISCUSSION PAPER

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THE IMPACT OF RURAL ELECTRIFICATION AND INFRASTRUCTURE ON AGRICULTURAL CHANGES IN INDIA, 1966-1980

by

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1. Introduction

The recent growth of agricultural production in India and many other developing nations often is not explicitly related to changes in infrastructure such as electricity. The increase in agricultural production generally is viewed as resulting from technological change, including the advent of hybrid seeds, fertilizer use, and other new farm practices. Likewise, failure to achieve significant growth in agriculture in many cases is attributed to failure of pricing policies and a general lack of farm level incentives. However, rural infrastructure also plays a significant role in agricultural development. The availability of electricity, roads, markets and credit are all part of the rural environment in which farmers make decisions about cropping practices. Recently arguments have been made for and against investment in electricity as an effective means of stimulating agricultural change. While some analysts support electrification as needed for irrigation and modernization of farm practices (Mellor, 1976; Samanta and Varma, 1979), others contend that these activities can be taken care of with other forms of energy such as diesel or renewable resources (Smith, 1980; Smith and Coauthors, 1983; Lovins, 1977).

In a macro-analysis of 108 villages in India this research has found rural electrification is positively associated with irrigation, agricultural innovations, and grain mills. This adds to the growing evidence of the importance of infrastructure for rural development.

Since the late 1970s the rural electrification program in India has been directed towards the improvement of agricultural productivity through the use of electric pumpsets (Barnes and Samanta, 1984). The Indian agricultural development strategy has been to make the necessary inputs available to farmers, and to subsidize the inputs in order to induce farmers to adopt new farming practices that result in higher agricultural production. Thus, the impact of rural electrification and infrastructure in general is conceived as a two-stage process. First, access to infrastructure has an impact on farming practices. Second, the adoption of new farming practices, including hybrid seeds and fertilizers in turn have an impact on agricultural yields. Whereas most improvements in agricultural production in India for the 1950s and early 1960s were a result of increase in land under cultivation, most of the increase in the late 1960s and 1970s has been from an increase in agricultural yields due to intensification of production and change in farming practices (Sen, 1974; Sanderson and Roy, 1979).

Rural electrification can affect agricultural production in many ways (Operations Research Group 1977; Sambrini and Coauthors, 1974; Saunders and Coauthors, 1975; Ross, 1972), (1) Electrically powered machines can be utilized directly in the process of agricultural production. Water pumps, mills, threshers or fodder choppers are machines which are commonly driven by electric motors. (2) Electricity can be utilized for lighting purposes in dairy or poultry farms. (3) Electricity may have more diffuse effects on agricultural modernization not directly captured in specific on-farm activities. These diffuse effects might include cooling milk in collection centers, driving film projectors, listening to radios or watching television sets which may transmit information useful in agriculture, and providing better lighting for reading, including reading agriculturally related matters. In the

Indian context the most important direct impact is probably through pump irrigation which can expand land under crops, allow double or even triple cropping, or make more profitable the use of high yielding varieties and other purchased inputs. In this investigation we will first try to measure the effect of electrification on irrigation and then proceed to investigate whether we can show any more effects on grain mills and agricultural innovations.

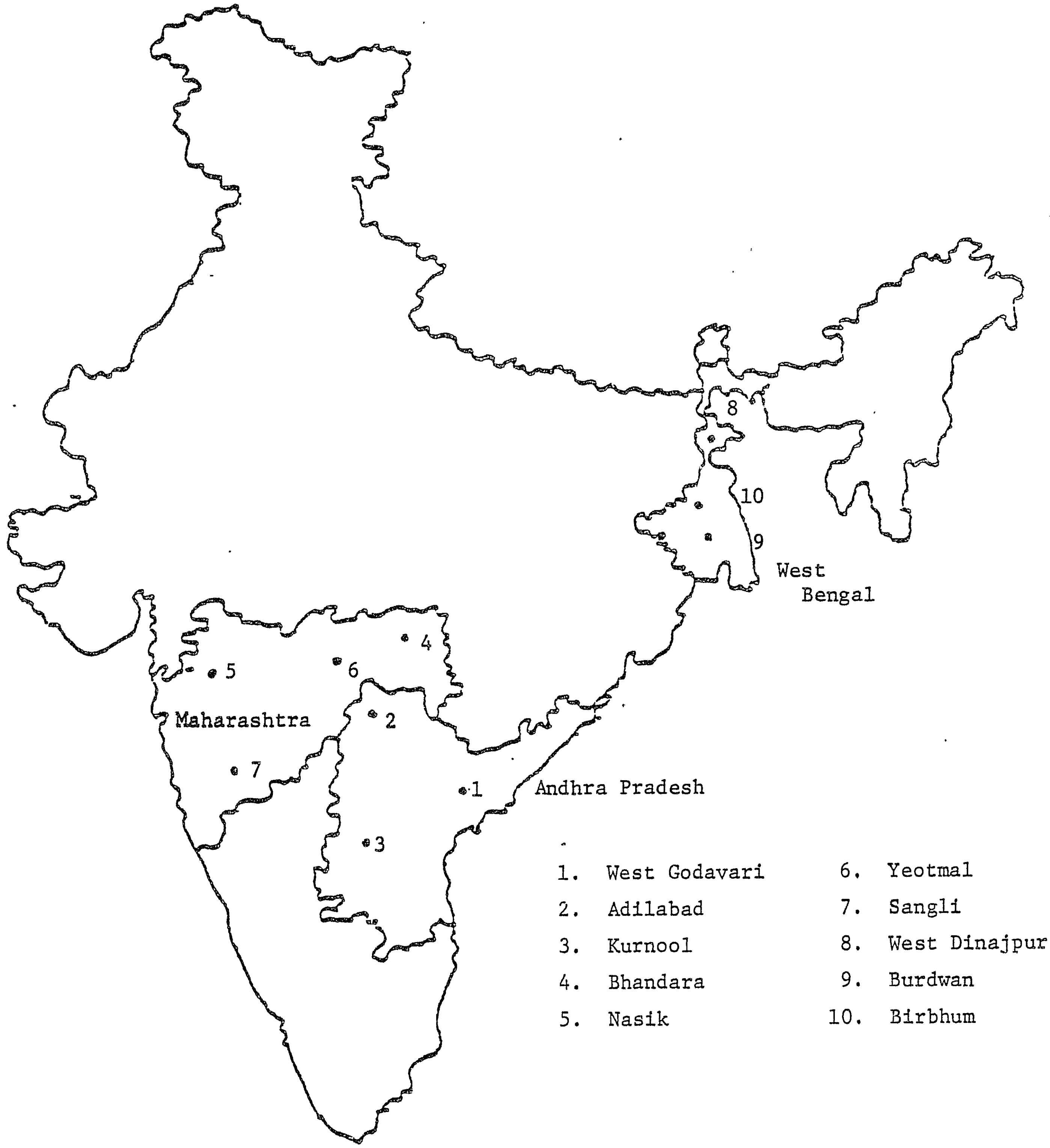
Electricity is subsidized for irrigation in India. In fact the electricity rates charged for agricultural pumps are one-third that charged for other types of electricity use. Thus, the incentive for farmers to obtain private returns on their investments by adopting electric pumps may be due only to the subsidized electricity rates (on electricity pricing see Turvey and Anderson 1977; Munasinghe and Warford, 1982). One clear result from the benefit-cost studies of rural electrification in India (National Council of Applied Economic Research, 1967, 1970; Administrative Staff College of India, 1980) is that the private agricultural benefits for farmers from investment in pumpsets are substantial for either electricity or diesel pumps. Also, under most circumstances the benefits for society outweigh both the private and the social costs of electricity. The exception is in relatively isolated regions where there are not enough consumers to justify the large capital costs involved in extending the central grid, and diesel engines would be a lower cost alternative (see Bhatia, 1979 and Tyner and Adams, 1977; Tendler, 1979; Sen, 1979 for discussion of Central Grid versus alternatives). About 20 electric pumps per village for the 30-year life of most electricity projects is the minimum number necessary for electricity to have significant positive rates of return for society. At these levels electricity also generally is more cost competitive than diesel engines, depending on the other uses of electricity in the system (see Barnes and Jechoutek, 1984).

In this research we will be examining both the direct effect of electricity and whether there are indirect benefits along the lines of (2) and (3) that are not typically measured in benefit-cost analyses. In addition electricity is generally more convenient to use since electric motors require much less maintenance than diesel engines. This would be especially true for deep wells or deep tubewells where diesel engines are not convenient or very practical to operate. Of course on the negative side electric pumps are not as mobile as diesel pumps and cannot be moved from well to well. The convenience factor of electricity may speed up the irrigation adoption rate even if measured private benefit-cost ratios of electric and diesel pumps were the same.

2. India Panel Survey

Identical surveys of 108 Indian villages were conducted in 1966 and 1980. This permits the analysis to examine both cross-sectional differences and overtime changes in the villages. The villages are located in three states in India (see Map 1). These states - Andhra Pradesh, Maharashtra and West Bengal - represent the diversity of India in terms of social, cultural, geo-climatic conditions and level of development. For instance they are located in the western, southern and eastern parts of India and they account for over 15% of India's population and land areas.

The selection of the villages was based on the decision to replicate questions in a 1966 survey of agricultural innovations in India's villages (see Fliegel and coauthors, 1968). Most past studies of rural electrification have been cross-sectional analyses which are subject to biased estimates because of fixed effects. Fixed characteristics include



Map 1. Location of states and districts in survey, India.

soil type, nearness to city, and groundwater availability. In a cross-sectional analysis these fixed characteristics, when unmeasured, can lead to biased estimates. The overtime dimension improves the study's ability to deal with the question of whether rural electrification is the cause of important changes in village socioeconomic development. In a panel study it is the change in village characteristics and not the unchanging fixed village characteristics that are analyzed. The 1966-1980 time period is also an extremely important period in India's agricultural development. In fact 1966 generally is recognized as being the start of the so-called "green revolution". In addition, 57% of the villages in the sample received new electrical service between 1966 and 1980.

The unit of analysis for the study is the village rather than the household. Examining the village as the unit of analysis offers the opportunity to examine structural changes among villages. In this respect village level information was collected (1) through structured interviews with four or more village leaders, (2) by an examination of village records, and (3) from the collection of data from state electricity boards. The village records contain information on crop yields, area irrigated, area double cropped, and census materials. The village leaders were interviewed to obtain information which would not be available through village records. The village leader information included the number of times they had talked with agricultural extension services, the number of times they had visited cities and other more subjective questions. Also all leader responses were aggregated to form a village level measure. Although the leaders in the two years are different individuals, this should not pose any problems since the objective of the questions is to examine village leaders as a representative category. Averaging leader responses also diminishes problems of random measurement error. One example is that the fertilizer subscale is comprised of the percent of the leaders in the village using fertilizer, which in turn is included in the agricultural innovation index.

Variables in the Analysis. The dependent variables represent various dimensions of agricultural development. They include percent area irrigated in the village, percent area double cropped and an index of agricultural innovations (fertilizer, improved implement, green manure, and hybrid seed use). The final dependent variable, the number of grain mills in the community, is an important measure of the development of rural service industries.

The explanatory variables can be classified in several categories. The first category is composed of rural infrastructure, which can be changed or improved through government or private investment. These variables include nearness to banks, agricultural extension services (village level workers, agricultural extension office, and block development officer), schools (middle and secondary), transportation (roads, bus stops and railroads), and mass media (post office, telegraph, telephone, and cinema). The subscale components (i.e. post office) are coded between zero and four, with the highest number indicating the service is located in the village and the lowest number meaning that the service is beyond ten miles. The subscales of several variables are added to obtain a more general index such as mass media index. Rural electrification is measured by the number of years that the village has had electricity. The village characteristics represent decisions in the village or by the government concerning education, investment in irrigation and migration or birth control.

Village demographic characteristics are the next set of dependent variables. These include structural characteristics of the village such as the level of literacy, population, number of diesel engines and the number of electric pumpsets. The measurement of all variables is for two points in time, generally for 1966 and 1980. There are some exceptions to this pattern. The literacy measures are for 1961 and 1971, the years of the Indian census. The 1971 irrigation measure is from the 1971 district census handbooks (India, Office of Director of Census Operations, 1972-74), while the 1980 measure is from village records. Although irrigation is measured slightly differently for the two years we have compensated for this by making a minor adjustment.[1/] Village population is for the years 1971 and 1980, with the 1980 measure being taken from the village records. With these few exceptions all of the data are for 1966 and 1980.

Changes in Indian Villages, 1966-1980. The year 1965 is generally recognized as the very beginning of the "green revolution", and therefore the 15 years of this study are a particularly important time period for Indian agriculture. The change in rural infrastructure for the 1966-80 time span is no less dramatic. The government nationalized the banks, built roads, developed the postal and communications systems, and extended electricity to many rural areas. These broad changes are evident in the 108 villages in the survey.

1/ An adjustment is made for the 1981 irrigation data. In 1980 the irrigation data are for gross cropped area, which means that the same acre of land cropped two seasons is counted as two acres. Meanwhile, for the 1971 data the area irrigated is reported in net area. In this case one acre cropped for two seasons would be counted as only one acre. Hence, for 1980 the area irrigated is adjusted by using the largest area irrigated for any one season rather than the gross cropped area, which makes the measures for the two years nearly identical.

Although total net percent area irrigated did not change very much for the villages, the total well irrigation expanded significantly during the 15 years between the surveys. The reason that total irrigation did not change is probably that the canal, stream, and tank irrigation modes vary significantly depending on the amount of rainfall received in the village to fill up tanks and streams. In fact the survey was taken at the end of the 1979-80 crop year, which was a below average rainfall year for the districts in the study. By contrast net well irrigation is not as dependent on rainfall as the canals, tanks, and streams, and it is well irrigation that increased significantly during the 1971-80 period. Whereas net percent irrigation remained fairly constant at 20-22% of total cultivated area, well irrigation expanded from below one to over 8% of total cultivated area (see Table 1). Because of the below average rainfall tanks, canals and streams contribute less to irrigation. Much of the new double cropping is a direct consequence of well irrigation so it is not surprising that double cropping increased an average of 11% during the 15-year period. Well irrigation offers cultivators more individual control over the time of irrigation, and is responsible for much of the double cropping for the period.

Agricultural innovations and grain mills also reflect the general development of agriculture in India. Agricultural innovations such as fertilizer and pesticide use are generally recognized as part of the development of commercial agriculture. The use of agricultural innovations increased an average of 14% by village leaders in the survey. For instance the use of fertilizers by village leaders increased from 78% to 97% during the 15 years, while the use of hybrid seeds grew from 60% to 94%. As Indian agriculture has moved from subsistence to more commercial modes of production,

Table 1

Agricultural Practices, Intrastructure Proximity
and Village Leader Changes in India
1966-1980 (108 villages)

	1966		1980		1966-1980 Changes	
	MEAN	Coefficient of VARIATION	MEAN	Coefficient of VARIATION	MEAN	Standard DEVIATION
Dependent Variables						
% irrigated area of net cultivated area	20.33	157.61	22.81	140.98	2.10	12.25
% well Irrigation of net cultivated area	.70	268.28	8.59	138.02	8.10	11.99
% multiple cropped area	16.47	148.75	28.26	110.63	11.00	29.96
Agricultural innovations index (0-4)	2.18	35.75	2.69	20.64	0.51	0.75
Village grain mills	0.76	176.67	1.81	176.37	1.05	2.65
Village Characteristics and Programs						
Village population	1,654.82	85.94	2,071.05	84.79	2.61*	3.34
Proximity to bank (0-4)	0.60	120.58	1.48	62.86	.08	1.04
Proximity to agricultural extension (0-8)	3.71	43.72	3.35	50.48	-0.35	1.67
Proximity to middle and secondary schools (0-8)	4.17	46.07	4.56	41.48	0.39	1.80
Proximity to transportation (0-12)	5.49	42.10	6.93	32.18	1.44	2.20
Proximity to mass media (0-16)	5.37	57.20	7.38	41.85	2.01	2.56
Proximity to wholesale and rental markets (0-8)	1.33	195.84	8.12	95.80	7.10	6.25
Years since village electrification	3.48	46.50	2.33	65.05	-1.16	1.93
Times talked to agricultural extension (0-24)	9.13	48.55	10.30	49.48	1.18	6.02
Percent literacy	19.25	49.31	25.89	57.48	6.64	11.45
Electric pumps	1.23	283.12	7.36	184.16	6.14	11.47
Diesel pumps	1.33	174.49	6.04	149.11	4.71	8.79

* Compound annual growth rate 1971-1980.

Note: The numbers in parenthesis represent the scale for the 1966 and 1980 measures of the variable. The 1966-1980 change is the difference between 1966 and 1980 for all cases. The literacy measures are for 1961 and 1971. The percent irrigated area for 1966 is from the 1971 District Census Handbooks. The population measures are for between 1971 and 1981.

the number of mills in the villages has increased to process the grain. In 1966 the average number of grain mills per village is less than one, but by 1980 this figure had improved to over two per village.

The changes in rural infrastructure in India may be a contributing factor to agricultural development in India. During the 15-year time period between the surveys, it is quite evident that infrastructure has improved. Schools, transportation, mass media and banks all became more abundant in the countryside. The only exceptions are agricultural extension and rural markets. The decline in the market proximity measure probably is a consequence of market consolidation typical of agricultural commercialization. Because of improved transportation, local markets may begin to concentrate in central rather than dispersed locations. Such a process is typical of the development of growth centers and market town (see Wanmali 1983). The availability of agricultural extension services also declines slightly during the 15-year period. This may be caused by the improvement in transportation which allows greater distance without any sacrifice in extension service.

The villages in the survey represent a broad range of rural electrification service. Some villages have had electricity for over 25 years, while others do not yet have electricity. Electricity service was extended to 57% of the villages in the sample during the 15 years since 1966. In 1966 only 33% of the villages in the sample had electricity. By 1980 the number had increased to 71%. This is reflected in the number of years that the villages have had electricity. In 1966 the average number of years with electricity was just over one year, reflecting the fact that most villages had not been connected to the central grid. By 1980 the average number of years with electricity for the sample villages is over eight years.

3. Rural Infrastructure and Fixed Village Characteristics

Rural infrastructure development is a consequence of government and private investment. Rural infrastructure like banks, schools and agricultural services are based on cumulative investments by governments and communities. Roads are not built and electricity lines are not strung randomly throughout the country. Thus the first step in understanding the relationship between infrastructure and rural development is to examine if the government selectively extends infrastructure to villages with particular fixed characteristics, such as good agro-climatic endowment, high population or proximity to large cities.

Econometrically this investigation is quite simple because the village characteristics are exogenous variables. We can therefore examine the issue of selected extension of infrastructure in the cross-section data of the individual survey years 1966 and 1980. We should note that the agro-climatic variables we have are not very good proxies for agro-climatic endowments. The only climate variables in the study are average rainfall and a broad classification of soils into five major types. With better rainfall and soils data it would have been possible to construct better agro-climatic index variables based. However, the population data is very good, and it is likely that larger villages are located where agro-climates are better. Moreover, population growth rates did not differ substantially across villages. We therefore include population levels as an additional quasi-fixed effect. In Table 2 for variables which are continuous ordinary least squares (OLS) techniques are used. Some variables, however, are bounded at zero, such as the years since rural electrification where a fairly high proportion of villages have not yet received electrical service.

OLS techniques are inappropriate to such analysis and instead the analysis technique is Tobit regressions.

Village population and proximity to cities, as expected, are the two most important village characteristics in determining access to almost all the rural infrastructure included in our study. The cross-sectional data include some interesting changes between the 1966 and 1980 surveys (see Table 2). For instance, the location of banks changed significantly between 1966 and 1980 surveys. In 1966 banks were located mainly in cities, so villages close to cities had better access to banks than those farther away. The proximity variable has a coefficient of .61 and is highly significant. By 1970 the banks in India were nationalized and the policy of the government was to locate more banks throughout the countryside. As a consequence the coefficient of proximity to cities declines by half. However, as the highly significant coefficient of population indicates for 1980, the nationalized banks chose to put their branches primarily in the large villages. Agricultural services also are located in the larger villages in 1980 and the relationship is even stronger in 1980 than in 1966 reflecting the continued emphasis on service development in the larger villages. The secondary and high schools are located in the higher population villages in both 1966 and 1980. Almost every village in the sample has a primary school so there is no reason to include them in the analysis.

The proximity to cities also is important for the extent of rural infrastructure. Transportation facilities are better for villages near cities, but the larger villages also have better access to roads and bus stops in 1980 compared to 1966. Once again this reflects the pattern of diffusion of services to the larger villages in the rural areas. Mass media

Table 2

Relationship Between Fixed Village Characteristics
and Government Programs in India, OLS and TOBIT Regressions
1966-1980

DEPENDENT VARIABLES	BANK 1966	BANK 1980	AGRICULTURAL SERVICES 1966	AGRICULTURAL SERVICES 1980	MIDDLE AND SECONDARY SCHOOLS 1966	MIDDLE AND SECONDARY SCHOOLS 1980	TRANSPORTATION 1966	TRANSPORTATION 1980	MASS MEDIA 1966	MASS MEDIA 1980	MARKETS 1966	MARKETS 1980	TOBIT YEARS SINCE** ELECTRICITY 1966	TOBIT YEARS SINCE** ELECTRICITY 1980
Intercept	.02	.98	2.39	1.33	3.50	1.98	4.01	4.79	7.14	5.25	2.98	1.47	-6.16	-7.76
	(.04)	(1.51)	(2.09)	(1.16)	(2.84)	(1.56)	(2.65)	(3.38)	(4.41)	(3.01)	(2.60)	(1.33)	(2.06)	6.40
Rainfall	.00008	-.0001	.0008	.001	.0003	.0008	.0006	.0003	-.002	-.00002	.0002	.0005	.0009	.005
	(.30)	(.26)	(1.15)	(1.67)	(.46)	(1.13)	(.70)	(.34)	(1.99)	(.02)	(.37)	(.73)	(.46)	(6.28)
Proximity to City	.61	.30	.29	.21	.21	.23	.82	.85	1.58	1.14	.25	.46	.72	2.75
	(6.66)	(2.83)	(1.23)	(1.11)	(.87)	(1.10)	(2.62)	(3.61)	(4.76)	(3.90)	(1.10)	(2.50)	(1.16)	(12.00)
Village Population	-.00002	.0002	.0003	.00001	.0007	.00005	.0002	.0002	.001	.0007	.0002	.0001	.0009	.001
	(.54)	(5.016)	(2.43)	(1.84)	(5.15)	(5.17)	(1.06)	(2.57)	(5.87)	(5.75)	(1.71)	(1.83)	(3.27)	(10.90)
Soil Type (Dummy Variable)														
Red - Yellow	.78	.38	-.26	.62	-.51	1.28	.55	2.65	-.99	.05	.07	.28	1.99	5.99
	(3.58)	(1.24)	(.43)	(1.13)	(.86)	(2.14)	(.74)	(3.97)	(1.26)	(.07)	(.14)	(.55)	(1.04)	(7.88)
Red - Yellow/Laterite	-.04	-.20	-.87	-.26	-.52	-.004	.05	.50	-1.34	-.05	-1.21	-1.52	.13	-1.56
	(.19)	(.63)	(1.49)	(.45)	(.82)	(.007)	(.06)	(.71)	(1.61)	(.06)	(2.07)	(2.73)	(.06)	(2.15)
Medium Black	.38	.01	-.22	-.24	-1.36	.54	-.80	.39	-3.08	-.81	-.34	-.14	3.48	9.76
	(1.62)	(.04)	(.37)	(.68)	(2.11)	(.82)	(.01)	(.53)	(3.61)	(.89)	(.57)	(.24)	(1.92)	(14.41)
Red Black/Deep Black	.44	-.33	-.22	1.13	-1.34	.17	1.03	1.08	-1.20	.93	.19	-.69	3.35	8.56
	(1.52)	(.41)	(.31)	(1.51)	(1.45)	(.22)	(1.04)	(1.21)	(1.55)	(.85)	(.26)	(.99)	(1.67)	(11.10)
R^2	.43	.29	.14	.26	.32	.30	.28	.36	.57	.52	.15	.18		
F Statistics	10.98	6.08	2.34	5.07	6.88	6.24	5.66	8.12	19.05	15.92	2.63	3.34		
Number of Cases	107	107	107	107	105	107	107	107	107	107	106	107	107	107

* Coefficients are unstandardized b's with t statistic in parenthesis.
**Tobit rather than ordinary least squares regression analysis. The soil dummy variable in these equations is alluvial rather than Red/Yellow Laterite.

is very highly related to both village size and proximity to city, but there are some important regional variations in the extent of mass media penetration. Market proximity also depends on nearness to city and to the village size, but the relationships are more significant in 1980 than in 1966. Once again this might suggest that there is a consolidation of markets into growth centers and market towns as opposed to a scatter of smaller markets throughout the countryside. The concentration of markets may be a consequence of the development of other infrastructure, including roads and transportation.

The central government has invested heavily in rural electrification during the 15 years between the surveys. One result is that both village population and proximity to cities are increasingly important indicators of the location of the central grid. Rural electrification programs in the 1960s stressed the connection of the larger towns and villages to the central grid, while in the 1970s the area coverage approach was adopted as a policy. Despite the fact that the coverage approach strives to connect all villages, large and small, within a specified area, economic considerations must have taken procedence and these equity considerations. Therefore, these policy changes do not shape up in the results from the survey. Electricity lines have already reached most of the major cities and towns in India, and the small villages located near the large towns and villages are only now beginning to receive electricity. Probably it would have been highly inefficient not to proceed in the manner indicated by the analysis.

The reason for examining the cross-sectional 1966 and 1980 results is to demonstrate whether fixed village characteristics have an impact on the allocation of government programs. From the results it is evident that population and proximity to cities do have an important effect on the location of rural infrastructure. Neither rainfall nor soil type can be shown to have a significant impact on infrastructure development, once population size and proximity to cities is controlled. As indicated the measure of soil is not very satisfactory since the data are for districts rather than for individual villages. Because there are significant differences in soil types within districts, the regressions may not be capturing the fixed effect of soil types. Nevertheless, the results indicate that village characteristics such as population and proximity to cities continue to be important for allocation of government programs. We can now proceed to examine the relationship between change in village infrastructure and change in farming practices.

4. Infrastructure, Electrification and Agricultural Change: A Panel Study

Methodological Considerations. The impact of infrastructural investments on agricultural productivity or factor use cannot be investigated with an analysis of simple cross-section data. As we have shown the government allocates more of its services to large villages or to villages close to cities. But such villages also have better access to urban markets than small, isolated villages even if there is little or no infrastructure investments. Agricultural producers respond to market opportunities, and productivity and factor use would be higher in larger villages close to cities even in the absence of the infrastructural investments. With data from a single cross-section there is an identification problem. The question cannot be answered whether productivity or factor use is higher because of the government investments or because of the fixed characteristics of the villages.

The data set in this study is well suited to overcome this identification problem because it measures the villages at two points in time. We can therefore relate the changes in productivity or factor use to changes in government infrastructure variables. Any pre-existing differences in productivity or factor use which are related to fixed village characteristics therefore are netted out.

We hypothesize that well investment or the other productivity and input use indicators are related to the independent variables, electrification, and unchanging village characteristics as follows:

$$Y_{it} = a_t + b_1X_i + b_2G_{it} + b_3Z_{it} + b_4X_iZ_{it} + U_i + V_{it} \quad (1)$$

where:

Y = dependent variable such as level of well irrigation

X = unchanging village characteristic(s)

Z = time since electrification

G = other infrastructure variable(s)

i = village subscript

$t = 1,2$ = time period subscript

U_i = unchanging but unobserved village characteristics

V_{it} = village and period specific error term

E_{it} = $U_i + V_{it}$ overall unobservable error

This means that well irrigation is a function of the observed and unobserved unchanging village characteristic X_i and U_i, of the government infrastructure variable G_{it}, of years since electrical service was established Z_{it}, and of an interaction between village characteristics and electrification. More complex versions can be written without altering the basic points.

As indicated in the previous section, investments in electrification and other infrastructure are allocated by the government to villages according to:

$$G_{it} \text{ or } Z_{it} = a_t^* + b_1^* X_i + U_i^* + V_{it}^* \tag{2}$$

where the star notation indicates that the effects are not the same as in relation (1), and where X_i stands for all village characteristics including size. The identification problem arises because the same unobservable factors determine both U_i and U_i^*, the unobservable village specific effects. Therefore, in equation (1) G_{it} and Z_{it} are correlated with U_i, i.e., with the unobserved "error" $E_i = U_i + V_{it}$. This violates the classic assumption of independence of the error terms from the independent variables and leads to biased estimates of b_2, b_3 and b_4. However, if we subtract the relation (1) for period 1 from that of period 2, the problem can be overcome. Let $\Delta(G)$ refer to the difference between any two variables, i.e., $\Delta(G) = (G)_2 - (G)_1$. Then performing the subtraction we obtain:

$$\Delta Y_i = \Delta a + b_2 \Delta G_i + b_3 \Delta Z_i + b_4 X_i \Delta Z_i + \Delta V_{it} \tag{3}$$

Note that, because their difference is zero, the terms in X_i and U_i drop out of the differenced equation. The remaining portion of the error term ΔV_{it} is now uncorrelated with the ΔG_i and the ΔZ_i variable and the problem of left out variable bias disappears. Causality inferences can therefore be made using the b_2, b_3 and b_4 coefficients.

The final statistical point to be discussed is the use of Mundlak's (1981) principal component regression technique. This technique allows the reduction of multicollinearity problems and the elimination of irrelevant variables without generating pretest bias (for a review of the pretest bias issue, see Wallace, 1977). The traditional approach to these problems is to run a regression with many variables, eliminate variables which are not statistically significant, and then estimate a reduced regression equation which does not contain the eliminated variables. The problem with this method is that the significant levels and coefficients of the new estimates are no longer the same without the excluded variables resulting in pretest bias. If some of the left out variables are correlated with the included variables and have been rejected when they should not have been, the included variables will pick up the effect of the wrongly left out variables.

Mundlak's method avoids this problem. The independent variables are transformed into principle component variables. A regression equation is then estimated, including all of the principle components, for as many variables as are in the original model. In a joint testing procedure, those principle components are found which jointly do not add significantly to the explanatory power of the regression. This method tests whether <u>any</u> linear combination of those principle component variables is statistically significant. In order to minimize type II error relative to type I error we have chosen a significance level of .10 for this test. Only those principle components are retained which affect the dependent variable significantly.[2/] Because principle components are orthogonal, the regression equation does not have to be reduced and reestimated, thus avoiding the pretest bias

2/ The method differs from the standard use of principle components in that the choice of which component to use is made in the context of the <u>dependent</u> variables, rather than only on the basis of variation <u>among the independent</u> variables.

problem. Instead the coefficients of the retained principle components are transformed back to the original variable space, and the technique produces a coefficient and statistical significance level for all original variables. If a variable is not relevant to the dependent variable it simply has a low t value and thus an insignificant coefficient.

The procedure provides both an R^2 and a statistical rank of the regression. The statistical rank indicates how many principle components were retained in the procedure. If the data is highly collinear the statistical rank may only be one, in which case no decision can be made as to which of the original variable relates to the dependent variable and which does not. Where this case arises principal components regression is not useful and only OLS results are reported.

Infrastructure, Irrigation and Multiple Cropping. The direct and indirect effects of rural electrification on irrigation controlling for other infrastructure can be interpreted from the models in Table 3. In equations 1-3 the direct impact of rural electrification on diesel and electric pump irrigation is examined. In equation 4 the focus is on the total investment in pumps, both diesel and electric. In equations 5, 10 and 11 we have precisely the same equations except that the dependent variables are total well irrigation and multiple cropping. Finally, from equations 6-9 it can be determined whether electrification speeds up irrigation through mechanisms other than pumpsets, since pumpsets are included as control variables in these models. The models include years since electrification, an electrification year*rainfall interaction term, and the square of the year since electrification. As a consequence the crucial coefficients are for the principle component regressions since the

Table 3

Change in Irrigation, Multiple Cropping and Rural Infrastructure,
Ordinary Least Squares and Principal Components Regressions
India, 1966-80

Independent variables / Dependent variables	(1) Total Electric Pumps	(2)	(3) Total Diesel Pumps	(4)	(5) Total Well Irrigation	(6)	(7)	(8)	(9)	(10) Multiple Cropping	(11)
	OLS	PC	OLS	OLS	OLS	OLS	PC	OLS	PC	OLS	PC
Intercept	1.97	4.43	2.26	4.23	72.11	50.74	8.04	53.41	97.72	20.39	15.29
	(.73)	0	(.49)	(.90)	(1.84)	(1.61)	0	(1.71)	0	(2.82)	0
Population	.07	.15	-.43	-.30	-3.94	-2.13	-2.27	-1.81	-.35	.60	.94
	(.23)	(2.04)	(.75)	(.61)	(.81)	(.54)	(.83)	(.47)	(.15)	(.67)	(1.59)
Literacy (percent)	-.09	-.18	.18	.09	.27	-.19	.08	-.44	-2.12	-.22	-.34
	(.89)	(3.55)	(1.02)	(.49)	(.17)	(.15)	(.18)	(.35)	(2.45)	(.79)	(2.99)
Proximity to: Middle and secondary schools	-.86	-.06	1.58	.71	-6.07	-10.27	-8.14	-12.48	-16.78	-4.12	-2.28
	(1.36)	(.94)	(1.43)	(.63)	(.71)	(1.37)	(1.35)	(1.65)	(5.58)	(2.40)	(1.80)
Bank	2.12	2.07	-2.83	0.71	-13.82	-10.23	-.53	-5.26	-12.29	-2.33	-4.61
	(1.88)	(3.62)	(1.45)	(.36)	(.84)	(.77)	(.09)	(.39)	(1.89)	(.77)	(4.14)
Agricultural Services	1.17	1.09	.43	1.61	3.37	-4.76	-10.20	-2.80	9.01	.44	.03
	(1.70)	(3.27)	(.36)	(1.32)	(.33)	(.58)	(1.50)	(.34)	(2.14)	(.24)	(.07)
Transportation	.23	-.44	1.06	1.30	5.17	-1.37	-4.40	-1.36	-9.98	-3.82	-4.26
	(.40)	(3.06)	(1.04)	(1.26)	(.60)	(.19)	(.76)	(.19)	(3.87)	(2.41)	(3.16)
Mass Media	-1.00	-.79	.93	-.06	2.91	3.23	8.64	1.04	-3.5[illegible]	4.65	3.50
	(2.02)	(2.93)	(1.09)	(.07)	(.40)	(.55)	(2.18)	(.17)	(4.57)	(3.49)	(4.14)
Markets	1.67	1.12	-2.71	-1.03	4.26	9.50	-4.67	13.61	15.45	1.19	1.28
	(2.77)	(2.85)	(2.60)	(.97)	(.48)	(1.33)	(1.65)	(1.82)	(4.78)	(.73)	(3.65)
Years since electrification	1.40	.27	-1.33	.06	-3.77	-4.10	.17	-1.02	1.16	-3.29	.08
	(2.62)	(4.71)	(1.44)	(.07)	(.48)	(.65)	(.21)	(.15)	(1.77)	(2.28)	(1.61)
Years since electrification^2	-.03	.01	.07	.04	.51	.29	.05	.21	.09	.04	.009
	(1.78)	(5.07)	(2.44)	(1.38)	(2.01)	(1.45)	(1.97)	(1.01)	(3.89)	(1.02)	(3.86)
Elect. Year * rainfall	-.0001	.0001	-.000002	.0001	-.0004	-.0009	.0001	-.0007	-.0004	.001	-.00009
	(.27)	(2.16)	(.004)	(.15)	(.07)	(.20)	(.15)	(.16)	(.52)	(1.24)	(4.06)
Total pumps in village	--	--	--	--	--	5.03	4.82	--	--	--	--
						(6.78)	(6.85)				
Electric pumps in village	--	--	--	--	--	--	--	3.22	3.95	--	--
								(2.41)	(5.49)		
Diesel pumps in village	--	--	--	--	--	--	--	5.43	4.01	--	--
								(7.01)	(6.53)		
R-square	.35	.23	.19	.21	.16	.47	.41	.48	.39	.28	.15
F-statistic	3.93		1.72	2.03	1.33	5.84		5.70		2.87	
Number of cases	91	91	91	91	91	91	91	91	91	91	91
Statistical rank		2					5		4		2

Derivative of year since electrification		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Minimum (0 years)	1.52	.42	-1.34	.18	-4.25	-5.18	.29	-1.88	.69	-1.78	-.03
		(3.60)	(3.52)	(1.83)	(.25)	(.69)	(1.04)	(.19)	(0.35)	(.46)	(1.56)	(.59)
	Mean (7.4 years)	1.06	.50	-.26	.81	3.34	-.75	1.14	1.29	2.10	-1.07	.10
		(4.85)	(3.97)	(.68)	(2.09)	(1.04)	(.28)	(.59)	(.44)	(1.15)	(1.88)	(1.48)
	Maximum (15 years)	.59	.78	.86	1.45	11.11	3.79	2.01	4.53	3.55	-0.34	.24
		(2.62)	(4.23)	(2.18)	(3.63)	(3.35)	(1.33)	(.85)	(1.58)	(1.63)	(1.55)	(2.48)

Note: coefficients are unstandardized b's with t statistics in parenthesis.

interaction terms inevitably lead to collinarity of the independent variables. However, both the ordinary least squares and principle component regressions are reported in Tables 3 and 4.

Rural electrification does have a substantial impact on overall investments in pumps. For electric pumps the relationship is consistent over the whole range of village years since electrification. As might be expected there is a negative relationship with diesel pumps in the early years that a village has electricity, indicating that there is some substitution of electric pumps for diesel ones. Yet surprisingly in the later years there actually is a positive association with diesel pumps. The implication is that over the long term there is greater investment in both diesel and electric pumps which is substantiated by the total pumps model (equation 4). The long-term growth of diesel pumps in a region with electricity contrasts with the short-term substitution of electric pumps for diesel pumps. It may be that once all of the easy locations for electric pumps in close proximity to the grid have been exhausted[3/], then after 10-20 years farmers may begin to invest in diesel pumps in locations more distant from the grid. At this time farmers know that the general return on investment from pumps is considerable.

The next question to be answered is whether electrification has a direct effect on irrigation and multiple cropping. As indicated previously irrigation from tanks and streams are more dependent on the extent of rainfall than on irrigation pumps. This is confirmed in an analysis not reported in Table 3, which indicates virtually none of the infrastructure variables related to total irrigation change between 1971 and 1980. This means that random fluctuation in irrigation is more important than

3/ The electricity industry installs only a certain length of low tension lines for agricultural pumping without charging the consumer.

infrastructure in determining levels of total irrigation in villages in any given year. Only an analysis which has annual changes in rainfall could investigate the changes in total irrigation for the sample villages. But partly as a consequence of the added security gained through not being as dependent on the yearly onsoons, diesel and electric pumps are becoming increasingly important for total net area irrigated and multiple cropped.

As opposed to the total irrigation results, the direct effect of rural electrification on well irrigation and on multiple cropping is significant and positive. In equations 5 and 11, the coefficients for rural electrification are significant and their magnitude increases over time indicating there is a long-term impact. In general, the positive association means that the longer a village has electricity the more likely it will have higher than average increases in well irrigation or multiple cropping. Also there is a probable lag involved between the time when villages receive electricity and the time when increases in irrigation and multiple cropping begin to appear.

Electricity also might possibly speed up well irrigation through mechanisms other than pump investments, such as the convenience of using electricity or a general change in the outlook of the farmers in the villages. To examine this issue in equations 6, 7, 8 and 9 pumps are added to the infrastructure variables found in the other equations. The electricity coefficient in these cases measures the more diffuse effect on electrification other than that explained by the addition of pumps in the villages. As might be expected the results are somewhat mixed for the more diffuse indirect effects of electrification. The coefficients for the pumpsets are uniformly positive and significant. But the coefficients for years of electrification are not significant, indicating that there are no significant impacts except through the investment in pumps. Although there may be some slight effects in the later years that villages have electricity, the overall conclusion is that after controlling for pumps there are no diffuse and indirect effects encouraging farmers to irrigate.

The interaction effects of rural electrification and rainfall are fairly inconclusive. While there seems to be less multiple cropping in villages with high rainfall and with electricity for a long period of time, and perhaps a slight positive relationship with electric pumps, the findings generally are not very robust. As indicated the rainfall measure is not ideal and it may not be a good indicator of water surplus or deficit for the villages.

Although rural electrification is the primary focus of the analysis, transportation, banks, agricultural extension, schools, literacy and markets also are included in the analysis as important control variables. A detailed interpretation of these variables is beyond the scope of this paper but we will briefly review the findings of the other infrastructure variables. The two measures of education in the study are literacy (extent of primary education) and proximity to middle and secondary schools. Neither schools nor literacy appears to play a significant role in irrigation. The effect of schools or literacy may be too diffuse to measure the influence on irrigation. We would caution that we are not using individual data here so these results should not be compared to many of the farm level studies on literacy and education. However, at the aggregate level it does not seem that education and literacy are a necessity for having higher than average increases in irrigation for the villages.

Changes in transportation proximity actually relate negatively to the irrigation variables in the analysis. It is quite possible that transportation encourages the migration of both labor and investment from villages with relatively poor endowments. Better transport may mean a more dynamic flow of capital and labor for the villages. By contrast markets are positively related to irrigation investments and irrigation. Presumably markets have a positive influence on development so capital and labor remain within the villages. The findings for mass media are mixed with a positive influence on irrigation and a negative one on multiple cropping. As expected banks have a positive association with investment in pumps, but the results are mixed for irrigation and double cropping. Thus, there may be an indirect link between changes in banks and changes in irrigation which runs through pumps. However, there is no direct relationship.

Rural Grain Mills and Agricultural Innovations. The growth of grain mills in rural areas is an important component of agricultural development. The addition of grain mills to the rural economy means several different processes may be taking place. New grain mills may indicate that a region is producing surplus agricultural output and more mills are needed to keep pace with the demand for services. This section examines the growth of grain mills which service the local agricultural economy. Secondly, the relationship between rural electrification and agricultural innovations is investigated. The final variable in Table 4 is the contact of village leaders with agricultural services.

The growth of grain mills is strongly related to the number of years that a village has had electricity. All three of the rural electrification variables in the principal components model (equation 2) are

Table 4

Change in Agricultural Innovations, Grain Mills and Rural Infrastructure,
Ordinary Least Squares and Principal Component Regressions
India, 1966-1980

Independent variables	Dependent variables	(1) Grain Mills OLS	(2) Grain Mills PC	(3) Agricultural Services OLS	(4) Agricultural Services PC	(5) Agricultural Innovations OLS	(6) Agricultural Innovations OLS	(7) Agricultural Innovations PC
Intercept		-.55 1.06	-.47 0	2.37 (1.74)	3.74 0	.65 (3.78)	.54 3.38	.56 0
Population		.03 (.52)	.05 (1.63)	.27 (1.52)	.09 (2.85)	.02 (.89)	.21 (.95)	-.01 (2.07)
Proximity to:	Middle and secondary schools	.07 (.61)	.11 (1.89)	-.22 (.67)	-.0006 (.02)	.06 (1.47)	.05 (1.29)	.02 (1.98)
	Banks	.79 (3.54)	.39 (2.72)	.30 (.52)	-.18 (3.31)	-.01 (.25)	-.006 (.09)	-.09 (-2.73)
	Agricultural services	-.09 (.68)	-.17 (3.45)	.24 (.71)	-.02 (2.90)	.01 (.30)	.01 (.31)	.005 (.54)
	Transportation	.05 (.47)	-.10 (1.86)	.40 (1.40)	-.002 (.31)	.05 (1.43)	.05 (1.480	.03 (2.73)
	Mass media	-.19 (2.04)	-.02 (.65)	-.44 (1.78)	-.09 (3.29)	-.05 (1.64)	-.05 (1.76)	.003 (.28)
	Markets	-.20 (1.75)	-.24 (4.85)	.02 (.06)	.07 (2.77)	.03 (.80)	.03 (.98)	.02 (2.64)
Rural electrification* Dummy variable		—	—	—	—	—	.21 (1.47)	.18 (3.16)
Years since electrification		.04 (.43)	.03 (2.78)	-.70 (2.47)	-.74 (2.62)	.01 (.52)	—	—
Years since electrification^2		.009 (2.59)	.009 (3.31)	-.006 (.69)	.009 (1.71)	-.001 (.91)	—	—
Elect year * rainfall (interaction)		-.0001 (1.31)	-.00009 (1.74)	.0005 (2.89)	.0002 (1.86)	-.000003 (.12)	—	—
Literacy (percent)		.01 (.67)	.01 (1.08)	-.04 (.78)	-.03 (1.94)	-.01 (2.13)	-.01 (2.32)	-.006 (3.18)
R-square		.37	.32	.21	.10	.16	.17	.10
F-statistic		5.16	—	2.28	—	1.71	2.25	—
Number of cases		104	104	104	104	104	104	104
Statistical rank		—	5	—	2	—	—	2
Derivative of years since electrification	Minimum (0 years)	-.07 (.85)	-.07 (1.05)	-.02 (.11)	-.42 (3.30)	.02 (.56)	na	na
	Mean (7.4 years)	.06 (1.45)	.06 (1.59)	-.11 (1.05)	-.28 (3.38)	-.002 (.012)	na na	na na
	Maximum (15 years)	.20 (4.39)	.20 (4.91)	-.21 (1.80)	-.14 (1.41)	-.02 (3.33)	na na	na na

na = not applicable

* The rural electrification dummy variable is coded 0 if a village had no electricity in 1980, 0 if a village had electricity in both 1966 and 1980, and 1 if it received electricity between 1966 and 1980.

Note: coefficients are unstandardized b's with t statistics in parenthesis.

related to the growth of grain mills in the villages. This means that (1) the growth rate of mills is higher for villages with electricity; (2) the growth rate accelerates over time; and (3) the combination of electricity and rainfall have a positive impact on the growth of mills. These positive findings should be tempered with the knowledge that on average there are only one or two grain mills in the villages. Nevertheless, villages without electricity have even fewer mills. As a consequence the availability of electricity does stimulate the development of rural service industries.

Even though electricity is not used directly in the production process, the possibility exists that rural electrification can have an effect on the adoption of innovations, such as fertilizers, hybrid seeds and other inputs. Thus, the regressions in Table 4 contain an analysis of change in agricultural inputs. Rather than taking each input individually, the adoption of inputs has been included in a total innovation adoption index. It is hypothesized that electricity will have a significant although rather diffuse affect on the use of farm innovations in the villages. Also it may have an impact on access to agricultural services, making the villages more attractive to visit for agricultural extension workers.

Rural electrification does appear to be related to agricultural innovations, but not to agricultural services. Although rural electrification year is related to agricultural innovations, there are some particular time lags involved in the correlation. Villages that have had electricity for 15 years or longer have high levels of innovations but they have experienced very little growth of innovations during the 15-year period. In other words, most farmers in this group already use innovations and there is no new increase in innovations. This is signified by the negative relationship between rural electrification year and agricultural innovations (see derivative of rural electrification year in equation 5). However, the growth of agricultural innovations is positively related to those that have received electricity during the last 15 years, as indicated in equations 6 and 7. This may mean that villages that receive electricity adopt innovations at a higher rate for several years, but a saturation point is reached after which there is no significant change. This finding is consistent with the familiar S-shaped adoption of innovation curve.

The introduction of other infrastructure also has an impact on grain mills, agricultural innovations and agricultural services. As might be expected the location of banks in villages has a significant impact on the growth of grain mills, but it is not associated with agricultural innovations or services. As indicated previously banks are related to investment in pumpsets, so banks appear to be directly related to those activities which require capital investment in motive power, probably because of the capital needed to purchase and install electric motors. However, the relationship does not appear for agricultural innovations which also require credit. The credit for agricultural innovations must be coming from sources other than banks.

In contrast to the irrigation results the school variables are positively associated with change in agricultural innovations and the number of grain mills. This highlights the need to examine a broad spectrum of development processes when making conclusions on the efficacy of rural infrastructure for development. Rural schools may be unimportant for change in irrigation in a village, but it is important for determining the change in agricultural innovations. Although proximity to middle and secondary schools does appear to stimulate agricultural innovations, the negative relationship with literacy requires some explanation. Generally, regions with a higher demand for labor experience an immigration of mostly non-literate agricultural laborers. Change in literacy measured at the aggregate level does not reflect of what happens to literacy of the original population.

The remaining relationships with infrastructure are somewhat less intuitive. Markets are significantly related to agricultural services and innovations, but negatively to grain mills. Markets are important for changes in farming practices. However, when there is a local mill then this may mean a consolidation of rural markets to villages elsewhere in a region. Mass media such as post offices and libraries do not seem to have any direct influence on grain mills or innovations. Increasing population densities do seem to have an impact on agricultural services in a region.

5. The Pitfalls of Cross-Sectional Analysis

As we have discussed one of the problems of cross-sectional analysis is the possibility that fixed effects such as population, proximity to cities, or soil types can lead to biased estimates of the effects of government programs. In Table 5 we illustrate this problem. The equations in Table 5 are very similar to the grain mill change equations presented in Table 4. The only differences are that proximity to cities and rainfall are included as independent variables in the cross-sectoral equations and the rural electrification square and interaction terms are not included in the model.

Table 5

Grain Mill Cross-sections and Change Analysis
Principal Component Regressions
India, 1966-80

	Number of Grain Mills in Village		
	1966 PC	1980 PC	1966-1980 PC
Intercept	-.63 0	-2.97 0	-.64 0
Proximity to City	-.008 (.05)	.10 (.45)	--
Population	.0003 (3.78)	.0003 (6.31)	.02 (1.66)
Rainfall	-.0005 (2.08)	.0009 (1.23)	--
Percent Literacy	.01 (3.23)	-.02 (1.91)	-.02 (4.70)
Proximity to: Middle and Secondary Schools	.26 (5.43)	.23 (3.44)	.07 (1.21)
Banks	-.22 (1.30	.93 (6.40)	.76 (5.66)
Agricultural Services	.09 (3.89)	.007 (.14)	.04 (.40)
Transportation	.09 (2.96)	.03 (.52)	-.07 (2.74)
Mass Media	-.15 (2.64)	.12 (3.12)	.11 (5.59)
Markets	.04 (3.74)	-.46 (3.11)	-.25 (4.98)
Years Since Electrification	.07 (3.40)	.10 (4.75)	.09 (5.66)
R Square	.43	.44	.23
Number of Cases	101	101	100
Statistical Rank	5	5	2

Note: Coefficients are unstandardized b's with t statistics in parenthesis.

The fact that we can estimate both change and cross-section equations for essentially the same variables enables us to conduct the specification test according to Hausman (1978). The change equation is a correct econometric specification under both of the following hypotheses:

H_0: The fixed effects of such as climate are not correlated with the infrastructure investment variables and there is no specification problem; and

H_1: There is correlation between unobservable fixed effects and infrastructure investments and therefore there is misspecification.

The cross-sectional equations, however, are only correct econometric specification under the H_0. H_0 has to be rejected if the coefficients of the level equations differ significantly from those of the change equations.

As indicated in Table 5, H_0 has to be rejected. In the change equation bank, mass media and years since electrification have a significant positive impact on grain mills, and these findings accord well with intuition. But in the cross-sectional equations only years since electrification is positive and significant in both years. On the other hand, schools are not significantly positive in the change equation but are significant in both cross-sectional equations. Transportation facilities and proximity to markets are negatively related to the number of grain mills in the change equation. This is not surprising. With better transportation or closer markets, the milling activity shifts to the larger market centers. However, the level equations would tend to support the opposite conclusion. Finally, the change equation is capable of showing only a weak influence of population growth on grain mills, while the population density variables in the cross-sectional analysis suggest a very strong and systematic one. This is probably because population is correlated with some other favorable left out factors such as favorable climactic condition. We are clearly forced to reject the null hypothesis. The impact of infrastructure variables on agricultural investments cannot be investigated properly with cross-section data.

6. Summary and Conclusion

Rural electrification has a varied impact on agricultural development in India. In this analysis we have examined well irrigation, multiple cropping, grain mills, and agricultural innovations. One unique feature of this study is that the panel analysis is able to sort out changes over time which is just not possible in cross-sectional analysis. It has been demonstrated that if we had relied on cross-sectional results, we would have been mistaken to conclude, for example, that the existence of schools in villages is a cause of the development of grain mills. Panel analysis is a more strict test of the causes of development, since the fixed village characteristics cancel out when examining the change relationships.

Despite the ideal of the electricity planners to extend electricity to both backward and advanced regions, selective investment has been the rule for extending the central grid. The analysis indicates that the villages closer to cities and with larger populations are the first to receive electricity. Rural equity would dictate a more even distribution of investment in infrastructure. However, because of the extensive costs involved in extending electricity to sparsely populated, isolated village, the current method of rural electrification distribution probably is appropriate on efficiency grounds.

Rural electrification has significant direct and indirect effects on changes in well irrigation, but for total levels of irrigation we found little or no impact. The most direct impacts include investment in pumpsets. Over the short term the presence of electricity in a village means that electric pumps increase while investment in diesel pumps lags behind compared to levels in villages that have not yet been connected to the grid. This substitution of electric pumps for diesel ones is expectd because electricity prices are subsidized in India, and diesel is taxed. However, over the longer term, say after 10 years or so, there appears to be a greater investment in diesel as well as electric pumps. All of this private investment in pumps leads to an overall expansion of well irrigation in the villages. Thus, rural electrification has a direct impact on investment in pumps and an indirect impact on well irrigation through this private investment.

The findings also suggest that electricity has an impact on multiple cropping, but the findings are not as robust as for well irrigation. This is probably because multiple cropping involves a complex interaction among rainfall, soils, water availability, and other factors. Also, in findings not reported in the paper, neither electrification nor any other infrastructure investments appear to be related to the level of total irrigation. Perhaps climactic factors such as local levels of rainfall are more important than electrification for predicting the overall levels of irrigation, since much surface irrigation is directly related to rainfall levels. However, one suggestive trend is that well irrigation acocunted for less that 5% of total irrigation in 1966 and over 30% by 1980, which was a low rainfall year. Thus, future sporadic weather conditions may have less influence on the variability in irrigation because of the impact of rural electrification on well irrigation.

In contrast to the well irrigation findings, the growth of grain mills in villages is directly related to the number of years that a village has had electricity, and there even seems to be a higher rate of growth in later years. Since grain mills use electricity directly in the production process and for lighting, it is not surprising that there is a direct and long-term relationship between electricity and the growth of mills.

The popular idea that electricity has diffuse modernization effects that would in turn stimulate greater well irrigation regardless of the number of pumpsets cannot be confirmed by the research. For instance, for villages with similar levels of investment in pumps, there does not appear to be any diffuse impact of electricity in the change in well irrigation.

Rural electrification probably has an impact on agricultural innovations, but there is a specific type of time lag involved. Villages receiving electricity between 1966 and 1980 have higher innovation adoption rates than the other villages. However, villages which have had electricity 15 years or more have high levels of agricultural innovations, but they were not increasing these levels between 1966 and 1980. In other words, the impact of electricity appears to reach relatively high levels after a number of years, but subsequently innovations as measured in this study, do not improve that much. It may be that for the specific kinds of innovations measured in this research the villages reach a saturation point.

Although electricity is the primary focus, the findings for infrastructure reveal some interesting and some unexpected results. The findings support most other research on the relationship between education and development. Proximity to secondary and middle schools is related to increases in agricultural innovations, although we also found that schools were not related to irrigation change. We also have been able to analyze infrastructure that are not normally included in other research. These include proximity to banks, transportation, communications and others. One particularly interesting finding is that with increases in bank proximity there is more investment in motorized pumps and grain mills, both of which require significant capital expenditures. Change in proximity to transportation has a significant impact on agricultural innovations, but not on irrigation. As expected, proximity to markets has a positive impact on irrigation practices, but a negative influence on grain mills. Grain mills typically service a local economy, and they might be expected to decline in importance with the growth in more specialized markets.

Infrastructure in many cases is prescribed for all that ails a developing country. The perception is that once the necessary infrastructure such as electricity is extended to a village or region, then development will almost be automatic. While this research has uncovered strong evidence linking infrastructure and rural development, the process is not analogous to a general tonic. To the contrary, particular kinds of infrastructure are important for different aspects of the development process. For example, the construction of new schools may have a direct impact on rural literacy and education, but little or no impact on irrigation. Transportation on the other hand, is important for number of times agricultural extension agents visit a village to talk with a leader, but it may have little impact on agricultural innovations. The direct impact of infrastructure on development includes specific consequences such as an increase in agricultural pumpsets which may in turn have indirect consequences such improving well irrigation and consequently agricultural yields.

The notion that infrastructure is an important component of development has been sharpened and more clearly defined by this research. The lessons learned from the panel analysis are that government investments in infrastructure such as electricity are justified on the basis of both direct and indirect socioeconomic benefits. The impact of rural electrification also varies with the emphasis of government policy. It is worth mentioning that in India the government adopted a policy that electricity should be used for improving agricultural and rural productivity. In other countries the emphasis has been on rural household use of electricity, and in those countries there is little or no impact on agriculture. Thus, the extension of infrastructure to rural areas is not a magical force which automatically leads to balanced development of all kinds. This analysis demonstrates the effects of rural electrification and other infrastructure can be both varied and complementary.

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