EPTD DISCUSSION PAPER NO. 43

ARE RETURNS TO PUBLIC INVESTMENT LOWER IN LESS-FAVORED RURAL AREAS? AN EMPIRICAL ANALYSIS OF INDIA

Shenggen Fan and Peter Hazell

Environment and Production Technology Division

International Food Policy Research Institute
2033 K Street, N.W.
Washington, D.C. 20006 U.S.A.

May 1999

ABSTRACT

Developing countries allocate scarce government funds to investments in rural areas to achieve the twin goals of agricultural growth and poverty alleviation. Choices have to be made between different types of investments, especially infrastructure, human capital and agricultural research, and between different types of agricultural regions, e.g., irrigated and high- and low-potential rainfed areas. This paper develops an econometric approach and provides empirical evidence on the impact of government investments in rural India using district-level data. While irrigated areas played a key role in agricultural growth during the Green Revolution era, our results show that it is now the rainfed areas, including many less-favored areas that offer the most growth for an additional unit of investment. Moreover, investments in rainfed areas have a much larger impact on poverty alleviation, making this a win-win development strategy. These results have important policy implications, and challenge conventional thinking that public investments in rural India should always be targeted to irrigated and other high-potential areas.

CONTENTS

ARE RETURNS TO PUBLIC INVESTMENT LOWER IN LESS-FAVORED RURAL AREAS? AN EMPIRICAL ANALYSIS OF INDIA

Shenggen Fan and Peter Hazell*

1. INTRODUCTION

Past agricultural development strategies have emphasized irrigated agriculture and "high-potential" rainfed lands in an attempt to increase food production and stimulate economic growth. This strategy has been very successful in many countries and was responsible for the Green Revolution. At the same time, however, large areas of less-favored lands have been neglected and lag behind in their economic development. These lands are characterized by lower agricultural potential, often because of poorer soils, shorter growing seasons, and lower and uncertain rainfall, but also because past neglect has left them with limited infrastructure and poor access to markets. Despite some out-migration to more rapidly growing areas, population size continues to grow in many less-favored areas, and this growth has not been matched by increases in yields. The result is worsening poverty and food insecurity problems, which in turn is contributing to the widespread degradation of natural resources (e.g., mining of soil fertility, soil erosion, deforestation, and loss of biodiversity) as people seek to expand the cropped area. The severity of these problems has now reached the point where some governments and donors are spending more resources on crisis relief than development in these areas

---

*Shenggen Fan and Peter Hazell are Senior Research Fellow and Director, respectively, Environment and Production Technology Division, International Food Policy Research Institute, Washington, D.C.

(Owens and Hoddinott 1999).

Less-favored lands are extensive in the developing world. According to a report prepared by the Technical Advisory Committee of the CGIAR, "marginal" and sparsely populated arid lands account for 75 percent and 85 percent, respectively, of the total agricultural area in Asia and Sub-Saharan Africa (CGIAR 1998). Their shares in total agricultural production are lower but still large. In China and India, for example, we estimate that less-favored lands account for about one-third and 40 percent of total agricultural output, respectively. Globally, some 500 million poor people live in less-favored lands (Hazell and Garrett 1996).

It is becoming increasingly clear that, on poverty and environmental grounds alone, more attention will have to be given to less-favored lands in setting priorities for policy and public investments. This leads to two important questions: 1) How much public investment can be justified in less-favored areas compared to higher-potential areas; and, 2) How should those funds be allocated among different types of investments? Both questions are especially germane at a time when many governments are having to cut their total expenditure and need to allocate resources more efficiently.

The amount of public investment that can be justified in any region should depend on the net social returns that are realized through productivity growth and poverty reduction. While "win-win" investments are usually more desirable, an investment that involves some tradeoff between these two social goals may also be attractive providing any sacrifice of one goal is adequately compensated by gains on the other goal.[1]

[1] An environmental goal could be added as a third dimension to this argument. Unfortunately, we do not have any relevant environmental data for India and hence have

Conventional wisdom suggests that the productivity returns to investment are highest in irrigated and high-potential rainfed lands, and that growth in these areas also has substantial “trickle-down” benefits for the poor, including those residing in less-favored areas. Even though investing in less-favored lands might have a greater direct impact on the poor living in those areas, it is argued that investments in high-potential areas give higher social returns for a nation. The logic behind this position is as follows. Investment in high-potential areas generates more agricultural output and higher economic growth at lower cost than in less-favored areas. Faster economic growth leads to more employment and higher wages nationally, and greater agricultural output leads to lower food prices, both of which are beneficial to the poor. Less-favored areas will benefit from cheaper food, from increased market opportunities for growth, and from new opportunities for workers to migrate to more productive jobs in the high-potential areas and in towns. Fewer people will try to live in less-favored lands, and this will help reduce environmental degradation and increase per capita earnings. Migrants may also send remittances back to less-favored areas, further increasing per capita incomes there, especially for the poor.

Many of the expected benefits arising from rapid agricultural growth in high-potential areas have been confirmed (Pinstrup-Andersen and Hazell 1985). Nevertheless, the rationale for neglecting less-favored areas is being increasingly challenged by: a) the failure of past patterns of agricultural growth to resolve growing poverty and food insecurity problems in many less-favored areas; b) increasing evidence of stagnating levels of productivity growth in many high-potential areas (Pingali and Rosegrant 1998); and c)

---

had to limit our analysis to growth and poverty.

emerging evidence that the right kinds of investments can increase agricultural productivity to much higher levels than previously thought in some less-favored lands (Scherr and Hazell 1994). It now seems plausible that increased public investment in many less-favored areas may have the potential to generate competitive if not greater agricultural growth on the margin than comparable investments in many high-potential areas, and have a greater impact on the rural poor living in less-favored areas. If so, then additional investments in less-favored areas may actually give higher aggregate social returns to a nation than additional investments in high-potential areas. In fact, they might even offer win-win possibilities.

This paper uses district level data from India for the period 1970 to 1994 to estimate the relative returns to public investments in irrigated and high- and low-potential rainfed areas.[2] In the process, we also obtain important insights about the returns to different kinds of public investments within each type of area. India is a good case study because past public investments have been biased towards high-potential areas, and the remarkable productivity gains achieved in those areas (which led to national food surpluses) can now be juxtaposed against the lagging productivity, and widespread poverty and food insecurity that exists in many less-favored rainfed areas. The results provide strong support for our hypothesis that greater levels of investment in less-favored lands are now warranted.

The paper is organized as follows. In the next section, we briefly overview the characteristics of the major agroecological zones in Indian agriculture, and present our

---

[2] The data used in this study were compiled from published statistical materials by Drs. S. Thorat and T. Haque.

definitions of rainfed and irrigated areas, and of low- and high-potential rainfed areas. In the third section, we review recent trends in the development of technologies and rural infrastructure by type of area, much of which has been publicly funded. The fourth section analyzes the corresponding trends in agricultural production and productivity growth, while the fifth section describes changes in rural poverty. In section six, we develop an econometric model to analyze and measure the effects of improved technologies and increased infrastructure on agricultural production growth and poverty reduction, and estimate results for irrigated and low- and high-potential rainfed areas in India. The final section discusses the implications of our results for investment priorities in India and other developing countries.

2. CLASSIFICATION OF INDIAN AGROECOLOGICAL ZONES

We classify districts as irrigated if more than 25 percent of the cropped area (averaged from 1970 to 1995) is irrigated, and as rainfed if the irrigated share is less than 25 percent.[3] We further subdivide rainfed areas into high- and low-potential areas according to their agroecological characteristics. There have been several attempts to define agroecological zones in India. In this study we use a classification scheme developed by the Indian Council of Agricultural Research (ICAR), which divides India into 20 agroecological zones based on soils and climate (NBSS&LUP 1992). The district

[3] This classification of rainfed and irrigated areas is similar to that used by the Ministry of Agriculture of India which, for the purpose of watershed development, considers rainfed areas to be those with less than 30 percent of their crop area under irrigation at the time of initiation of the program. But the Ministry of Agriculture's classification is only applied in recent years, whereas we take averages for 1970 to 1994.

data available to us cover 18 of these 20 zones. One of the excluded zones is in the Himalayas, and the other is in the Andaman, Nicobar and Lakshadweep Islands. These are minor zones in terms of their agricultural production and rural population size. Table 1 presents some distinguishing features of each zone. Rainfed districts in zones 2 to 8 are considered low-potential areas in this study because of their poor soils, short growing seasons, and low rainfall. Rainfed districts in zones 9 to 19 are considered high-potential because these zones have better soils, longer growing seasons, and higher rainfall. Defined in this way, irrigated and high- and low-potential rainfed areas account for 48, 17, and 35 percent of the total cropped area, and 56, 17, and 27 percent of total agricultural output, respectively.

3. TECHNOLOGIES AND INFRASTRUCTURE

One of the most significant changes in Indian agriculture in recent decades has been the widespread adoption of high-yielding varieties (Figure 1).[4] This has been a major engine of growth in agricultural production and factor productivity. In 1970, the area under high-yielding varieties as a share of the total cropped area was still low,

[4] High-yielding varieties (also referred to as modern varieties) are those released by the Indian national agricultural research system and the international agricultural research centers. The yields of these varieties are substantially higher than those of traditional varieties when grown under irrigated conditions with fertilizer.

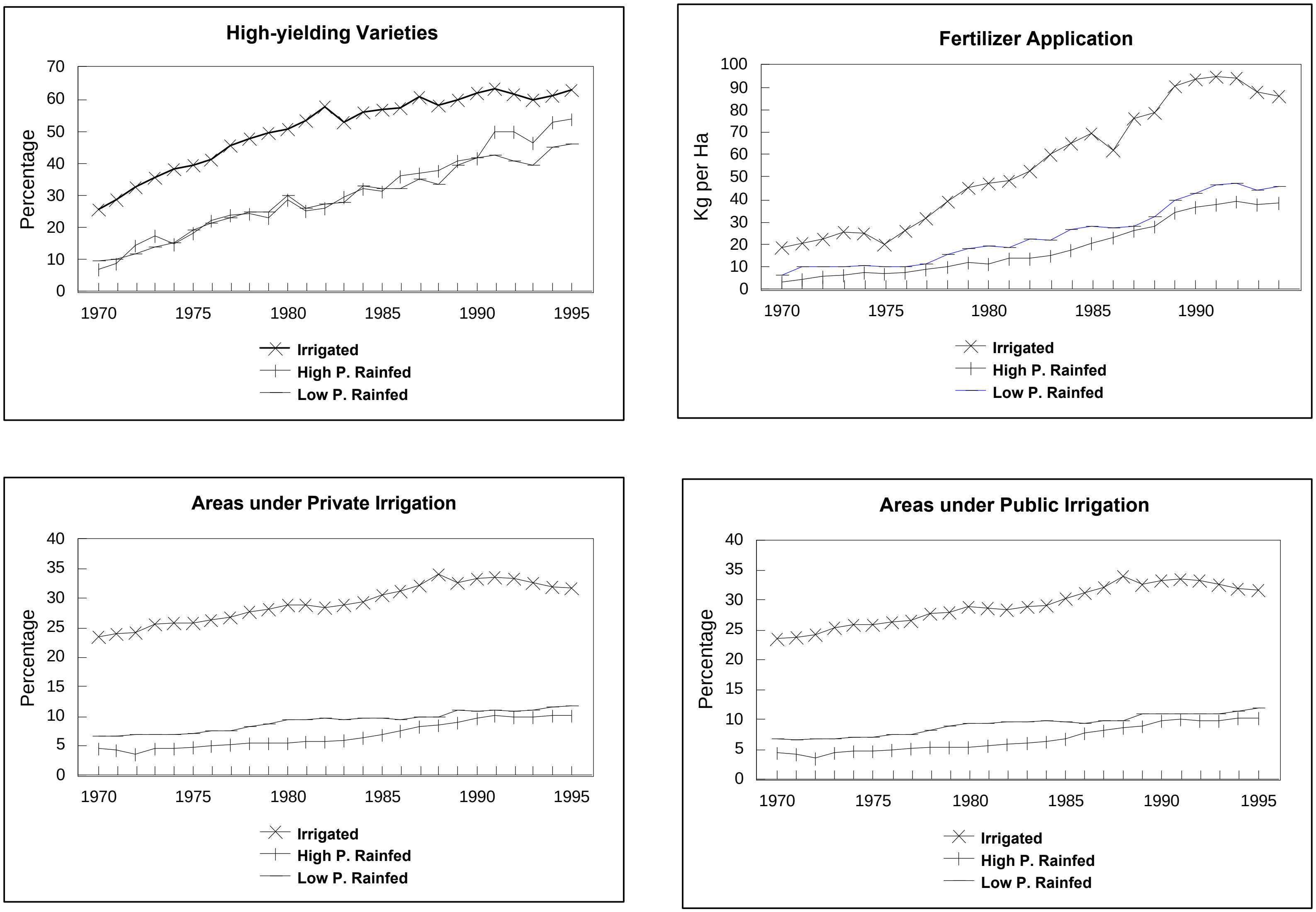
Table 1 ICAR s 20 agroclimatic zones

1*	Western Himalayas, cold arid ecoregion, with shallow skeletal soils and length of growing period (GP) less than 90 days
2 [l]	Western plain, Kachch and part of Kathiawar peninsula, hot arid ecoregion, with desert and saline soils and GP < 90 days
3[l]	Deccan Plateau, hot arid ecoregion, with red and black soils and GP < 90 days
4 [l]	Northern plain and central highlands including Aravalli hills, hot semi-arid ecoregion, with alluvium derived soils and GP 90-150 days
5 [l]	Central (Malwa) highlands, Gujarat plains and Kathiawar peninsula, hot semi-arid ecoregion, with medium and deep black soils and GP 90-150 days
6 [l]	Deccan Plateau, hot semi-arid ecoregion, with mainly shallow and medium but also some deep black soils and GP 90-150 days
7 [l]	Deccan Plateau of Telengana and Eastern Ghats, hot semi-arid ecoregion with red and black soils and GP 90-150 days
8 [l]	Eastern Ghats, Tamil Nadu uplands and Deccan Plateau of southern Karnataka, hot semi-arid ecoregion with red loamy soils and GP 90-150 days
9	Northern plain, hot subhumid (dry) ecoregion, with alluvium-derived soils and GP 150-180 days.
10	Central highlands (Malwa, Bundelkhand and Eastern Satpura), hot subhumid ecoregion, with black and red soils and GP 150-180 days (up to 210 days in some places)
11	Eastern plateau (Chhatisgarh), hot subhumid ecoregion, with red and yellow soils and GP 150-180 days
12	Eastern (Chhotanagpur) plateau and Eastern Ghats, hot subhumid ecoregion with red and lateritic soils, and GP 150-180 days (up to 210 days in some places)
13	Eastern Gangetic plain, hot subhumid (moist) ecoregion, with alluvium-derived soils and GP 180-210 days
14	Western Himalayas, warm subhumid (to humid and perhumid) ecoregion, with alluvium-derived soils and GP 210+ days
15	Bengal and Assam Gangetic and Brahmaputra plains, hot subhumid (moist) to humid (and perhumid) ecoregion, with alluvium-derived soils and GP 210+ days
16	Eastern Himalayas, warm perhumid ecoregion with brown and red hill soils and GP 210+ days
17	Northeastern hills (Purva chal), warm perhumid ecoregion with red and lateritic soils and GP 210+ days
18	Eastern coastal plain, hot subhumid to semi-arid ecoregion, with coastal alluvium-derived soils and GP 90-210+ days
19	Western ghats and coastal plain, hot humid-perhumid ecoregion with red, lateritic and alluvium-derived soils, and GP 210+ days
20*	Islands of Andaman-Nicobar and Lakshadweep hot humid to perhumid island ecoregion, with red loamy and sandy soils, and GP 210+ days

* Indicates zones not included in the district-level data.
[l] Indicates low-potential areas.

Source: NBSS&LUP, 1992

Figure 1 Development of technologies and infrastructure



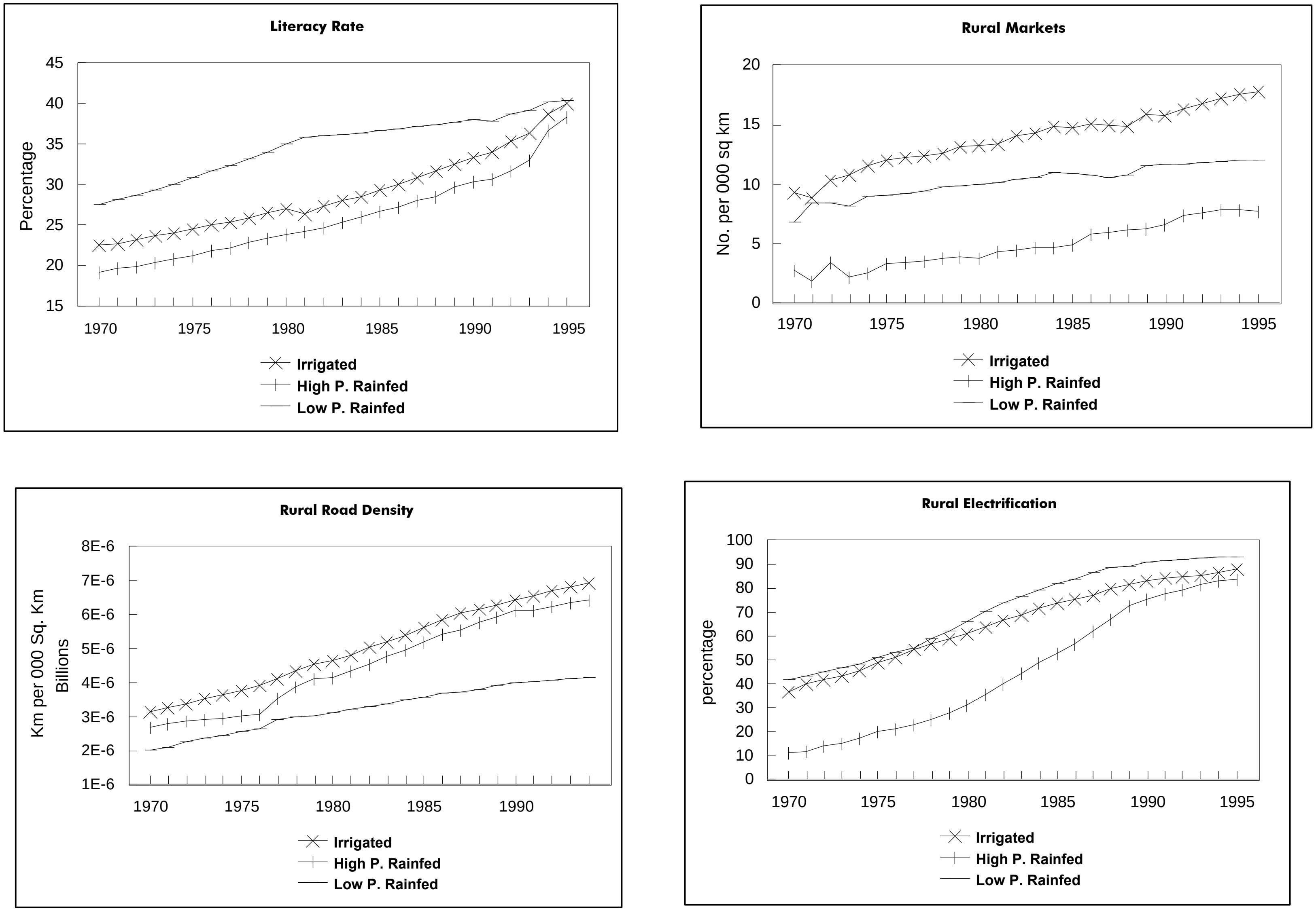
though higher in irrigated than in high- or low-potential rainfed areas (26 verses 7 and 10 percent, respectively). These shares have since grown significantly, and the gap between rainfed and irrigated areas has also narrowed. By 1995, high-yielding varieties were planted on about 60 percent of the total cropped area in irrigated areas, and 50 and 40 percent, respectively, in high and low-potential rainfed areas. The share is still increasing in rainfed areas, but growth has been flat in irrigated areas since the late 1980s.

Since high-yielding varieties require higher applications of fertilizer to realize their yield potential, fertilizer application in Indian agriculture has also increased rapidly since 1970 (Figure 1). On a per hectare basis, fertilizer use increased from 19 kg in 1970 to over 90 kg in the 1990s in irrigated areas. It also grew rapidly in high- and low-potential rainfed areas (from 3 kg and 7 kg in 1970 to 38 kg and 46 kg, respectively, by 1995), but is still less than half the rate used in irrigated areas.

Irrigation, another important growth factor in Indian agriculture, has also increased steadily over the years, but with considerable regional variation (Figure 1). We have disaggregated the total irrigated area into canal and private irrigation. Canal irrigation is nearly all provided by the public sector, while private irrigation (tanks, wells, and tube wells) is mainly the result of farmers' private investment. In irrigated areas, more than 60 percent of the cropped area was irrigated in 1995, compared to only 20-24 percent in rainfed areas. More than half of the irrigated area is under private irrigation in all three types of areas, and the share of private irrigation has been increasing.

Another significant achievement in recent decades has been the increase in the literacy rate of the rural population (Figure 2). Initially highest in the low-potential

Figure 2 Development of rural markets, education, and production and productivity growth



rainfed areas, it has increased and converged to about 40 percent in all types of areas.

Rural markets (including both secondary and principal markets), measured as the number of regulated agricultural markets per thousand square kilometers of geographic area, increased in all three types of areas between 1970 and 1994. But the density in rainfed areas is still much lower than in irrigated areas, and it remains particularly sparse in the low-potential rainfed areas (Figure 2).

The road density in irrigated areas, measured as the length of roads in kilometers per thousand square kilometers of geographic area, increased from 3,145 in 1970 to 6,926 in 1995; a growth rate of 3.3 percent a year (Figure 2). The road density in high-potential rainfed areas is now approaching the level of irrigated areas, but the road density in low-potential rainfed areas is 40 percent lower.

The percentage of villages electrified has also increased substantially since 1970 (Figure 2). Most of the increase occurred during the 1980s, and further growth has been modest since then. Moreover, while high-potential rainfed areas initially lagged irrigated and low-potential rainfed areas, all three types of areas now have most of their villages electrified.

4. PRODUCTION AND PRODUCTIVITY GROWTH

As a result of the rapid adoption of new technologies and increases in rural infrastructure, agricultural production and factor productivity have grown rapidly in Indian agriculture in recent decades (Table 2). Five major crops (rice, wheat, sorghum, pearl millet, and maize), fourteen minor crops (barley, cotton, groundnut, other grain,

Table 2 Production and productivity growth

Year	Production growth index			Land productivity (Rps/ha, 1990 prices)			Labor productivity (Rps/worker,1990 Prices)			Total factor productivity		
	Irrigated	Rainfed		Irrigated	Rainfed		Irrigated	Rainfed		Irrigated	Rainfed	
		High potential	Low potential		High potential	Low potential		High potential	Low potential		High potential	Low potential
1970	100	100	100	5,046	3,478	2,287	3,645	3,337	2,881	100	100	100
1971	100	102	96	5,037	3,513	2,202	3,613	3,367	2,746	100	102	96
1972	93	101	78	4,735	3,475	1,819	3,366	3,306	2,224	93	101	78
1973	96	96	104	5,015	3,340	2,474	3,437	3,112	2,910	95	95	102
1974	96	99	99	4,994	3,539	2,233	3,431	3,168	2,733	95	98	97
1975	107	112	117	5,620	3,986	2,657	3,802	3,528	3,186	106	110	114
1976	105	100	111	5,545	3,552	2,519	3,700	3,105	2,977	104	98	107
1977	116	115	119	6,140	4,088	2,713	4,037	3,526	3,146	114	112	115
1978	122	119	121	6,474	4,174	2,748	4,198	3,590	3,149	119	116	116
1979	103	98	114	5,447	3,433	2,592	3,517	2,917	2,917	101	95	109
1980	120	124	118	6,462	4,471	2,713	4,047	3,626	2,949	116	119	111
1981	127	128	129	6,860	4,568	2,942	4,217	3,683	3,150	122	123	121
1982	129	130	126	6,855	4,674	2,864	4,189	3,674	3,023	123	124	117
1983	141	154	144	7,531	5,518	3,292	4,507	4,266	3,394	134	146	133
1984	143	152	136	7,571	5,504	3,084	4,460	4,103	3,121	134	143	125
1985	151	179	120	8,115	6,471	2,744	4,632	4,751	2,703	142	167	109
1986	146	162	120	7,927	5,772	2,775	4,395	4,214	2,635	136	150	108
1987	149	171	126	8,160	6,145	2,932	4,371	4,345	2,710	138	157	112
1988	172	183	157	9,609	6,630	3,782	4,952	4,554	3,305	159	168	139
1989	169	185	156	9,101	6,637	3,520	4,765	4,508	3,203	155	169	137
1990	170	195	148	9,209	6,992	3,338	4,688	4,651	2,954	155	178	129
1991	170	194	154	9,154	7,198	3,470	4,588	4,507	2,996	155	175	134
1992	173	207	168	9,290	7,699	3,787	4,585	4,707	3,178	157	186	145
1993	178	222	166	9,439	8,223	3,693	4,605	4,934	3,051	160	199	142
1994	189	233	171	9,963	8,469	3,845	4,770	5,069	3,057	169	208	146
Annual growth rate												
1970-80	1.88	2.15	1.67	2.50	2.54	1.72	1.05	0.83	0.23	1.53	1.79	1.09
1980-90	3.49	4.68	2.26	3.61	4.57	2.10	1.48	2.52	0.02	2.93	4.05	1.48
1990-94	2.67	4.47	3.77	1.99	4.91	3.60	0.44	2.18	0.86	2.13	4.03	3.06
1970-94	2.68	3.58	2.26	2.88	3.78	2.19	1.13	1.76	0.25	2.21	3.10	1.58

other pulses, potato, rapeseed, mustard, sesame, sugar, tobacco, soybeans, jute, and sunflower), and three major livestock products (milk, chicken, and sheep and goat meat) are included in our measure of total output. Unlike traditional measures of aggregate production which use constant output prices, we use the more appropriate Tornqvist-Theil index (a discrete approximation to the Divisia index).[5]

For the period 1970 to 1994, agricultural production grew fastest in the high-potential rainfed areas (3.58 percent per year), followed by irrigated areas (2.68 percent) and then low-potential rainfed areas (2.26 percent). This may reflect a catching-up effect, since irrigated production grew rapidly prior to 1970 as a result of the Green Revolution, and the use of HYVs and fertilizers spread more slowly to rainfed areas. Production growth in irrigated and high-potential rainfed areas slowed in the early 1990s, whereas it increased in the low-potential rainfed areas to 3.77 percent per year, more than double the rate of growth achieved in the 1970s.

Land productivity, measured as the gross value of output in rupees (1990 prices)

---

[5] The formula for the index of aggregate production is:

$$lnYI_t = \sum_i 1/2 * (S_{i,\,t} + S_{i,\,t-1}) * \ln(Y_{i,\,t} / Y_{i,\,t-1}), \qquad (1)$$

where $lnYI_t$ is the log of the production index at time t, $S_{I,\,t}$ and $S_{i,\,t-1}$ are output I's share in total production value at time t and $t-1$, respectively; and $Y_{i,t}$ and $Y_{i,\,t-1}$ are quantities of output I at time t and $t-1$, respectively. Farm prices are used to calculate the weights of each crop in the value of total production. Unlike traditional measures of production growth which use constant output prices, the Tornqvist-Theil index (a discrete approximation to the Divisia index) is desirable because of its invariance property: if nothing real has changed (e.g., the only input quantity changes involve movements along an unchanged isoquant) then the index itself is unchanged (Diewert 1976; Lau 1979).

per hectare of net cropped area, also grew fastest on average in the high-potential rainfed areas, but the most rapid growth in these areas occurred after 1980 when it increased to nearly 5 percent per year (Table 2). Average growth in land productivity has also been quite high in irrigated areas (2.88 percent per year since 1970), though it slowed to less than 2 percent per year after 1990. In contrast, low-potential rainfed areas experienced the slowest average growth in land productivity between 1970 and 1990, but growth has accelerated to 3.6 percent per year since then. Land productivity remains more than twice as high in irrigated and high-potential rainfed areas than in low-potential areas, and this gap has widened since 1970.

Growth in labor productivity has been consistently low in all types of Indian agriculture since 1970, averaging only 1.13, 1.76 and 0.25 percent per year in irrigated and high- and low-potential rainfed areas, respectively (Table 2). It has accelerated a little in the low-potential rainfed areas since 1990 (but only to 0.86 percent per year), but has slowed in irrigated and high-potential rainfed areas. Given that the welfare of the rural poor can be expected to be closely linked to labor productivity in agriculture, these trends should be a matter of considerable concern to Indian policymakers.

Total factor productivity (TFP), a measure of the return to all direct and indirect inputs used in agriculture, grew fastest in high-potential rainfed areas during 1970-1994 (3.1 percent per year), followed by irrigated areas (2.21 percent per year) and then low-potential rainfed areas at 1.58 percent per year (Table 2).[6] TFP growth has slowed in irrigated areas since 1990, remained unchanged at nearly 4 percent per year in high-potential rainfed areas, and accelerated to 3.06 percent per year in low-potential rainfed areas.

5. RURAL POVERTY

Although the literature on poverty and its links to agricultural growth is extensive for India, there has been little work on how these relationships are affected at a disaggregated level by differences in the characteristics of different agro-ecological zones (Dreza and Srinivasan are an exception) (Ahluwalia 1978; Mellor and Desai 1985; Ghose 1989; Gaiha 1989; Bell and Rich 1994; Ravallion and Datt 1995; Datt and Ravallion 1997 and 1998; Dreze and Srinivasan 1997).

---

[6] A Tornqvist-Theil index is used to aggregate both inputs and outputs. Specifically,

$$lnTFP_t = \sum_i 1/2 * (S_{i,\ t} + S_{i,\ t-1}) * \ln(Y_{i,\ t} / Y_{i,\ t-1}) - \sum_i 1/2 * (W_{i,\ t} + W_{i,\ t-1}) * \ln(X_{i,\ t} / X_{i,\ t-1})$$

where $lnTFP_t$ is the log of the total factor productivity index; $W_{i,t}$ and $W_{i,t-1}$ are cost shares of input *I* in total cost at time *t* and *t-1,* respectively; and $X_{i,t}$ and $X_{i,t-1}$ are quantities of input *I* at time *t* and *t-1,* respectively. Five inputs (labor, land, fertilizer, tractors and buffalo) are included. Labor input is measured as the total number of male and female workers employed in agriculture at the end of each year; land is measured as gross cropped area; fertilizer input is measured as the total amount of nitrogen, phosphate, and potassium used; tractor input is measured as the number of four-wheel tractors; and bullock input is measured as the number of adult bullocks. The wage rate for agricultural labor is used as the price of labor; rental rates of tractors and bullocks are used for their respective prices; and the fertilizer price is calculated as a weighted average of the prices of nitrogen, phosphate, and potassium. The land price is measured as the residual of total revenue net of measured costs for labor, fertilizer, tractors, and bullocks.

Table 3 shows the incidence of rural poverty for our three land types in 1972, 1987 and 1993. Poverty has been measured as the percentage of the rural population falling below the official poverty line (Rs 15 per capita per month at 1960-61 prices) for different regions in 1972, 1987, and 1993. The underlying regional (agroecological zone) data used to calculate this table are taken from Dreze and Srinivasan and the Government of India.[7]

In 1993 there were 184 million rural poor in the areas covered by our data set, and this total had hardly changed since 1972 when there were 192 million rural poor. Of the 184 million rural poor in 1993, 154 million (or 84 percent) lived in rainfed areas. These were distributed about equally between high- and low-potential rainfed areas, a feature that has also not changed since 1972. The density of poor people is highest in the high-potential rainfed areas; 1,629 poor people per thousand hectares of geographic area in 1993, compared to 705 in irrigated areas and 599 in low-potential rainfed areas. The percentage of the rural population living in poverty is also highest in the high-potential rainfed areas (44 percent in 1993), and lowest in the irrigated areas (28 percent). The poverty shares declined by 25-30 percent between 1972 and 1993 in all three types of areas, but more because of population growth than because of any decline in the number of rural poor. The large number of rural poor remaining in rainfed areas represents a continuing challenge for India's policymakers, and highlights the importance of investing more in these areas.

[7] We aggregated the available poverty data by agroecological zone into our three land types using rural populations as weights. Since agroclimatic zones are more aggregated than districts (an agroclimatic zone usually consists of 5-10 districts), we define agroclimatic zones as rainfed if less than 40 percent of the total cropped area is irrigated, and as irrigated if the irrigated share is more than 40 percent. Rural poverty was estimated on the basis of consumer expenditure surveys carried out by the National Sample Survey Organization (NSSO).

Table 3 Poverty changes by type of region, rural India

		Irrigated areas	Rainfed areas		
			Total	High potential	Low potential
Percentage of poor in total population (%)	1972	39	52	59	47
	1987	32	46	48	44
	1993	28	39	44	36
Number of poor (millions)	1972	37	155	80	75
	1987	35	167	79	88
	1993	30	154	78	76
Number of poor per thousand hectares geographic areas (millions)	1972	862	880	1,680	583
	1987	813	951	1,660	688
	1993	705	878	1,629	599

Sources: Authors' calculation based on data from Dreze and Srinivasan (1996) and the Government of India.

Notes: Only 47 agroclimatic zones (of total 65) are included in the calculation due to data unavailability. An agroclimatic zone is defined as rainfed if less than 40 percent of the total cropped areas is irrigated, and as irrigated if irrigated share is over 40 percent.

6. EFFECTS OF INFRASTRUCTURE AND TECHNOLOGIES ON PRODUCTION AND RURAL POVERTY

In this section, we analyze how technologies and rural infrastructure have contributed to production growth and poverty reduction in irrigated and high- and low-potential rainfed areas.

CONCEPTUAL FRAMEWORK

The conceptual model for our econometric analysis is given by equations (1) to

(7). Equation (1) is the production function. The dependent variable is agricultural output ($Y_{i,t}$), while explanatory variables include traditional farm inputs such as labor ($LABOR_{i,t}$), land ($LAND_{i,t}$), fertilizer ($FERT_{i,t}$), machinery ($MACH_{i,t}$), and draft animals ($ANIMAL_{i,t}$); technology inputs like the percentage of HYVs in total cropped area ($HYV_{i,t}$), the percentage of the total cropped area that is under canal irrigation ($GIRRI_{i,t}$) and private irrigation ($PIRRI_{i,t}$); infrastructure variables such as road density ($ROAD_{i,t}$), development of rural markets ($MKT_{i,t}$), and rural electrification ($ELECT_{i,t}$); literacy rate of the rural population ($LITE_{i,t}$); and a time trend variable that is intended to capture any time-related changes that are not captured by other variables. The subscripts *i* and *t* represent districts and years, respectively. Our list of technology and infrastructure variables is incomplete, but these are key ones for which we have district level data. Due to the endogeneity of HYVs and irrigation variables in the production function, these variables are also modeled as endogenous variables in equations (2), (3) and (4).[8] The explanatory variables are lagged output prices ($ATT_{i,t}$), measured as the previous five-year moving average of agricultural prices divided by a relevant GNP deflator, and other social and infrastructure variables like rural education and road density. The estimation of these equations also enables us to measure the indirect impact of rural infrastructure and education on agricultural production through improved technologies.[9]

---

[8] Using cross-section data from a survey of rural households in West Bengal, India, Mukhopadhaya found that farmers' decision to adopt new technology depend mainly on the quality of their land, irrigation, and profitability (Mukhopadhyay1994).

[9] The interaction between education and technological change during the Green Revolution in rural India was recognized by A. Foster and M. Rosenzweig (1996). In our model, we attempt to model the effects of education and infrastructure development on

Poverty (defined as the percentage of the rural population living below the official poverty line) is modeled in equation (5) as a function of agricultural production, wages (a weighted average of the daily agricultural wages for male and female workers deflated by the CPI for agricultural labor), and a terms of trade variable (*TT*) measured as the agricultural GDP deflator divided by the non-agricultural GDP deflator. Increases in agricultural output or wages should help the poor to increase their incomes, and hence reduce poverty. Improvements in the terms of trade for agriculture can be expected to benefit farmers, but by raising the price of food they can also increase poverty in the short run, particularly among the landless and small farmers who are net purchasers of food. However, in the long run, improvements in the terms of trade for agriculture should lead to greater investment in irrigation and HYVs (see equations 2, 3 and 4) which in turn can be beneficial to the poor.

Equation (6) models wages as a function of agricultural output, roads, electrification, and rural literacy. All four variables are expected to contribute to higher wages. Roads have an indirect impact on wages through agricultural growth (equation 1), but may also contribute directly by promoting growth of the rural nonfarm economy (not modeled explicitly here) and through enhancing commuting opportunities.[10]

---

production directly and indirectly through the adoption of new technologies such as the use of HYVs and private irrigation.

[10] A. Sen (1997) argued that the real explanation for the rise in agricultural wages lies in the rapid growth of rural nonagricultural employment. However, the development of rural nonagricultural employment depends largely on the development of rural infrastructure. Including the infrastructure variables in the wage equation captures the direct impact of improved infrastructure on wage increases.

The agricultural terms of trade is modeled in equation (7) at the district level. They are expected to decline with increases in agricultural production at the national and district levels. National agricultural output is included to capture downward pressure on prices arising from increases in output anywhere in India. We initially included some demand side variables in the equation (population size and per capita income), but these turned out not to be statistically significant and were dropped from the model.

As specified above, estimation biases could arise if government investments in technology and rural infrastructure are systematically targeted to different kinds of regions (e.g., if government gives higher priority to high-potential areas). In this case, the investment variables may be correlated with the error terms in the production and poverty equations (Binswanger, Rosenzweig, and Khandker 1993). We do not have enough exogenous variables to fully resolve this problem, and have attempted to reduce the size of the possible estimation biases by including annual rainfall in many of the equations. We expect rainfall to act as a proxy for agricultural potential, which is presumed to drive any selection bias in government decisions. We also added district dummies in all equations to capture any remaining fixed effects of agroecological characteristics.

$$Y_{i,t} = f(LABOR_{i,t},\ LAND_{i,t},\ FERT_{i,t},\ MACH_{i,t},\ ANIMALS_{i,t},\ HYV_{i,t},\ GIRRI_{i,t},\ PIRRI_{i,t}\ LITE_{i,t},\ ROAD_{i,t},\ MKT_{i,t},\ ELECT_{i,t},\ T), \quad (1)$$

$$HYV_{i,t} = f(ROADS_{i,t},\ LITE_{i,t},\ GIRRI_{i,t},\ PIRRI_{i,t},\ ELECT_{i,t},\ ATT_{i,t}), \quad (2)$$

$$GIRRI_{i,t} = f(ROADS_{i,t},\ ELECT_{i,t},\ ATT_{i,t}), \quad (3)$$

$$PIRRI_{i,t}=f(ROADS_{i,t},\ LITE_{i,t},\ ELECT_{i,t},\ GIRRI_{i,t}\ ATT_{i,t}), \quad (4)$$

$$P_{t,i} = f(Y_{i,t},\ WAGE_{i,t},\ TT_{i,t}), \quad (5)$$

$$WAGE_{i,t} = f(Y_{i,t},\ ROADS_{i,t},\ LITE_{i,t},\ ELECT_{i,t}), \quad (6)$$

$$TT_{i,t}=f(Y_{i,t},Yn_t). \quad (7)$$

ESTIMATES OF THE PRODUCTION AND POVERTY EQUATIONS

Estimation of all the equations except the poverty equation was based on time series (25 years: 1970 to 1994), and cross-sectional (337 districts) data. However, because of missing values for some variables, the actual number of districts used in our final analysis is only 250. Because we are interested in differences in the impacts of infrastructure and technology variables across different types of agricultural lands in India, a variable coefficients model was estimated. This is equivalent to adding slope dummies for each variable. The error term of each equation is specified as:

$$\varepsilon_{ijt} = \rho_j \varepsilon_{ijt-1} + e_{ijt},$$

where ε_{ijt} is the error term of equation *j* at year t in district *i*. In this specification, the error term of equation j is serially correlated over time; an unobserved shock in any one period will affect the behavioral relationship for at least the following few periods (Baltagi 1995).[11] Ignoring serial correlation results in consistent but inefficient estimates of the regression coefficients and biased standard errors.

Since our poverty data is only available for agro-climatic zones and only for three years (1972, 1987, and 1993), a two-step procedure was used in estimating the full equations system. The first step involved estimating all the equations without the poverty equation using the district level data from 1970 to 1994. Then the values of *Y*, *WAGE* and *TT* at the agro-climatic zone level were predicted using the estimated parameters. The second step involved estimation of the poverty equation using the predicted values of

---

[11] For more information about the specification of serial correlation in an equation system, and its estimation, refer to pages 81 and 113 of Baltagi (1995).

independent variables at the agro-climatic zone level using the available poverty data for 1972, 1987 and 1993. Both linear and double-log forms of the equations were estimated. However, we only report the results of the double-log specification since these gave superior fits and had more statistically significant coefficients. As such, all the coefficients are in elasticity form.

The results for the production function in Table 4 are satisfactory from a statistical perspective: the majority of the coefficients are significant at the 5-percent confidence level or better; only two of the few negative coefficients obtained are significant; and the R^2 value of the equation is 0.972. The coefficients in this equation measure the direct impact of farm inputs, improved technologies and infrastructure on agricultural production.

The coefficients for labor and land vary greatly, but demonstrate that one or both of these inputs have high marginal returns on production in each of the three land types. Both land and labor have large coefficients in irrigated areas, whereas labor is the more critical input in high-potential rainfed areas, and land is the more critical input in low-potential rainfed areas. Most of the coefficients for fertilizer, machinery and animal inputs are small, but are statistically significant. Important exceptions are fertilizer use in irrigated and high-potential rainfed areas.

There is considerable variation in the direct impacts of different infrastructure and technology variables on agricultural production. The adoption of high-yielding varieties

Table 4 Estimated production functions for Indian agriculture, 1970-94

	Irrigated areas		High-potential rainfed areas		Low-potential rainfed areas	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
Labor	0.254	7.16*	0.373	8.40*	0.089	3.59*
Land	0.470	9.46*	0.097	4.86*	0.278	6.51*
Fertilizer	0.002	0.20	0.004	0.32	0.039	2.36*
Machinery	0.008	1.48	0.016	2.34*	0.025	4.03*
Animals	0.037	2.81*	0.053	3.28*	0.080	4.81*
HYV	0.005	0.43	0.013	2.33*	0.061	5.548*
Roads	0.091	3.69*	-0.004	-1.02	0.167	5.50*
Market	-0.001	-0.15	-0.016	2.11*	-0.019	-1.46
Canal irrigation	0.028	2.09*	0.071	3.97*	0.002	0.52*
Private irrigation	0.039	2.25*	-0.042	-0.69	0.089	4.47*
Electrification	-0.069	-4.69*	0.007	1.33	0.032	1.86
Education	-0.025	-1.05	-0.029	-1.25	-0.003	-1.05
Time trend	0.025	14.41*	0.019	12.88*	0.042	3.96

Note: R^2 = 0.972 and * indicates statistically significant at the 5% level.

has a positive impact on production in all areas, but the coefficient is largest in low-potential rainfed areas and smallest in irrigated areas. Canal irrigation has a larger impact in irrigated and high-potential rainfed areas than in low-potential rainfed areas, whereas the reverse is true for private (mostly tube well) irrigation.

Roads have their biggest direct impact on production in irrigated and low-potential rainfed areas but have an insignificant impact in high-potential rainfed areas. The coefficient on the market density variable is not significant in irrigated and low-potential rainfed areas, but is positive and very significant in high-potential rainfed areas. Rural electrification only has a positive and statistically significant coefficient in low- potential rainfed areas. The direct impacts of education are not statistically significant in any of the three regions. The positive and statistically significant coefficients for the time trend variable suggest that there are important but missing technology and infrastructure variables in the model. These may include the impacts of agricultural research not captured by the HYV variable (e.g., research on improved husbandry practices), and agricultural extension and technical education for farmer.

The results for the HYV equation in Table 5 show that the adoption of high-yielding varieties increases with roads, irrigation, and electrification. Therefore, in addition to their direct impact on production in the production function, these infrastructure variables also affect production growth indirectly through the HYV equation. Increases in the literacy rate seem to have little impact (negative in some cases) on the adoption of HYVs, while changes in the terms of trade only impact significantly on HYV adoption in irrigated areas.

Table 6 presents the estimated canal irrigation equations. Since most canal irrigation is provided by the government, this equation is really a model of the government's investment behavior in irrigation. As such, it is not surprising to find that government investment in irrigation is positively correlated with roads, electrification, and the terms of trade.

The estimated equations for private irrigation are given in Table 7. As with canal

Table 5 Estimated equation for high-yielding varieties in India

	Irrigated areas		High-potential rainfed areas		Low-potential rainfed areas	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
Roads	-0.074	-1.70	0.274	3.77*	0.258	3.51*
Canal irrigation	0.182	7.22*	-0.068	-1.68	0.014	2.89*
Private irrigation	0.087	2.64*	0.338	7.55*	0.205	5.44*
Electrification	0.110	4.37*	0.020	1.98*	0.050	2.58*
Education	-0.261	-5.92*	0.267	1.88	-0.334	-6.23*
Terms of Trade	0.141	2.70*	-0.127	0.57	-0.160	-1.10

Note: R^2 = 0.903 and * indicates statistically significant at the 5% level.

Table 6 Estimated canal irrigation equations for India

	Irrigated areas		High-potential rainfed areas		Low-potential rainfed areas	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
Roads	0.164	4.62*	0.298	6.84*	0.657	13.26*
Electrification	0.122	5.66*	0.211	8.53*	0.266	10.15*
Terms of Trade	.053	1.13	-0.160	1.25	0.198	3.03*

Note: R^2 = 0.959 and * indicates statistically significant at the 5% level.

Table 7 Estimated private irrigation equations for India

	Irrigated areas		High-potential rainfed areas		Low-potential rainfed areas	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
Roads	0.101	3.69*	0.05	2.40*	-0.13	1.78
Electrification	0.142	8.81*	0.110	7.53*	0.140	8.65*
Canal Irrigation	0.221	12.18*	0.580	26.36*	0.310	16.58*
Education	0.101	3.27*	0.278	6.58*	0.539	11.62*
Terms of Trade	0.024	0.74	-0.070	-0.64	0.059	1.95*

Note: R^2 = 0.952 and * indicates statistically significant at the 5% level.

irrigation, private investment in irrigation increases with roads, electrification, and the terms of trade. In addition, government investment in canal irrigation is complementary to private irrigation investment in all three types of areas; it raises the groundwater level which makes tubewell investments more profitable. Government investment in irrigation not only affects agricultural production directly, but also enhances production indirectly through greater use of high-yielding varieties, and by encouraging greater private investment in irrigation. Literacy also has a large and significant impact on private irrigation.[12]

The coefficients of the poverty equation in Table 8 are all signed according to expectations. Higher production growth and higher wages both contribute to reductions in rural poverty (hence the negative signs), while increases in the agricultural terms of trade are harmful to the poor in the short run.[13]

Table 8 Estimated poverty equations for India

	Irrigated areas		High-potential rainfed areas		Low-potential rainfed areas	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
Production growth	-0.160	-1.83	-0.170	-1.75	-0.310	-2.18*
Wage	-0.157	-1.99*	-0.161	-2.01*	-0.022	-1.41
Terms of Trade	0.258	1.48	0.268	1.41	0.123	1.97*

R^2 = 0.757 and * indicates statistically significant at the 5% level.

Table 9 presents the estimated coefficients for the wage equations. With only one exception (literacy in low-potential rainfed areas), increases in agricultural production,

[12] The evidence from Tables 4 to 7 show that education and electrification have little direct impact on production growth, but they affects production mainly through the adoption of HYVs and improved irrigation.

[13] The correlation between the change in the terms of trade and rural poverty was also found by Misra and Hazell (1996).

roads, education and rural electrification all have a positive and statistically significant impact on wages. However, increases in the agricultural terms of trade have a negative impact on real wages in the short run.

Table 9 Estimated wage equations for India

	Irrigated areas		High-potential rainfed areas		Low-potential rainfed areas	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
Production growth	0.201	9.91*	0.050	5.63*	0.101	6.36*
Roads	0.098	4.47*	0.097	4.46*	0.248	8.77*
Education	0.103	4.36*	0.233	7.50*	-0.03	-1.09
Electrification	0.190	15.39*	0.150	13.20*	0.251	18.63*
Terms of Trade	-0.190	-7.25*	-0.160	-6.35*	-0.371	-11.55*

Note: R^2 = 0.847 and * indicates statistically significant at the 5% level.

The estimated terms of trade equations in Table 10 show that increases in local and national agricultural production both contribute to lower real prices for farmers. Markets apparently do work despite the heavy intervention policies of the government during much of the period analyzed.

Table 10 Estimated terms of trade equations for India

	Irrigated areas		High-potential rainfed areas		Low-potential rainfed areas	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
District production growth	-0.134	-8.29*	-0.018	-4.11*	0.005	1.80
National production growth	-0.208	-8.07*	-0.104	-5.78*	-0.258	-9.56*

Note: R^2 = 0.347 and * indicates statistically significant at the 5% level.

MARGINAL RETURNS OF INFRASTRUCTURE AND TECHNOLOGIES

The estimated elasticity coefficients in Tables 4 to 10 measure the direct impact of each infrastructure and technology variable on the dependent variables in each equation. But the full model captures indirect as well as direct impacts. For example, roads not only contribute directly to agricultural production in equation 1, but also affect the adoption of HYVs (equation 2) and investment in irrigation (equations 3 and 4), and these variables in turn also impact on agricultural production. To capture the full impact of each infrastructure and technology variable on production and poverty requires totally differentiating the full equations system with respect to each variable of interest. The marginal impacts obtained from these calculations are shown in Table 11, where the derivatives were evaluated using the 1994 values for all relevant variables.

For every investment, the highest marginal impact on production and poverty alleviation occurs in one of the two rainfed lands, while irrigated areas rank second or last. Moreover, many types of investments in low-potential rainfed lands give some of the highest production returns, and all except markets and education have some of the most favorable impacts on poverty. These results provide strong support to the hypothesis that more investment should now be channeled to less-favored areas in India.

The marginal impact of HYVs on production is much larger in high- and low-potential rainfed areas (Rps 243 and 688 per hectare of HYVs adopted, respectively) than in irrigated areas (Rps 63 per hectare). HYVs also contribute more to poverty alleviation in rainfed areas; another hectare of HYVs raises 0.02 and 0.05 persons above the poverty

Table 11 Marginal returns to infrastructure and technology investments in rural India

		Irrigated areas	High-potential rainfed areas	Low-potential rainfed areas
Economic returns to production (1990 prices)				
HYV	Rps/Ha	63	243	688
Roads	Rps/Km	100,598	6,451	136,173
Markets	Rps/Number	(276,745)	7,808,112	(4,794,073)
Canal Irrigation	Rps/Ha	938	3,310	1,434
Private Irrigation	Rps/Ha	1,000	(2,213)	4,559
Electrification	Rps/Ha	(546)	96	1,274
Education	Rps/Ha	(360)	571	102
Returns to poverty reduction				
HYV	Persons/Ha	0.00	0.02	0.05
Roads	Persons/Km	1.57	3.50	9.51
Markets	Persons/Number	(2.62)	537.79	(313.72)
Canal irrigation	Persons/Ha	0.01	0.23	0.09
Private irrigation	Persons/Ha	0.01	(0.15)	0.30
Electrification	Persons/Ha	0.01	0.07	0.10
Education	Persons/Labor	0.01	0.23	.01

Note: The numbers in parentheses are negative, in many cases they are not statistically significant.

line in high- and low-potential rainfed areas, respectively. Although these varieties are often harder to develop for rainfed areas, the potential economic and social gains when successes occur are clearly quite high. Roads have sizeable productivity impacts in all three types of areas, but a much larger impact on poverty alleviation in rainfed areas, particularly the low-potential rainfed lands. Rural electrification and education have their biggest productivity impacts in rainfed areas, and they also impact favorable on the poor in these areas. Their impacts in irrigated areas are very small. Canal irrigation has its biggest productivity and poverty impacts in high-potential rainfed areas, while private irrigation has its biggest impacts in low-potential rainfed areas. Market development has a huge marginal impact on production and poverty alleviation in the high-potential rainfed areas, but not in irrigated and low-potential rainfed areas.

It should be noted that the marginal impacts of different investments reported above are gross of their costs. It could be argued that some investments are more expensive to undertake in less-favored areas, because of their diverse and generally less favorable agroecological conditions. For example, the development of HYVs may be more difficult for less-favored areas, and their widespread adoption may be more constrained by the diversity of growing conditions. Investments in roads and other infrastructure may also be more costly in many less-favored lands because of difficult topographical conditions, or remoteness from major population centers or markets. Data that we have obtained at the state level for India suggest that the unit costs of key investments are not all that different across states, despite considerable diversity in the proportions of their irrigated and rainfed areas (Fan, Hazell, and Thorat 1998).

7. CONCLUSIONS

In order to promote economic growth and to redress poverty, policymakers in developing countries will need to promote agricultural intensification for both high- and low-potential regions. This dual strategy will be particularly challenging if government budgets for investment in agriculture and rural areas continue to remain tight, and striking the right investment balance between irrigated and rainfed regions, and between high and low-potential rainfed areas will be particularly important. Investments in irrigated and high-potential rainfed areas cannot be neglected because these areas still provide much of the food needed to keep prices low, and to feed growing livestock and urban populations.

On the other hand, the poverty, food security and environmental problems of many low-potential areas are likely to remain serious in the decades ahead as populations continue to grow. While out-migration and economic diversification should become increasingly important in the development of most low-potential areas, agricultural intensification will often offer the only viable way of raising incomes and creating employment on the scale required in the near future. Even when the investments needed to achieve this growth yield lower economic returns than investments in high-potential areas, they might still be justified on the basis of their significant social benefits in the form of poverty alleviation and improved environmental management. Moreover, with worsening income disparities between many high- and low-potential areas, policymakers are likely to come under increasing pressure to invest more in low-potential areas.

The size of the potential tradeoffs between investing in high- and low-potential areas have yet to be widely quantified, and it is possible that they may be changing. Productivity levels in many high-potential areas have reached a plateau, while at the same time recent agricultural research in some low-potential rainfed areas is suggesting new avenues for increasing their productivity. Our analysis of investments in irrigated and high- and low-potential rainfed areas in India suggests that investments in rural infrastructure, agricultural technology and human capital are now at least as productive in many rainfed areas as in irrigated areas, and they have a much larger impact on poverty. These results raise the tantalizing possibility that greater public investment in some low-potential areas could actually offer a “win-win” strategy for addressing productivity and poverty problems.

The successful development of less-favored lands will require new and improved approaches, particularly for agricultural intensification (Hazell and Fan 1998). These will require stronger partnerships than needed in high-potential areas between agricultural researchers and other agents of change, including local organizations, farmers, community leaders, nongovernmental organizations, national policymakers and donors. It will also require time and innovation; new approaches will need to be developed and tried on a small scale before they are scaled up, and their testing will take time to assess and evaluate, particularly given the noise introduced by climatic variability. All this will require patience and perseverence on the part of policymakers and donors, perhaps more than the current aid culture allows.

REFERENCES

Ahluwalia, M. 1978. Rural poverty and agricultural performance in India. *Journal of Development Studies* 14: 298-323.

Baltagi, B. 1995. *Econometric analysis of panel data.* New York: John Wiley & Sons.

Bell, C., and R. Rich. 1994. Rural poverty and aggregate agricultural performance in post independence India. *Oxford Bulletin of Economics and Statistics* 56.

Binswanger, H., M. Rosenzweig, and S. Khandker. 1993. How infrastructure and financial institutions affect agricultural output and investment in India *Journal of Development Economics* 41 (99): 337-66.

Consultative Group on International Agricultural Research. 1998. CGIAR Study on Marginal Lands. Technical Advisory Committee. Washington, D.C.: CGIAR.

Datt, G., and M. Ravallion. 1997. Why have some Indian states performed better than others at reducing rural poverty? FCND Discussion Paper No. 26. International Food Policy Research Institute, Washington, D.C.

Datt, G., and M. Ravallion. 1998. Farm productivity and rural poverty in India. *Journal of Development Studies* 34: 62-85.

Diewert, W. 1976. Exact and superlative index numbers. *Journal of Econometrics* 4: 115-46.

Dreze, J., and P. Srinivasan. 1996. Poverty in India: Regional estimates, 1987-8. Delhi School of Economics and Indira Gandhi Institute of Development Research. Mimeo.

Fan, S., P. Hazell, and S. Thorat. 1998. Government spending, growth, and poverty: An analysis of interlinkages in rural India. EPTD Discussion Paper No. 33, International Food Policy Research Institute, Washington, D.C.

Foster, A., and M. Rosenzweig. 1996. Technical change and human-capital returns and investments: Evidence from the Green Revolution. *American Economic Review* 86: 931-53.

Gaiha, R. 1989. Poverty, agricultural production and prices in rural India - A reformation. *Cambridge Journal of Economics* 13: 333-352.

Ghose, A. 1989. Rural poverty and relative prices in India. *Cambridge Journal of Economics* 13: 307-331.

Hayami, Y., and V. Ruttan. 1985. *Agricultural development: An international perspective*. Baltimore, Md.: Johns Hopkins University Press.

Hazell, P., and S. Fan. 1998. Balancing regional development priorities to achieve sustainable and equitable agricultural growth. Paper prepared for the AAEA International Conference on Agricultural Intensification, Economic Development and the Environment, July 31 - August 1, Salt Lake City, Ut.

Hazell, P., and J. Garrett. 1996. Reducing poverty and protecting the environment. The overlooked potential of less-favored lands. 2020 Brief 39. Washington, D.C.: International Food Policy Research Institute.

Lau, L. 1979. On exact numbers. *Review of Economics and Statistics* 61: 73-82.

Mellor, J., and G. Desai, eds. 1985. Rural poverty, agricultural production, and prices: A reexamination. In *Agricultural Change and Rural Poverty*. Baltimore, Md., U.S.A.: Johns Hopkins University Press.

Misra, V. and P. Hazell. 1996. Terms of trade, rural poverty, technology and investment: the Indian experience, 1952-53 to 1990-91. *Economic and Political Weekly* 31: A2-A13.

Mukhopadhyay, S. 1994. Adapting household behavior to agricultural technology in West Bengal, India: Wage labor, fertility and child schooling determinants. *Economic Development and Cultural Change* 43: 91-115.

NBSS&LUP. 1992. *Agro-ecological regions of India*, 2nd ed. NBSS Publication No. 24. Nagpur: National Bureau of Soil Survey and Land Use Planning, and New Delhi: Oxford and IBH.

Owens, T., and J. Hoddinott. 1999. Investing in development or investing in relief: Quantifying the poverty tradeoffs using Zimbabwe household panel data. Washington, D.C.: International Food Policy Research Institute.

Pingali, P., and M. Rosegrant. 1998. Intensive food systems in Asia: Can the degradation problems be reversed? Paper presented at the pre-conference workshop "Agricultural Intensification, Economic Development and the Environment" of the Annual Meeting of the American Agricultural Economics Association held in Salt Lake City, Utah, July 31-August 1.

Pinstrup-Andersen, P., and P. Hazell. 1985. The impact of the green revolution and prospects for the future. *Food Reviews International* 1 (1).

Ravallion, M., and G. Datt. 1995. Growth and poverty in rural India. World Bank Policy Research Working Paper. Washington, D.C: World Bank.

Scherr, S., and P. Hazell. 1994. Sustainable agricultural development strategies in fragile lands. EPTD Discussion Paper No. 1, International Food Policy Research Institute,Washington, D.C.

Sen, A. 1997. Structural adjustment and rural poverty: Variables that really matter. In *Growth, employment and poverty: Change and continuity in Rural India*, ed. G. Chadha and A. Sharma. New Delhi: Vikas Publishing House.