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How Infrastructure and Financial Institutions Affect Agricultural Output and Investment in India

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and
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Prices matter — but so do banks, markets, and infrastructure.

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Agriculture

How do the decisions of farmers, financial institutions, and government agencies interact and affect agricultural investment and output in a region — and to what extent are these "actors" influenced by a region's location and agroclimatic endowments (for example, rainfall or the soil's moisture-holding capacity).

This paper is an attempt to quantify the relationships of key factors, using district-level time-series data from India.

Agricultural opportunities in a district are seen as the joint outcome of the agroclimatic endowments of the district and new technology that becomes available to it. Better agroclimatic opportunities improve output (relation 1), but also increase the economic return for a private farm investment — say, in a tractor (relation 2). Greater private profit in a well-endowed region induces farmers to press for more investment in infrastructure (relation 3). Financial institutions find it more profitable to locate where there is more demand for capital and more repayment capacity (relation 4) and where good infrastructure reduces their costs (relation 5). Private agricultural investment and use of input is more profitable the better the agricultural opportunities (relation 2), the better the infrastructure (relation 6), the cheaper the cost of financial services (relation 7), and the more favorable government's price and interest policies (relation 8). Exactly the same factors affect the output supply (relations 9, 10, 11). Traditional approaches to production function estimate the direct impact of capital stocks (investment) and input use on output (relation 12), ignoring many of the factors discussed here.

After comparing data on these factors, the authors conclude that:

• Agroclimatic factors continue to govern the rate at which districts can take advantage of new agricultural opportunities, and govern public, bank, and private investment decisions.

• The availability of banks (credit) is more important than the real interest rate as a factor in aggregate crop output and farmers' demand for fertilizer. Rapid bank expansion in an area increased fertilizer demand by about 23 percent, rates of investment in pumps 41 percent, in milk animals 46 percent, and in draft animals about 38 percent. Despite their impact on investment and fertilizer use, the impact of banks on output appears to be fairly small (nearly 3 percent).

• Unsurprisingly, commercial banks prefer to locate in well-watered areas where the risk of drought or flood is relatively low. Bank expansion is facilitated by government investments in roads and regulated markets, which improve farmers' liquidity and reduce banks' and farmers' transaction costs.

• In the 1970s, expansion of regulated markets contributed 4 percent to growth of agricultural output and 17 percent to demand for fertilizers. Expansion of electrification increased output 2 percent in a decade by increasing investment levels for pumps and fertilizer. A primary education added a large 8 percent to crop output over the decade, primarily by increasing fertilizer demand nearly 30 percent.

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THE IMPACT OF INFRASTRUCTURE AND FINANCIAL INSTITUTIONS ON AGRICULTURAL OUTPUT AND INVESTMENT IN INDIA

by

Hans P. Binswanger, Shahidur R. Khandker,
and Mark R. Rosenzweig

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I. Introduction

Government expenditure on physical infrastructure and human resource development influence the private production and investment decisions in agriculture and thus are essential ingredients of increased agricultural productivity. Government investments (both physical and human) can directly increase agricultural output by shifting the production frontier as in the case of irrigation. This is what might be called the direct effect of government infrastructure. Government investment also increases the rate of return to private agricultural investment and thereby leads to greater investment and output. Moreover, by increasing the viability and profitability of financial intermediaries, infrastructure can facilitate the emergence and growth of financial institutions that increase access to working and investment capital or reduce the costs of borrowing for long-term investment. Better credit facilities, by enabling the smoothing of consumption, may also increase the willingness of farmers to take risk.

1/ This paper would not have been feasible without the patient and persistent efforts of a large number of people who assembled, checked and processed the enormous data base required. The ICRISAT economics staff graciously provided their district data base for the semiarid tropics. Robert Evenson and Ann Judd in turn contributed their North India district data base. James Barbieri assembled the data required to update these data bases to 1982, added additional states, and collected the data on banking, on private capital stocks and investment. He was advised in this endeavor by Devendra B. Gupta who provided the liaison with the respective Indian authorities who were gracious to release data which were still in manuscript form. Dr. D.R. Gadgil opened the data base of NABARD and personally organized the
Continued on next page

Thus agricultural output and investment respond to the separate actions undertaken by three economic actors-- farmers, government agencies and banks. All three actors respond positively to agricultural opportunities implied in the agroclimatic endowments of a region and in new technologies when it becomes available. The magnitude of the effects depends on how each of the actors responds to agricultural opportunities and how farmers and banks respond to the government investment decisions. This paper seeks to quantify the inter-relationships among the investment decisions of government, financial institutions and farmers and their effects on agricultural investment and output.

The central problem of estimating these relationships is that, once government agencies and banks are admitted as actors who respond to agricultural opportunities, one can no longer take the distribution of government infrastructure and banking institutions as exogenously given or randomly distributed. The impact of government infrastructure on investment and output is likely to be more pronounced in a better endowed region than in a poor endowed region and governments will therefore invest more where opportunities are greater. The resulting unobserved variable problem may be circumvented by either a precise quantitative characterisation of the agroclimatic potential or by using the fixed effects technique of estimation. For analyzing growth in aggregate output

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Continued from previous page
assembly of the banking data. Apparao Katikineni organized the screening, and further computer processing of the many different and disparate data bases which had to be merged into a single data base. Kathy Graham did all of the cartographic measurements. We were also assisted by Sneylata Gupta and Dan Ghura.

both Binswanger, Yang, Bowers and Mundlak (BYBM, 1986) and Lau and Yotopoulos (1988) have implemented the appropriate fixed effects technique using time-series x cross section data of countries.[2]

The paper is structured in the following order. Section II outlines an analytical framework. Section III describes the data and discusses the variables. Section IV shows how various agroclimate variables affect government decision on where to build roads, markets and schools and where to provide electricity and canal irrigation. Section V looks at the joint impact of agroclimatic endowments and infrastructure on the growth of financial intermediaries. We do this in a cross-section and time series framework using district level data from India. Section VI then considers the joint determination of private agricultural investment as functions of agroclimatic endowments, technology change, infrastructure, financial intermediaries and of price and interest policy. In Section VII we estimate the impact of the same variables on fertilizer demand and aggregate crop output. The results are summarized in the concluding part of the paper.

II. Analytical Framework

In our framework (see Figure 1), agricultural opportunities in a district are the joint outcome of the agroclimatic endowments of the district and the new technology which becomes available to the district

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2/ Bapna, Binswanger and Quizon (BBQ, 1984) used random effects techniques to analyze output supply in time-series x cross section data of districts in India.

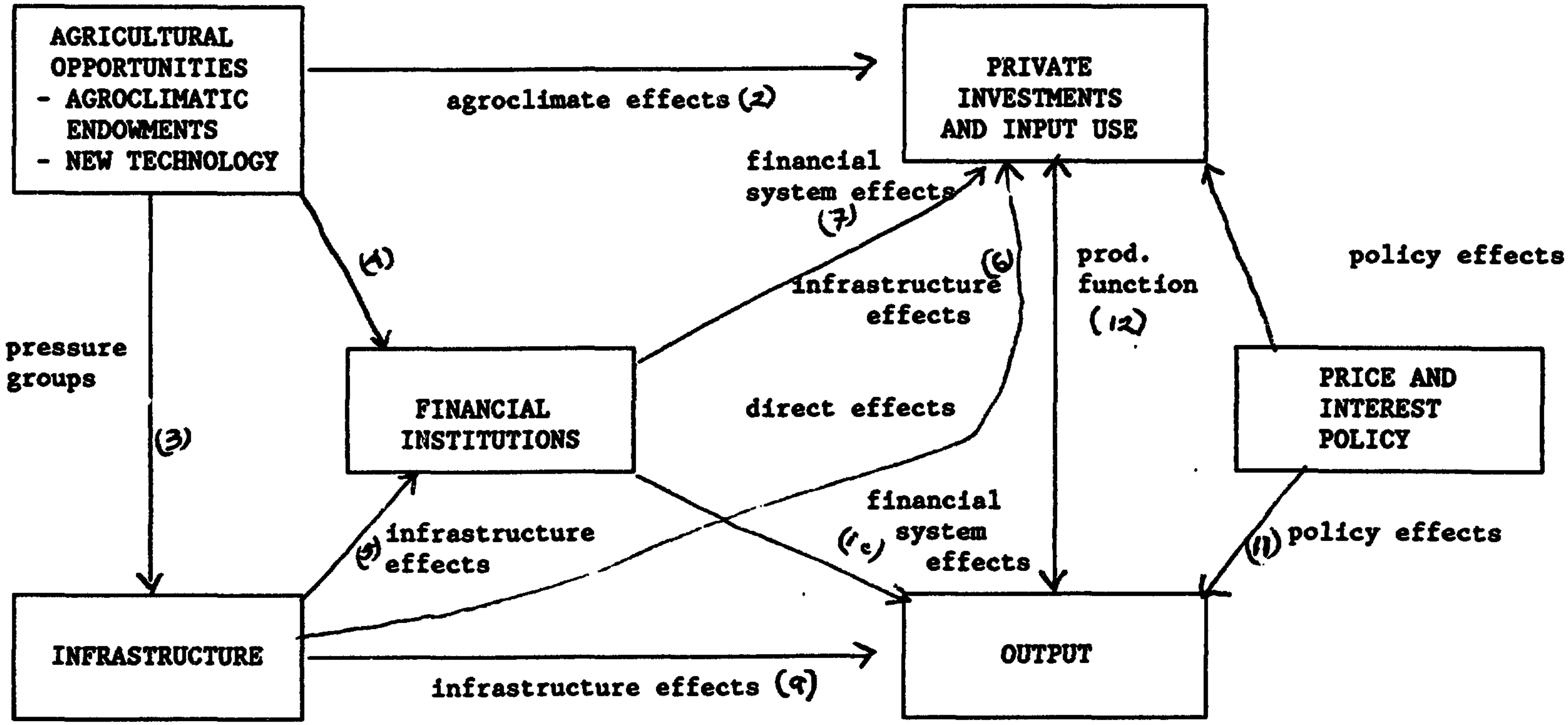

Figure 1: Major Relationships among Agroclimate Endowments, Financial Institutions, Government Infrastructure and Agricultural Investment and Output

from industry and from foreign, national and state research systems.[3] The same technology is potentially available to all districts, but the extent to which it is actually applicable to a given district depends on its agroclimatic endowments. For example high yielding varieties of wheat are not relevant for districts with high winter temperatures or districts with excessive amounts of rainfall and flooding problems. Thus the size and the growth of the set of agricultural opportunities varies across a district according to their agroclimatic characteristics.

Better agroclimatic opportunities such as better rainfall, a higher moisture holding capacity of the soil and a better irrigation potential directly affect agricultural output (relation 1). But better opportunities also increase the economic return to private farm investments such as tractors, draft animals or pumpsets (relation 2). The greater private profitability of agriculture in well endowed regions induces farmers to press government for <u>increased investment in the supportive infrastructure</u> (relation 3). <u>Financial institutions</u> find it more profitable to locate in environments where a good agroclimate and rapid technical change leads to a substantial demand for agricultural investment and working capital and a high repayment capacity (relation 4) and where good infrastructure reduces their cost of intermediation (relation 5). <u>Private agricultural investment</u> and input use is more profitable the better the agricultural opportunities (relation 2), the better the government

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3/ Although technology investments are themselves government decision variables, for the purpose of this paper technology is treated as exogenous to the decisionmaking of specific government agencies, banks and farmers when they make investment, location and input decisions.

infrastructure (relation 6), the cheaper the cost of financial services (relation 7) and the more favorable price and interest policies are which are pursued by the government (relation 8). Exactly the same factors affect the output supply. (relation 9, 10, 11). This means that agricultural opportunities must be translated into public and private investment efforts in order to affect agricultural output (For a discussion see BYBM, 1986 and Mundlak, 1985).

The traditional production function approach has attempted to estimate the direct impact of capital stocks (investment) and input use on output, (relation 12), ignoring much of the factors discussed here and all the simultaneity problems (see for example Hayami and Ruttan, 1986).[4]

Estimation Equations and Econometric Specifications

Let R_{rjt} be the level of the r-th infrastructure variable (say roads) in district j at time t. As agroclimate variables are strictly exogenous, the dependence of the infrastructure variables on a set of measured agroclimate variables and location factors σ_j can be estimated simply in a cross section regression

$$(1) \quad R_{rjt} = R_{rjt} \quad (\sigma_j, \mu_j, \epsilon_{jt})$$

4/ A profit-oriented producer will take input and output decisions jointly. In order to deal with this simultaneity, the correct way to estimate the production function (12) is to use the predicted instead of actual levels of capital stocks and other inputs. However, as clearly apparent from figure 1, we do not have any instruments which affect only the inputs but not the output. Therefore the production function cannot be estimated econometrically.

where μ_j is the effect of unmeasured agroclimatic and location factors, and ϵ_{jt} is a time-specific error term. [5]

Financial institutions in turn are assumed to locate in districts with good agroclimate and infrastructure, i.e.

$$(2) \quad B_{jt} = B_{jt} (R_{jt}, \sigma_j, \mu_j, T_{jt}, \epsilon_{jt})$$

where B_{jt} stands for the number of banks operating in the district at time t, T_{jt} is a region-and time-specific technology index, and ϵ_{jt} is an error term specific to the banking equation.

The simultaneity between banks, B_{jt}, and infrastructure, R_{jt}, arising from their joint dependence on unobserved agroclimatic variables, μ_j, can be overcome if an additive model is chosen such as

$$(3) \quad B_{jt} = a_0 + a_1 R_{jt} + a_2 \sigma_j + a_3 \mu_j + T_{jt} + \epsilon_{jt}$$

For the mean overtime in district j this relationship reads

$$(4) \quad \bar{B}_{j.} = a_0 + a_1 \bar{R}_{j.} + a_2 \sigma_j + a_3 \mu_j + \bar{T}_{j.} + \bar{\epsilon}_{j.} .$$

Taking the difference of these equations, i.e. by transforming the variables to differences from their means, leads to the following estimation equation in terms of difference from the means

$$(5) \quad (B_{jt} - \bar{B}_{j.}) = a_1 (R_{jt} - \bar{R}_{j.}) + (T_{jt} - \bar{T}_{j.}) + (\epsilon_{jt} - \epsilon_{j.})$$

5/ Similar ultimate reduced forms can be established for all other endogenous variables in the system, the banks, private investment and output. However, the reduced forms for output, for example, is not very informative as it includes both the direct or technical impact of the agroclimate on output (relation (1)) as well as all the indirect effects via its impact on infrastructure, banks and private investment.

As ϵ_{jt} is a randomly distributed error term which is uncorrelated with σ_j and R_{jt}, relationship (5) can be estimated by the Ordinary Least Squares technique.

The disadvantages of using this fixed effects model is that the direct impact of the agroclimate (i.e. relation (4)) cannot be estimated. [6] These direct effects could only be estimated (in this and all subsequent equations) if the infrastructure variables were randomly distributed across the districts, i.e. were not dependent on the unobserved agroclimatic variables μ_j. This could happen if the measurement of the observed agroclimatic variables σ_j were so good that no unobserved effects were left over to significantly affect the infrastructure investments. In that case a random effects model would be appropriate. We will use Hausman-Wu specification tests to determine whether to use the fixed effects or random effects model and present results accordingly.

Private agricultural investment in capital item k (say draft animals or tractors), depends on the agroclimate, the infrastructure and the banks. In addition it depends on policy variables such as the output price P, the fertilizer price P_f, and the real interest rate π, i.e.

$$(6) \quad I_{kjt} = I_{kjt}\,(K_{jt-1}, P_{fjt}, \pi_{jt}, B_{jt}, R_{jt}, T_{jt}, \sigma_j, \mu_j, \epsilon_{jt})$$

where K_{jt-1} is the capital stock of year (t-1). In these equations the

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6/ As discussed in footnote 1, it cannot be estimated either in a reduced form equation of the form of equation (1).

simultaneity problem between B_{jt}, R_{jt}, and μ_j can be overcome just as for equation (3) by using the fixed effects technique. For the interest rate, however, a simultaneous equation problem may arise if higher investments demand leads credit suppliers to raise the interest rate. In the application below this problem is minimized by the fact that the interest rate used is fixed by the government of India. Only if the government specifically takes agricultural investment demand (rather than more aggregate credit conditions) into account in fixing the interest rate will the simultaneity problem persist. For the other prices a simultaneity can also arise if increased investment leads to higher output supply (and fertilizer demand) and therefore lower output prices (higher fertilizer prices). The fertilizer price used below is the railhead price set by the government and the endogeneity problem is likely to be minimal. However, in order to overcome the simultaneity problem associated with output prices we use an index of international commodity prices as an instrumental variable for the domestic price index. As India is a small country in virtually all international agricultural commodity markets, this completely eliminates the simultaneity bias.[7] The index of international commodity prices is computed separately for each district using district-specific production weights for the year 1975. Since agricultural wages are clearly endogenously determined with agricultural output and investment we replace this variable with state-specific urban wages as an instrument.

7/ India has state trade in agriculture. So the domestic prices do not correspond in any simple way to international prices. Nevertheless, estimates show that domestic prices respond positively to international prices, with a lag of 3 to 4 years.

As can be seen from figure 1, the variables entering the aggregate crop supply equations are exactly the same as those entering the investment equation and all estimation problems are the same.

Obviously no data exist on the district-specific index of available (but not necessarily implemented) technology T_{jt}. Evenson and Kislev (1975), BYBM (1986) and others used expenditure data, or manpower data for public research and for extension. (Alternatively Boyce and Evenson (1975) has used research publications). However, data for these variables do not exist at the district level. Moreover they do not include technology opportunities arising from private industry and seed corporations. Other researchers have used simple time trends to proxy technology opportunities (e.g. Binswanger, 1974). However, simple time trends assume technology opportunities grow at constant and identical rates in each district. But the point is that agroclimatic endowments affect the extent to which new technology options are applicable to a district. Hence technology trends must differ across districts. If, for example, banks systematically located in districts where the green revolution had raised the input and borrowing requirements of farmers, an output supply function including common time trends and banks would erroneously allocate to banks a part of the output contribution of technology, i.e. the coefficient of banks would be upwards biased. In order to circumvent this problem the district specific technology trend is entered into the models as follows:

$$(7)\quad T_{jt} = \sum_{m} b_m \sigma_{mj}\, t + b_t t$$

The regression include a common time trend and interaction terms of all the agroclimatic variables with the time trend, and the district specific time trend is an estimated function of time and time x climate interactions.[8] For example in the output supply equation one would expect the interaction between time and irrigation potential to be positive, consistent because high yielding varieties of rice and wheat require good control over water and soil moisture.

III. Data and Variables

The data we have used here are drawn from India. The cross-section units are 85 randomly drawn districts of India. These 85 districts belong to 13 states of India--Andhra Pradesh, Bihar, Gujarat, Haryana, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. The 85 districts are part of the 99 districts from 17 states randomly drawn by the India's National Council for Applied Economics for its well known Additional Rural Income Survey.[9] The period covered in this paper is the agricultural years 1960/61 to 1981/82. The study period covers the agricultural years 1960/61 to 1981/82, but for some dependent variables with more limited data availability shorter periods are used.

8/ Alternatively one could introduce a trend for each district separately as in Lau and Yotopoulos.

9/ In fact, 80 districts are drawn from NCAER sample, while the remaining 5 districts are the ICRISAT districts. All NCAER districts could not be included because of deficiencies in the data for both primary and secondary districts.

TABLE 1: Descriptive Statistics of Variables

Variable	Number of Observations	Mean	Standard Deviation
Dependent variables			
Aggregate crop output index	1785	1.192	1.045
Fertilizer consumption, nutrient tons/10 sq. km	1148	22.054	924.045
Net investment in draft animals; numbers per year/10 Sq.Km	304	4.962	15.504
Net investment in tractors; numbers per year/10 Sq.Km	304	0.119	0.260
Net investment in pumps; numbers per year/10 Sq.Km	304	1.343	1.864
Net investment in milk animals; numbers per year/10 Sq.Km	304	13.555	25.489
Net investment in small stocks; numbers per year/10 Sq.Km	.304	5.308	15.291
Rural population, numbers/10 Sq.Km	1785	2070.304	1547.327
Time-varying independent variables			
Canal irrigation, '000 ha/10 Sq.Km	1785	0.064	0.099
Number of villages with primary schools/10 sq. km	1785	1.139	0.605
Electrified villages, numbers/10 Sq.Km	1785	0.688	0.764
Commercial banks, numbers/10 Sq. Km	1785	0.069	0.108
Regulated markets, numbers/10 Sq.Km	1785	0.014	0.022
Road length, '000 km/10 Sq.Km	1785	4.389	4.277
Real interest rate of cooperative societies	1785	4.010	4.485
Aggregate real domestic crop - price index	1785	0.968	0.295
Aggregate Real International Price index	1785	0.687	0.355
Real urban wage (annual earnings)	1785	4186.336	1195.586
Real fertilizer price index	1785	3.413	0.505
Annual rainfall (in mm)	1785	1138.573	986.503
Time-invariant independent variables			
Length of rainy season in months	85	3.653	1.368
Number of excess rainy months	85	1.236	1.393
Number of cool months (Temp < 18°)	85	0.935	1.313
Percentage of district area liable to flooding	85	1.389	3.531
Irrigation potential, percentage	85	30.001	31.897
Urban distance (km)	85	298.441	152.029
Soil moisture capacity index	85	2.350	1.009

For each district the aggregate crop output is the index of 20 major crops with district-specific prices of 1975/76 as the base. Agricultural investment is represented by private investment in draft animals, milk animals, small stock (i.e. sheep and goats), tractor, and irrigation pump. Investment for each period is the difference in the stocks measured for each of the agricultural censuses which occurred at five year or six year intervals. It is therefore net investment per year during each of four intercensal intervals. Government infrastructure consists of primary schools, canal irrigation, rural electrification, regulated rural markets, and total road length. The only rural financial intermediary is the number of rural branches of Commercial Banks--the only comparable data available for the study period 1960-81. The variables that characterize the district's agroclimate environment are the irrigation potential, the length of the rainy season in months, the number of months in a year with excessive rain (where rainfall exceeds potential evapotranspiration),[10] the number of cool months in a year when mean temperature is less than 18 degree Farenheit (this is related to the ability to grow wheat), the proportion of a district liable to flooding, an index of the moisture capacity of the soils in the district, and the district's distance to the nearest major urban center (out of eight centers i.e., Delhi, Bombey, Madras, Banglore, Kanpur, Ahmedabad, Hyderabad and Calcutta). The price variables consist of the annual per capita earnings of industrial workers as a proxy for urban wages, a price index of fertilizers at railheads, the rate of interest charged by the Primary Agricultural Cooperative Societies, and the district specific real

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10/ Evapotranspiration is a sum of transpiration via plants and evaporation from soil.

international price index for the aggregate output. The international prices of 17 crops have been converted to Rupees at the official exchange rate and aggregated using district-specific production weights for the agricultural year 1975/76. Domestic price indices using district level farm harvest prices have also been computed for comparison. All the prices or price indices are deflated by the consumer price index for rural workers using 1975/76 as the base year. The interest rate charged by cooperative credit societies is the expected real rate i.e., the nominal rate for the current year less the average percentage increase in the consumer price index for the previous five year, i.e. inflationary expectations are assumed to form over a five-year period.[11] The means and standard deviations of these variables are listed in table 1.

The data relating to the agroclimate and the urban distance are single data points for each of the 85 district, because they are the permanent characteristics of each district. The data relating to agricultural output, government investment, prices and Commercial Banks are time-series data covering the period, 1960/61-1981/82. In contrast, the investment data refer to the four intercensal periods 1961-66, 1966-72, 1972-77, 1977-82. When investment equations are estimated the independent variables are their respective means over the corresponding census intervals.

11/ In both the output supply and investment equations, the inflation rates are averaged over five years, except for the years prior to 1965 where data limitation led us to use averages for 2, 3 and 4 years respectively. The rate of inflation did not fluctuate sharply in the late fifties, or early sixties.

The following variables require additional explanation: The aggregate output index reflect both variation over time in each district relative to its base year 1975 as well as variations in output across districts relative to a hypothetical average district formed by computing the averages of all variables across districts in 1975. The agregate output is normalized for district size, i.e. it compares aggregate "yields" per unit of geographic area. When fixed effect techniques are used the across- district variability is of course lost.

Regulated markets do not include all rural markets but only those where government provides market infrastructure and regulates all trades via a supervised auction system. The government does not regulate the market price but may enter as a purchaser in order to prevent market prices from falling below its guaranteed level.

The rural banking system is complex. It consist of traditional moneylenders and traders for whom no data exist. Cooperative credit societies were the first formal institutions to achieve wide rural coverage. They lend largely for short-term production purposes such as fertilizers. By 1969 such societies existed in virtually all districts of India covering 94 percent of the villages in the country and they were providing 51 percent of total formal credit extended to famers. Their number has been declining as smaller societies have been merged in recent years. Yet by 1979 they were providing 49 percent of all formal credit. We include the regulated government lending rate of these societies among the explanatory variables. At this regulated interest rate credit rationing is pervasive and we test whether the rate has an influence on output and investment despite the rationing. Land Development Banks are also cooperative institutions which lend primarily for investment purposes. Between 1969 and 1979 their share of lending in formal credit increased from 15 percent to 19 percent. Their lending rates are closely tied to the official rates of the Cooperative Credit Societies, i.e. the interest variable will capture the effect of interest rate changes of both the cooperative credit societies and the Land Development Banks.

The Commercial Banks, in 1960, were not involved in lending to farmers except perhaps to plantations and very wealthy farmers. However, they did considerable lending to agroindustrial enterprises. After their nationalization in 1969 they were compelled by the government to expand their lending to farmers and agroindustry with targets set both for number of rural branches as well as the proportion of lending to the agricultural sector. Between 1969 and 1979 the share of commercial banks in formal credit provided to farmers rose from 34 percent to 49 percent at the all India level. In the 85 districts considered here the role of commercial banks rose even farther. Their share in formal credit rose from 52 percent in 1972 to 72 percent in 1979. At the same time the number of rural and semi-urban commercial bank branches rose from 3,625 to 7,690. Unlike the volume of lending and outstanding loans in any period, which is influenced by farmer demand, the number of branches is strictly controlled by the Banks and therefore strictly exogenous to farmer decision making. Other than for the joint dependence of farmer and bank decision making on agroclimatic and infrastructure variables, no endogeneity problem therefore arises. Unfortunately the number of Cooperative Societies and Land Development Banks cannot be used in these equations as exogenous measure of the growth of these systems because the process of consolidation has reduced their numbers but not necessarily the availability of their services in the affected villages.

Soil moisture capacity is a variable which can be viewed as a substitute for either rainfall or irrigation. For a given rainfall a higher soil moisture capacity means that a crop can withstand more days without additional rainfall. In addition where soil moisture capacity is very high, a full moisture reservoir in the soil may be able to support several months of a crop cycle without the addition of rainfall or irrigation. For given annual rainfall, payoffs to irrigation investments are therefore more limited where soil moisture capacity is higher.

Irrigation potential is defined as the percentage of a district's area inside any type of irrigation command area, i.e., sum of proposed command area, command area under construction and already existing command area.[12] This variable has been measured using the Irrigation Atlas of India. Planned command areas are a good indicator of the remaining potential for canal irrigation in India as they reflect long range plans and any area not yet included in these plans has virtually no potential.

IV. Agroclimatic Endowments, Infrastructure, Population and Crop Output

In Table 2 we see that the seven measured agroclimatic and location factors explain between 24 percent of the variation in the density of primary schools to 41 percent of the variation in government provided

12/ An irrigation command area is an area which receives or is expected to receive water from an irrigation system.

Table 2: Effects of Agroclimate Endowments on Infrastructure, Population and Aggregate Crop Output

(Observation = 85)

Explanatory Variables	Rural Road	Regulated Market	Canal Irrigation	Primary School	Electricity	Rural Population	Aggregate Crop Output
Cool months	-0.222	0.004	0.012	0.303	0.389	285.725	0.229
	(-0.587)	(1.647)*	(1.559)	(4.770)*	(4.293)*	(2.261)*	(2.417)*
Excess rain	0.229	-0.002	-0.001	-0.041	0.009	425.138	0.019
	(0.477)	(-0.751)	(-0.067)	(0.077)	(2.679)*	(2.679)*	(0.158)
Rainy season	2.442	-0.004	0.007	0.079	0.089	541.396	0.264
	(4.901)*	(-0.140)	(0.708)	(0.988)	(0.775)	(3.386)*	(2.200)*
Flood potential	-0.077	-0.001	-0.004	0.021	-0.064	-10.649	-0.094
	(-0.509)	(-1.622)*	(-1.234)	(0.852)	(-1.825)*	(-0.220)	(-2.574)*
Irrigation potential	0.033	0.001	0.002	0.003	0.009	20.589	0.034
	(1.935)*	(5.372)*	(6.706)*	(1.127)	(2.332)*	(3.712)*	(8.252)*
Soil moisture capacity	0.422	0.004	-0.019	0.115	0.231	-146.535	0.102
	(1.670)*	(2.827)*	(-2.187)*	(2.159)*	(-0.982)	(-0.034)	(0.914)
Urban distance	-0.003	0.00004	0.0001	-0.0002	-0.001	-0.671	0.034
	(-0.118)	(2.331)*	(2.266)*	(-0.320)	(-1.419)	(-0.625)	(0.026)
Constant	-4.218	-0.014	-0.018	0.586	0.185	-415.025	-0.804
	(-1.692)*	(-0.978)	(-0.384)	(1.474)	(0.326)	(-0.524)	(-1.352)
Adjusted R-square	0.37	0.36	0.43	0.24	0.28	0.41	0.53

Notes: t-Statistics are in parentheses. Asterisk refers to significance level of 10 percent or better. Rural road corresponds to the agricultural year 1974, while the remaining variables relate to agricultural year 1981.

irrigation and the population density of the region. The explanatory power is thus very substantial, not much smaller than that for output itself (53 percent). The traditional treatment of agricultural infrastructure as exogenous variables in output supply analysis is unwarranted.

The variable with the most powerful effect across the equations is irrigation potential, i.e. the proportion of the area which is included in an existing or planned irrigation command area. It significantly increases the density of all infrastructure variables, except schools. It is also clear that population has migrated to, or grown more rapidly in regions with a high irrigation potential, i.e. private and public decisions are influenced by the same factors.

For the other variables the impact varies substantially across the government investments. Regions with a fairly cool winter, which are able to grow wheat, have higher density of regulated markets, more primary schools, more electrification and higher population density. Population density is also very high in regions with many months with excess rain, i.e. the humid tropical zones such as Kerala. Population and roads are higher the longer the rainy season, or said otherwise, government has found it less worthwhile to build roads in semiarid and arid regions. Areas which are liable to flooding are not well served by regulated markets, roads, and electrification. As discussed in the data section, the results show that high soil moisture capacity acts as a substitute for canal irrigation. But high soil moisture capacity is a positive agroclimatic attribute and thus attracts investment in regulated markets, roads and in electrification. Distance to major urban centers tends to increase the

Distance to major urban centers tends to increase the density of regulated rural markets, and also the level of government provided irrigation.

One point which stands out from the regressions is that for the purpose of government infrastructure investments, agroclimatic potential cannot be measured by a single variable or an agroclimatic index. Different aspects of the endowment affect the government investments differentially.

The total effects--both direct and indirect effects via government infrastructure and banks--of agroclimate and location factors on output supply are also shown in table 2. They suggest that agroclimatic endowments explain 53 percent of the variation in agricultural production of 85 districts in the agricultural year, 1981. Agricultural output supply is high in regions well endowed with water from either irrigation or rainfall. Regions with a relatively cool winter have high agricultural output while agricultural output is low in regions with a high flood potential. All the effects are as expected.

Using data for the three census years (1961, 1970, 1981) we investigate in table 3 whether the investment trends over the past two decades were similiarly influenced by the agroclimatic characteristics. This is done in regressions which include time trends according to equation 7, i.e. interactions between time and the agroclimatic characteristics. The Hausman-Wu test suggests that a fixed effects model is appropriate for explaining variation in public infrastructure over time, while a random effects model can be used for rural population growth.

TABLE 3. Effects of Agroclimate Endowments on Growth in Infrastructure and Population.
(Obs. = 255)

Explanatory Variable	Regulated Market Fixed Effects	Canal Irrigation Fixed Effects	Primary School Fixed Effects	Rural Electrification Fixed Effects	Rural Population Random Effects
Year	0.0005	0.0001	0.008	-0.004	0.283
	(1.514)	(0.102)	(1.023)	(-0.222)	(0.034)
Year x cool months	0.0001	-0.000	0.010	0.018	4.643
	(1.824)*	(-0.237)	(7.532)*	(5.329)*	(3.229)*
Year x excess rain	-0.000	0.0005	-0.001	-0.001	6.186
	(-0.283)	(3.269)*	(-0.525)	(-0.305)	(3.540)*
Year x flood potential	-0.000	0.0001	0.0002	-0.002	-0.163
	(-2.053)*	(1.149)	(0.411)	(-1.642)*	(-0.301)
Year x irrigation potential	0.000	0.000	-0.000	0.0004	0.235
	(5.583)*	(2.152)*	(-0.455)	(2.489)*	(3.757)*
Year x soil moisture capacity	0.000	-0.000	0.005	0.011	-1.847
	(0.184)	(-0.125)	(3.132)*	(2.801)*	(-1.085)
No. of cool months					-96.323
					(0.648)
Excess rain					-79.314
					(-0.431)
Rainy season					121.471
					(0.644)
Flood potential					0.253
					(0.004)
Irrigation potential					1.835
					(0.283)
Soil moisture capacity					-1.405
					(0.008)
Urban distance					-0.494
					(0.534)
Constant					-494.956
					(-0.852)
F-Statistic	32.152	5.148	63.427	38.991	55.113
Hausman-Wu (Chi-square,7)	15.222	19.274	20.482	22.328	1.364

Note: Asterisk refers to significance level of 10 percent or better on a two-tail test.

The results are consistent with the simple cross section results. They suggest that better agroclimatic attributes such as irrigation potential contribute to the growth in public infrastructure as well as population, while unfavorable attributes such as flood potential reduces their growth over time. This clearly indicates that agroclimatic endowments did not only affect the placement of public programs and institutions in the distant past, but also their growth over the study period.

V. Development of Commercial Banks

In Table 4 the cross-section results indicate that Commercial Banks have tended to locate in areas which are well endowed with water, either from irrigation or from a long and over-abundant rainy season. Such areas are characterized by relatively low risk of agriculture and therefore less repayment problems for the banks (Binswanger and Rosenzweig, 1986). Th. implies that the banks have avoided areas where drought risk is high. That banks try to avoid high-risk areas, is also apparent in the negative coefficient of flooding potential.

The simple cross section relation for the year 1980 included the indirect effects of the agroclimate on Bank, via the improved infrastructure. The pure infrastructure effects, on the other hand, are estimated and presented in Table 4 using the cross-section time-series data of 85 districts for the years 1972-80. As the results of the Hausman-Wu test suggest, the fixed effects model appears more appropriate than the random effects model in explaining the variation in the bank growth over time and only the fixed effects results are therefore shown. The

TABLE 4: Effects of Agroclimatic Endowments and Government Infrastructure on Commercial Bank

Explanatory Variable	Cross-section effects (observations = 85) Year 1980	Fixed effects (observations = 765)
Canal irrigation[a]		-0.193 (-2.190)*
Regulated Market[a]		0.196 (3.227)*
Primary School[a]		0.026 (0.077)
Rural Electrification[a]		-0.115 (-1.457)
Road[a]		0.821 (4.584)*
Year		-0.011 (-4.873)*
Year x Cool Months		0.002 (3.835)*
Year x Length of Rainy season		0.002 (4.514)*
Year x Flood Potential		-0.001 (-3.983)*
Year x Irrigation Potential		0.0001 (6.639)*
Year x Soil Moisture Capacity		-0.0001 (-0.093)
Year x Excess Rain Months		0.005 (11.372)*
No. of Cool Months	0.016 (1.156)	
Length of Rainy Season	0.046 (2.735)*	
Flood Potential	-0.010 (-1.992)*	
Irrigation Potential	0.002 (3.848)*	
Soil Moisture Capacity	0.0002 (0.068)	
Excess Rain Months	0.050 (2.985)*	
Urban Distance[a]	-0.205 (-0.089)	
Constant	-0.132 (-1.570)	
F-Statistic	6.90	94.792
Hausman-Wu (Chi-square, 12)		51.631

NOTE: t-Statistics are in parenthesis. Asterisk refers to significance level of 10 percent or better.
[a] Coefficients of these variables are in elasticity form.

regression clearly shows that Banks are more likely to locate in areas where the road infrastructure and the marketing system are improving. Markets provide both higher incomes to producers and reduce the price risk they face, i.e. they improve their repayment capacity. And roads have an effect on farmer income, demand for inputs and hence credit and they reduce the credit transactions costs of both the customers and the banks. Of the two variables, roads have the most powerful effect with an elasticity of about 0.83, followed by regulated markets with an elasticity of 0.20. Markets, of course, are a relatively cheap investment which can be increased much more rapidly than roads. Rural electrification does not contribute to Bank growth. Indeed it has a negative effect which is statistically significant at the 10 percent level.

The time trend and the interaction effects with time confirm that Bank growth has been more rapid in districts with a high irrigation potential, where the rainy season is longer, and where cool months allow for the growth of wheat. This is fully consistent with the hypothesis that banks have systematically located in environments which were favorable to the green revolution technologies; i.e. that banks responded to opportunities created by technical change. In addition bank growth was lower where the flood potentially high, i.e. where they face higher risk and where green revolution technology is less applicable because of lack of water control.

VI. Determinants of Private Investment

The investment data in table 5 relate to average annual levels of investment for each of the intercensus intervals for which we have data.

Table 5. Effects of Agroclimatic Endowments, Government Infrastructure, Commercial Bank and Prices on Agricultural Investment

(No. of Observations = 304)

Explanatory variable	Investment in: Draft animals	Milk animals	Small stocks	Pumps	Tractors
Aggregate real international price, lagged [a]	2.896	1.007	1.697	-0.497	-0.076
	(3.709)*	(2.358)*	(2.163)*	(-1.327)	(-0.197)
Real fertilizer price [a]	-12.252	-6.396	-7.636	-1.140	-1.127
	(-4.292)*	(-4.139)*	(-2.662)*	(-0.834)	(-0.799)
Real urban wage [a]	5.665	3.405	2.105	-0.470	1.127
	(5.305)*	(5.884)*	(1.977)*	(-0.922)	(2.284)*
Real interest rate [a]	-0.586	-0.115	-0.302	-0.109	0.092
	(-3.033)*	(-1.103)	(-1.591)§	(-1.162)	(0.962)
Roads [a]	-2.128	-1.443	1.185	0.107	0.319
	(-3.228)*	(-4.002)*	(1.806)*	(0.362)	(0.983)
Canal irrigation [a]	-0.198	-0.074	0.756	-0.057	0.481
	(-0.327)	(-0.220)	(1.238)	(-0.250)	(1.610)§
Primary schools [a]	3.815	0.585	-0.949	-0.782	0.037
	(2.341)*	(0.665)	(-0.596)	(-1.233)	(0.047)
Electrification [a]	0.713	0.520	-0.157	0.356	-0.031
	(1.957)*	(2.634)*	(-0.428)	(2.072)*	(-0.173)
Commercial banks [a]	0.536	0.849	0.657	0.375	0.143
	(2.492)*	(7.146)*	(3.045)*	(3.605)*	(1.310)§
Regulated markets [a]	-0.065	0.212	0.225	-0.041	0.158
	(-0.184)	(1.119)	(0.649)	(-0.246)	(0.910)
Rainfall x 10^3	1.505	11.309	-8.241	0.287	0.042
	(0.362)	(1.801)*	(-1.871)*	(0.711)	(0.857)
Past stock	-0.183	-0.068	-0.139	-0.047	0.134
	(-12.625)*	(-2.099)*	(-12.056)*	(-4.983)*	(10.704)*
Year	-1.740	-1.160	-0.773	0.104	0.002
	(-3.199)*	(-1.438)	(-1.340)	(1.412)	(0.259)
Year x cool months	0.083	-0.289	0.408	0.028	0.002
	(0.813)	(-1.912)*	(3.743)*	(2.119)*	(1.485)
Year x rainy season	0.135	0.693	0.127	-0.001	-0.001
	(1.112)	(3.870)*	(0.997)	(-0.904)	(-0.749)
Year x flood potential	0.003	0.027	0.081	0.002	0.0003
	(0.088)	(0.479)	(2.002)*	(0.473)	(0.067)
Year x irrigation potential	0.004	0.004	-0.010	0.0001	0.001
	(0.904)	(0.606)	(-2.256)*	(0.262)	(2.503)*
Year x Soil moisture capacity	0.134	-0.218	0.096	-0.000	0.001
	(1.176)	(-1.299)	(0.791)	(-0.002)	(0.078)
Year x excess rain months	0.121	-0.684	-0.307	-0.014	-0.002
	(1.130)	(-4.326)*	(-2.747)*	(-0.968)	(-1.780)*

CONT'D

Explanatory variable	Investment in: Draft animals	Milk animals	Small stocks	Pumps	Tractors
Length of rainy season	-4.362	-43.948	-10.125	-0.096	0.039
	(-0.431)	(-2.891)*	(-0.934)	(-0.083)	(0.336)
Flood potential	-0.781	-2.918	-5.104	-0.133	-0.001
	(-0.218)	(-0.539)	(-1.314)	(-0.325)	(-0.017)
Irrigation potential	-0.037	-0.211	-0.018	-0.015	-0.012
	(-0.096)	(-0.360)	(-0.086)	(-0.342)	(-2.396)*
Soil moisture capacity	-14.200	10.765	-14.375	0.283	0.002
	(-1.375)	(0.689)	(-1.277)	(0.239)	(0.013)
Excess rain months	-4.644	48.592	16.868	0.707	0.155
	(-0.484)	(3.352)*	(1.620)*	(0.635)	(1.357)
Urban distance [a]	-0.035	-0.030	-0.062	-0.004	-0.0003
	(-0.840)	(-0.459)	(-1.321)	(-1.243)	(-0.528)
No. of cool months	1.652	25.946	-21.461	-2.007	-0.113
	(0.194)	(2.023)*	(-2.321)*	(-2.024)*	(-1.101)
Constant	178.718	121.793	198.410	-1.450	-0.032
	(3.319)*	(1.489)	(3.361)*	(-0.229)	(-0.050)
F-Statistic	15.188	20.951	8.979	4.282	21.599
Hausman-Wu (Chi-square, 19 df)	20.808	16.420	21.161	10.574	11.150

Notes: t-Statistics are in parenthesis. Asterisk refers to significance level of 10 percent or better on a two-tail test.

[a] Coefficients of these variables are in elasticity form.

§ refers to significance level of 10 percent or better on a single-tail test.

The independent variables similarly are the means for the intercensal periods of the corresponding data. Unlike in the banking equation which used annual data and where fixed effects model were appropriate, the random effects model is not rejected for the investment equations which used four census data.

The lagged price of aggregate crop output (instrumented by the aggregate international price index) has a positive effect on three of the classes of investment (draft animals, milk animals and small stocks). For the animals the elasticities of investment with respect to price are between 1.0 and 2.9, i.e. much higher than typical values of output supply elasticities for individual crops. But note that these elasticities are investment elasticities and investment can be postponed and is therefore much more volatile than current planned output. The elasticities of the investment equations can therefore not be directly compared to output supply elasticities. An increase in the price of fertilizer reduces private investment of all categories although the effect is not statistically significant for pumps and tractors. If an investment good, for example, draft animals were a substitute for fertilizer we should see a positive substitution effect. But an increase in fertilizer price also means reduced farm profits and perhaps reduced liquidity, resulting in a negative effect on investment. The negative fertilizer price elasticities of the investments suggest that the negative profit or liquidity effects dominate the positive substitution effect of fertilizer price increases.

If the urban wage measures the opportunity cost of labor in agriculture, then its increase means both a positive cross-price effect (if labor and capital goods are substitutes in production) and a negative profitability effect on farm capital investment. Unlike for the fertilizer price, the positive substitution effects appear to dominate the negative profit effects.[13] The results suggest that a 10 percent increase in urban wages would increase annual investment (not capital stocks) in draft animals by about 57 percent, and in tractors by about 11 percent, milk animals by about 34 percent, and small stocks by 21 percent. Rising interest rates have negative effects on draft animals, milk animals, small stocks and pump investments, but only the effects for draft animals and small stock are statistically significant. Overall the price and interest variables are seen to influence investment decisions in the expected direction.

Of the infrastructure variables the expansion of the commercial bank branches appears to most clearly accelerate the pace of private agricultural investment. A 10 percent increase in the number of commercial bank branches increases investment in animals and pumpsets by between 4 to 8 percent. The effects on tractors is 1.4 percent. These are substantial effects of bank expansion on investments.

A 10 percent increase in electrified villages increases investment into pumps (which are often driven by electricity) by 4 percent. Barnes and Binswanger (1986), using fixed effects technique with Indian village data, also found that electricity tended to increase the number of pumpsets

13/ The effects of urban wage may also capture the impact of an exogenous increase in urban income on the demand for agricultural output. These effects are expected to be positive which then only reinforce the positive substitution effects.

in the villages. The increase in electrification is also seen to spur investment in draft and milk animals by 7 and 5 percent respectively. These are effects of electrification which had not previously been demonstrated.

Canal irrigation should not be expected to reduce any of the investments, except for that pumpsets, which can be substituted for canal irrigation. The results suggest that canal irrigation increases investment in tractors with an elasticity of 0.48. The estimated positive effect on small stocks investment is not statistically significant.

The effects of road expansion on investments are not very convincing as roads appear to reduce investment in draft and milk animals and increase investment in small stocks. This may partly be because the growth data for roads is derived from state level statistics and does not differ across the districts within a state. (However the level data for roads for 1974 were available). Neither is it possible to show any effect for regulated markets. Primary school expansion increases draft animal investment, while favorable rainfall within the census interval increases only investment in milk animals.

The only comparable study using fixed effects techniques is the BYBM study of tractor stocks which include a number of similar explanatory variables. Unlike in the present study aggregate prices (both crop and livestock) tend to increase tractor stocks with an elasticity of 0.16. Fertilizer prices also reduced tractor stocks while urban wages increased it (but not significantly). Again in contrast to the current results roads and irrigation both had statistically significant positive effects on tractor stocks.

The investment equations include the past stocks of the capital item. Except for tractors, the higher the past stocks, the lower the current investment, i.e., there is clearly stock adjustment. For tractors, on the other hand, investment is much more rapid where past stocks are larger. Tractor stocks were very small in India in 1961, with an average of only 0.14 tractors per 10 sq. km. By 1982 this number had risen to 2.58. Unlike for the other capital items the tractor equation includes both technology adoption and investment phenomena. The adoption process has not yet run its full course. It is therefore not surprising to see districts with an early lead in tractor stocks experiencing higher rate of adoption-cum-investment, as an early lead may indicate better development of the supporting sales and service infrastructure which is not measured.

The investment equations include the agroclimatic characteristics themselves and their interaction with time. Together with the time trend the interaction terms form the district-specific time trends. From the interaction terms we can therefore see that investment in all items except milk animals grew more rapidly in areas with more cool months, consistent with a strong response of private investment to the green revolution in wheat.

Tractors investment was less in areas with excess rain but more rapidly in districts with a high irrigation potential, i.e. areas where on account of double cropping demand for tractors is particularly high. Milk animal investment was higher where the rainy season was longer while smallstock, i.e. sheep and goats grew less in areas with high moisture — either from irrigation or from excess rain.

The pure effects of agroclimate variables themselves are their net impacts other than via their impact on growth of infrastructure, changes in prices or new technology. If investment tends to eventually bring capital stocks into equilibrium with respect to agricultural opportunities, net investment should become zero in the absence of other changes and no effect of the agroclimatic factors should show up. This tendency can indeed be seen in the resulting coefficients: only 7 out of a total of 35 are statistically significant. This compares to 10 statistically significant effects of the interaction terms with time (out of the same total of 35). Since the expected sign of the agroclimatic variables in the investment equations is zero, it is not worth interpreting them.

VII. Determinants of Fertilizer Demand and Aggregate Crop Output

For fertilizer demand and output supply the fixed effects model has to be used. The measured permanent district characteristics are therefore not sufficient to fully characterize the endowment of a district. Fertilizer demand is seen to decline significantly when the price of fertilizers is increased (elasticity of -0.57) and to increase when the urban wage rises (elasticity of 0.13). This effect is statistically significant if the appropriate one-tail test is used, as it makes no sense to expect a negative sign here. In contrast, we see a perverse positive interest elasticity, but the effect is not statistically significant.[14] A positive interest rate effect may indicate that there is still an

14/ Since a positive sign expectation makes no economic sense in this case a one-tail test is inappropriate.

unresolved simultaneity problem with respect to this variable if government responds to higher demand for fertilizers by increasing the rate of interest. Fertilizer demand increases with all infrastructure investments, although effect of canal irrigation is not significant. The effects of primary schools, regulated markets and commercial banks are particularly large and precisely estimated.

These extremely clear results accord fully with what is known from other studies of the growth of fertilizers. To the previous literature they add the first estimates of the impact on fertilizer demand of changes in the rural bank network.

Finally the agroclimate x time interactions accord very well with what what is known about the influence of agroclimatic endowments on the potential of green revolution technologies, with fertilizer demand growing especially fast in green revolution areas with cool months, irrigation or high soil moisture capacity, while being held back in areas of excessively high rainfall and poor water-control.

In order to illustrate the endogeneity problem of using domestic prices in explaining aggregate crop output we present results with both the domestic and the international price indices. The comparisons clearly show that an endogeneity problem is being circumvented when prices are instrumented via the international price index. The coefficient of the domestic price is only 0.06 while that with the international price is 0.24. Moreover, the aggregate crop supply elasticity of 0.13 estimated with the international price exceeds the elasticities estimated for India in BBQ and that estimated for the world in BYBM by a factor of 1.5 to 2.

Table 6. Fixed Effects of Government Infrastructure, Commercial Bank and Prices on Fertilizer Demand and Aggregate Crop Output

Explanatory Variable	Fertilizer Demand	Aggregate Crop Output: Domestic Prices	Aggregate Crop Output: International Prices
Aggregate real price index (lagged) [a]	0.056	0.045	0.130
	(1.049)	(1.364)§	(6.472)*
Real fertilizer price [a]	-0.572	0.021	-0.117
	(-3.484)*	(0.435)	(-2.316)*
Real urban wage [a]	0.125	0.056	0.053
	(1.424)§	(1.548)§	(1.497)§
Real interest rate [a]	0.025	0.004	-0.001
	(1.308)	(0.642)	(-0.202)
Road [a]	0.224	0.215	0.201
	(1.780)*	(6.963)*	(6.549)*
Canal irrigation [a]	0.059	0.033	0.026
	(0.638)	(1.039)	(0.827)
Primary school [a]	1.433	0.331	0.335
	(5.291)*	(4.215)*	(4.322)*
Rural electrification [a]	0.085	0.031	0.028
	(1.389)§	(1.746)*	(1.603)§
Commercial bank [a]	0.247	0.018	0.020
	(6.687)*	(1.755)*	(1.918)*
Regulated market [a]	0.406	0.079	0.084
	(6.687)*	(4.627)*	(4.972)*
Rainfall x 10^3	1.273	0.073	0.071
	(1.252)	(3.482)*	(3.458)*
Year	-2.236	-0.019	-0.026
	(-5.358)*	(-3.179)*	(-4.299)*
Year x cool months	0.287	0.006	0.006
	(2.998)*	(4.891)*	(4.816)*
Year x length rainy season	-0.007	-0.003	-0.003
	(-0.076)	(-2.[illegible]6)*	(-1.989)*
Year x flood potential	-0.034	-0.001	-0.001
	(-1.247)	(-3.716)*	(-3.679)*
Year x irrigation potential	0.023	0.001	0.001
	(6.781)*	(12.446)*	(12.057)*
Year x soil moisture capacity	0.570	0.005	0.005
	(6.500)*	(4.324)*	(3.791)*
Year x excess rain months	-0.398	-0.005	-0.004
	(-4.305)*	(-3.549)*	(-3.086)*
F-Statistic	79.957	98.864	103.936
Hausman-Wu (Chi-square, 18)	42.918	46.308	44.754
No. of Observation	1148	1785	1785

Notes: t-statistics are in parenthesis. Asterisk refers to significance level of 10 percent or better on a two-tail test.
[a] coefficients are in elasticity form.
§ refers to a 10 percent level of significance on a one-tail test.

Nevertheless, the classic result of the aggregate supply elasticity literature is reconfirmed: short-run aggregate crop supply elasticities are small and do not exceed a level of 0.2.[13]

The endogeneity problem with the output price also affects the estimation of the fertilizer price elasticity. Using the domestic output price the fertilizer price does not appear to affect aggregate output. In the specification using international output prices the fertilizer price elasticity is negative (-.12) and statistically significant. The results are consistent with BYBM (1986) and BBQ (1984). The remaining discussion will therefore only consider the results with the international price.

Increasing real interest rates of the cooperative sector reduces aggregate output marginally an elasticity of about -0.001, while increasing the density of commercial banks tends to increase crop output with an elasticity of 0.020. The expansion of financial institutions thus seems to exert a direct impact on aggregate crop output and a larger effect in fertilizer demand as well as on some of the private agricultural investments.

Except for irrigation, all other infrastructure variables affect aggregate crop output positively. The overwhelming impact of infrastructure on aggregate crop output found in BYBM for international

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13/ We attempted to estimate the long-run aggregate elasticity of supply with this data set, using a free form lag structure of five past prices. The sum of the coefficients was .28, and we could not, with this technique, estimate a larger long-run aggregate supply response. However, long-run supply responses must be larger, as discussed in BYBM.

data is thus confirmed in this Indian study. Quantitatively the effects of primary schools and roads are the largest, with elasticities of 0.34 and 0.20 respectively. BYBM found large effects for education as well. They also found large irrigation effects but irrigation in the BYBM study include both private and canal irrigation.

As expected residual growth of output (after account is taken of prices, interest rates, infrastructure and banks) was larger in areas with good irrigation potential, high soil moisture capacity, and cool winters. It was lower in areas with excess rain and in areas liable to flooding.

VIII. Discussion

In the paper we have successfully demonstrated that with appropriate panel data it is possible to overcome simultaneity and unobservable variable problems arising from the joint dependence of the decision of farmers, financial institutions and government agencies on location and agroclimatic factors of the region within they operate. It then becomes possible to explain in an integrated fashion how the decision of these actors interact and ultimately affect agricultural investment and output. In addition, by judiciously using international prices we have shown that it is possible to overcome simultaneity problems which have long plagued the analysis of aggregate supply response to output prices.

The reduced form regressions of infrastructure, banks, investments and output on agroclimatic and location characteristics show the overwhelming importance these factors which must have had over the history of these districts on all decision-makers in the system. The importance of the interaction terms with time shows that the agroclimate factors have continued to govern the rate at which districts can take advantage of new agricultural opportunities and have continued to govern public, bank and private investment allocation decisions over the period analyzed.

For the first time this paper presents results on the effect of the expansion of financial intermediation on agricultural investment and output which are not seriously flawed because they ignore fungibility of financial resources or the other econometric problems discussed above. The expansion of the commercial banks into rural areas had a large effect on fertilizer consumption and on fixed private investment. It also affects output, but with an elasticity of only 0.02. In order to see how much the bank expansion has contributed we tabulate in table 7 the estimated impact of all independent variable, on the dependent variables in the decade of the 1970s. These estimates are the percentage change in the dependent variable caused by the changes in the independent variable, estimated as the product of the change in the independent variable times the regression coefficient which is divided by the average value of the dependent variable. Here we can see the contributions of different factors to growth of dependent variables over the decade, 1971-1981. Obviously the effects of a particular variable will be small if it did not change much over the decade, irrespective of its potential impact as measured by the regression coefficient.

The rapid Bank expansion increased fertilizer demand by about 23 percent, investment levels in tractors by 13 percent, investment in pumps by 41 percent, milk animals by 46 percent, and in draft animals by about 38 percent. They also increased the aggregate crop output by nearly 3 percent. This contribution to output is less than that of any other infrastructure variable except canal irrigation and rural electrification. Given the large contribution of the banks to investment and fertilizer use, their impact on output appears to be fairly small. It may arise because, while spurring specific investments on account of their lending activity, the banks also may reduce liquidity in rural areas by their transfer of rural deposits to urban areas. This issue will be investigated in a future paper.

TABLE 7. Contributions of Different Factors to Growth of Dependent Variables 1971-1981

Variable	Output	Fertilizer	Pump	Tractor	Draft Animal	Milk Animal
Aggregate real price index	0.023*	0.025	-0.026	-0.008	0.101*	0.034*
Real price of fertilizer	-0.009*	-0.044*	-0.025	-0.021	-0.174*	-0.092*
Real urban wage	0.008§	0.018§	-0.117	0.254*	0.912*	0.558*
Interest rate	0.001	0.023	-0.018	0.013	-0.063*	-0.012
Road	0.067*	0.065*	0.040	0.101	-0.513*	-0.355*
Canal irrigation	0.004	0.008	-0.008	0.058§	-0.018	-0.007
Primary school	0.080*	0.304*	-0.171	0.007	0.542*	0.085
Rural electrification	0.021*	0.048§	0.281*	-0.021	0.365*	0.271*
Commercial bank	0.026*	0.229*	0.408*	0.131*	0.378*	0.610*
Regulated market	0.044*	0.173*	-0.023	0.075	-0.024	0.079
Growth explained by all factors	0.265	0.849	0.341	0.594	1.506	1.171
Actual growth	0.239	0.729	-0.081	1.327	1.924	1.654

Note: Asterisk refers to significance level of 10 percent or better on a two-tail test.
§ refers to significance level of 10 percent on a one-tail test.

In addition to estimating the impact of the banks we have also shown that commercial banks prefer to locate in well-watered areas where agricultural risks are relatively low and avoid areas characterized by high risks of droughts and floods. Moreover, bank expansion is greatly facilitated by government investments in roads—and regulated markets which enhance the liquidity position of farmers and reduce transaction costs of both bank and farmers.

Our estimates of interest elasticity of investment while econometrically a bit less secure than the effect of bank expansion, suggest that changes in real interest clearly reduce some of the long-term private investments. On the other hand, we are unable to show an impact of interest rates on either fertilizer demand or aggregate output, i.e. the impact of higher interest rates on reducing investment in long-term assets is not sufficiently large to have a perceptible impact on output. And for short-term credit used to buy fertilizer it appears that availability of credit (as measured by the bank network) is clearly more important than the interest rate.

In the reduced form cross-sectional regressions regions with high irrigation potential have larger population density, better infrastructure, a more developed banking system, higher private investment rates and higher aggregate crop output. They are also favored in the allocation of new infrastructure and are preferred by banks. They are also able to benefit more from new technology in terms of fertilizer demand, investments and output. On the other hand, the analysis of the government's own additional investment in irrigation between 1961 and 1981 suggest positive, but barely statistically significant, impact of these irrigation investments on Bank expansion, tractor investment and crop output. As table 7 shows the estimates imply a near zero contribution of canal irrigation to aggregate crop output over the 1970s. In order to understand this puzzle it is important to recall that the measure of irrigation potential must include both the already developed as well as the yet to be developed potential. There is therefore collinearity between past investment in canal irrigation and potential and the reduced form effects of irrigation potential include the effects of the past investments. The fixed effects analysis over time, however, looks only at the impact of the additional government investment over the period. Therefore finding a low impact of recent government investments is not inconsistent with high impact of past investment. This would be especially the case if the rate of return to new canal irrigation had been declining over time as the best sites for irrigation became progressively exhausted. Moreover the estimates do not measure the impact of the very important private investment in irrigation.[14] The findings therefore do not imply that private investment in irrigation had a low return, an issue which cannot be analyzed with the techniques utilized. Canal irrigation investment in the 1960s and 1970s was insignificant compared to private investment. Over the 21 years analyzed, area irrigated by the government (canal) increased from 58 ha to 75 ha per 1000 ha of geographic area. Area irrigated by wells, i.e. privately increased much more rapidly from 54 ha to 114 ha per 1000 ha of geographic area, i.e. private additions to irrigation exceeded government additions by a factor of nearly 4 to 1.

Improved road investment has been shown to enhance agricultural output with an elasticity of about 0.20. In the 85 sample district roads have on average increased by 40 percent between 1971 and 1981. Roads would thus have contributed directly 7 percent each to the growth of agricultural

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14/ These results are not altered if the canal irrigation variable is replaced by the public irrigation, i.e. including the area under tanks which has been declining.

output and fertilizer use over this period. We have seen above that they have also contributed to bank expansion. On the other hand, for given bank density and other infrastructure, the direct effect of roads on private investment is mixed, suggesting that the major effect of roads is not via their impact on private agricultural investment but rather on marketing opportunities and reduced transaction costs of all sorts.

Regulated markets have an elasticity with respect to output of 0.08. They have expanded rapidly after 1969 and the growth (87 percent) during this period would have contributed nearly 4 percent to agricultural output and 17 percent to the demand of fertilizers. As in the case of roads, the markets also have little effect on the private investments, i.e. their effect works directly on output supply decisions.

In contrast electrification has a clear impact on investment in fixed capital, especially on pumps where it has contributed an increase of 28 percent to investment levels. Via these investments and also via fertilizer demand (about 5 percent increase) electrification has increased output over the decade by about 2 percent.

Finally primary education has added 8 percent to crop output over the decade, a very large effect indeed. This has come about primarily via a nearly 30 percent increment to fertilizer demand.

In terms of prices the study confirms that short run aggregate crop supply elasticities are inelastic even once simultaneity problems which have plagued this literature are overcome. In addition it shows that output prices, fertilizer prices and urban wages can have substantial impacts on private fixed capital investments even in the long run, as the lagged prices in these equations refer to prices ruling in the previous intercensal period, i.e. 5 years earlier on average. The results suggest that wages increases tend to lead to increased private investment while fertilizer price increases tend to reduce investments. Thus for wages substitution effects dominate the profitability effects while for fertilizers the opposite is the case.

The agricultural development literature has been dominated by schools which tended to emphasize the importance, or lack thereof, of specific determinants of agricultural growth. Price fundamentalists have been at odds with irrigation determinists. The 1970s and early 1980s have been dominated by advocates of cheap sources of growth from agricultural research and education. In World Bank projects road infrastructure and market development have taken a backseat relative to the forced expansion of cheap agricultural credit. Advocates of such agricultural credit have been attacked by scholars emphasizing the virtues of savings and market-determined interest rates. As the evidence in this paper suggests, reality is far too complex to be put into such black and white terms. Prices really do matter but so do infrastructure, markets, and banks.

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