The Green Revolution in Punjab, India: The Economics of Technological Change

Nirvikar Singh & Deepali Singhal Kohli
University of California, Santa Cruz and New Delhi, India

This paper addresses the question of what explains the relatively rapid diffusion of 'Green Revolution' technology in Punjab, versus the rest of India. To construct an answer, the paper reviews studies that have attempted to explain the pattern of rapid innovation in Punjab agriculture, and suggests that there is no single explanatory variable that stands out in comparing Punjab with other Indian states. It is argued that relatively high levels of innovation and investment in Punjab agriculture can be understood in terms of three categories of variables: infrastructure, information and incentives.

1. Introduction

The state of Punjab in India has, in the last few decades, been one of the world's most remarkable examples of agricultural growth. Growth in Punjab has been closely associated with the well-known 'Green Revolution', which saw the development and adoption of new, high-yielding varieties (HYVs) of wheat, rice and other food crops. The impressive agricultural growth in Punjab is exemplified by the increase in the state's wheat production from 1.9 to 5.6 million tons during the years 1965 through 1972.[1] Growth in rice production has been equally strong.

Numerous state level studies have attributed Punjab's agricultural growth experience to rapid technology diffusion in the state. These studies have argued that economic growth can occur as a result of technological change or an increase in the inputs used in the production process. However, the greatest potential for development lies in the productivity advances associated with technological innovations, rather than just the increased use of inputs.

The question arises as to what explains the relatively rapid diffusion of new technology, and associated changes in the quantities and kinds of inputs used, in Punjab, versus the rest of India. To construct an answer to this question, this paper reviews studies that have attempted to explain the pattern of rapid innovation in Punjab agriculture during the Green Revolution period. We suggest that there is no single explanatory variable that stands out in comparing Punjab with other Indian states. However, we argue that relatively high levels of innovation and investment in Punjab agriculture can be understood in terms of three categories of variables: infrastructure, information and incentives (which we refer to as the 'three I's'). We use this conceptual framework in our review and analysis.

The remainder of the paper is organized as follows. Section II presents basic statistics as evidence in support of the claim that levels of adoption of innovations in

Punjab have been higher than in other states. Section III discusses several reasons that have been suggested for interstate differences in the level of adoption.[2] Section IV reviews the explanations that have been specifically advanced for greater adoption of technological inputs by farmers in Punjab. Section V summarises the findings of this study, discusses them in terms of the 'three I's', and briefly attempts to relate them to economic theories of technological change. In our conclusion, we also briefly discuss the current state of Punjab agriculture, and potential future problems.

II. Technology Adoption in Punjab

The statewise growth rates of production of food grains between the triennia ended 1961-62 and 1985-86 are presented in Table 1. During this period, Punjab experienced the highest annual growth rate of food grain output among all the states of India. In fact, Punjab's annual growth rate of food grain output of 6.4 per cent was almost two and a half times that recorded at the all-India level. In Punjab, the high level of food grain production resulting from these growth rates has also been accompanied by high levels of adoption of technological innovations such as high yielding varieties (HYVs) of seeds, chemical fertilisers, pesticides, tubewells, diesel pumpsets, and tractors.

Table 1: Annual rate of increase in food grain production 1961-62 to 1985-86

State	**Percentage growth rate**
Punjab	6.4
Haryana	4.7
Gujarat	3.4
Uttar Pradesh	3.2
Rajasthan	2.4
Assam	2.3
West Bengal	2.2
Karnataka	2.1
Andhra Pradesh	2.0
Orissa	2.0
Madhya Pradesh	1.8
Maharashtra	1.7
Bihar	1.6
Tamil Nadu	1.0
Kerala	1.0
All India	**2.6**

We have data on percentage of HYVs used in two sub-periods. In both the periods from 1974 to 1976 and from 1983 to 1985, the percentage of HYV of seeds in the total area under food grain was the highest in Punjab, 73 per cent and 95 per cent respectively (Table 2). Once again, these percentages are much higher than the all-

India figures. It can be argued that comparing Punjab's performance to that of India as a whole includes some states that are not comparable with Punjab in terms of size, climate, and development. However, even when compared to similar states, such as Haryana, Punjab has fared far better. Moreover, in the case of rice, which occupied about 29 percent of the total cropped area in Punjab in 1981-82, the percentage of that area under HYVs of rice was 95, while in states like Assam, Orissa, and West Bengal where rice covered 50 per cent or more of the total cropped area, the percentage under HYVs of rice was less than 50.[3]

Table 2: Percentage of HYV of seeds in the total area under food grain

States	**1974-76**	**1983-85**
Punjab	73	95
Haryana	54	81
Gujarat	41	61
U.P.	39	60
Rajasthan	13	31
Assam	18	46
W.B.	23	41
Karnataka	28	48
A.P.	39	66
Orissa	10	39
M.P.	18	38
Maharashtra	22	51
Bihar	29	60
T.N.	62	80
Kerala	27	40
All India	**31**	**54**

Source CMIE Vol.2: States, Sept. 1987

As in the case of the adoption of HYVs of seeds, Punjab also attained the highest level of chemical fertiliser consumption. Both the level of fertiliser consumption per hectare of gross cropped area and the level of fertiliser consumption per operational holding were the greatest in Punjab among all Indian states, for the years 1971-72 and 1985-86 (Table 3). In the latter year Punjab was also the highest consumer of pesticides both in terms of tonnes per lakh[4] hectares of gross cropped area and in terms of tonnes per lakh operational holdings (Table 3). Even Haryana, which is very similar in terms of size, climate, and development and was second only to Punjab in the consumption of both fertilisers and pesticides, consumed much lower levels than Punjab. In the years 1979-80 and 1984-85, Punjab also had the highest number of registered tractors per lakh hectare of gross cropped area (Table 4).[5]

Table 3: Consumption of Fertilisers and Pesticides

State	Fertilisers (NPK) per ha. of GCA (kg)		Per operational holding (kg)		Pesticides per lakh ha. of GCA (tonnes)	per lakh operational holdings (tonnes)
	1971-72	1985-86	1971-72	1985-86	1985-86	1985-86
Punjab	73.05	157.4	210	593	112.68	423.85
Haryana	24.06	65.5	91	275	97.25	267.26
Gujarat	18.20	40.5	75	167	45.73	144.28
U.P.	26.32	78.7	30	104	34.05	66.85
Rajasthan	3.49	11.6	19	46	11.82	51.34
Assam	3.12	4.7	5	7	25.63	33.47
W.B.	18.77	52.2	22	66	88.65	81.30
Karnataka	14.69	48.4	47	113	27.61	66.67
A.P.	21.87	66.3	55	108	101.69	174.97
Orissa	7.60	14.7	14	39	22.81	33.43
M.P.	5.57	19.1	22	57	15.34	44.74
Maharashtra	11.38	31.7	49	83	14.44	38.23
Bihar	9.40	48.8	14	42	17.09	14.83
T.N.	44.88	36.2	65	87	128.20	129.70
Kerala	40.37	49.8	23	29	64.57	23.11
All India	**10.22**	**48.4**	**23**	**89**	**41.00**	**68.78**

Source CMIE, Sept. 1993
GCA: gross cropped area
Note that the 1971-72 figures are found using the number of operational holdings and the gross cropped area of 1970-71.

Table 4: Tractors, Diesel Pumpsets and Energised Tubewells (per lakh ha. of GCA)

	Tractors		**Diesel Pumpsets**		**Energised Tubewells**	
States	**1979-80**	**1984-85**	**1968-69**	**1984-85**	**1968-69**	**1985-86**
Punjab	2570	4642	730	7512	1486	10756
Haryana	448	1897	87	2507	1304	7601
Gujarat	322	624	2150	7449	420	3221
U.P.	457	878	468	6974	418	3054
Rajasthan	196	190	88	348	88	1384
Assam	148	199	n.a.	32	n.a.	127
W.B.	164	184	593	2376	20	851
Karnataka	141	225	273	488	809	4124
A.P.	75	160	280	1250	906	5198
Orissa	27	32	78	361	16	627
M.P.	36	152	118	523	118	2297
Maharashtra	119	179	604	1159	590	4740
Bihar	82	165	244	1689	435	1973
T.N.	132	180	869	1833	5318	16769
Kerala	233	232	310	2000	870	8646
All India	**230**	**426**	**445**	**2168**	**672**	**3753**

Source CMIE Sept. 1993

GCA: Gross Cropped Area, n.a.: not available

GCA figures for 1970-71, 1980-81 and 1985-86 are used in the calculations.

Punjab has not always been the highest consumer of all technological innovations. For instance, in 1984-85, more diesel pumpsets per lakh hectare of gross cropped area were installed in Punjab than in any other state. However, in 1968-69, although Punjab was amongst the states with the highest levels of installations of diesel pumpsets, it was exceeded by Gujarat both in terms of installations per lakh hectares of gross cropped area and per lakh operational holdings, and by Tamil Nadu in terms of installations per lakh hectares of gross cropped area (Table 4), as well as by Maharashtra in terms of installations per lakh operational holdings (not shown). The shift in position from 1968-69 to 1984-85 reflects the higher level of technology diffusion in Punjab. In 1968-69, Tamil Nadu had a greater number of tubewells per lakh gross cropped area (Table 4) and per lakh operational holdings than Punjab. In the same year, Haryana also had more tubewells per lakh operational holdings than Punjab. By 1985-86, there were more tubewells per lakh operational holdings in Punjab than in any other state, but Punjab was still second to Tamil Nadu in terms of tubewells per lakh hectares of gross cropped area. All the same, the data support the statement that Punjab experienced high levels of technology adoption in this period.

III. Inter-State Differences

Several reasons have been postulated for the interstate differences in adoption levels of agricultural innovations. Some of these reasons are specific to the innovations. For instance, the high levels of adoption of HYVs of wheat in Punjab have been attributed to two factors. Sen (1974) claims that (1) wheat seeds responded better than rice or *jowar* (sorghum) seeds to supporting inputs and (2) wheat seeds have been adapted to local conditions with the help of agricultural research facilities. The initial success of the crop provided a strong demonstration effect that induced the farmers to adopt the HYV of wheat. These reasons may help explain the differences in the percentage of HYVs in total cropped area under different food grains, but the higher level of adoption of all the HYVs of seeds in Punjab remains unexplained. Furthermore, the data indicate that rice yields in Punjab also rose rapidly in the period from 1965 to 1985.[6]

As noted earlier, in 1981-82, 95 per cent of the gross cropped area in Punjab under rice used HYVs. In the same year, of the total area covered by *bajra* (millet), 61.7 per cent was under HYVs of *bajra*. In comparison, in Rajasthan and Uttar Pradesh, where *bajra* also occupied a very small portion of the total cropped area, 23.8 per cent and 9.3 per cent, respectively, of total area covered by bajra was under HYV's of *bajra*. Thus, other factors, such as levels of supporting inputs, infrastructure development, and credit availability, may help determine the interstate differences in the levels of adoption of technological innovations.[7] In a study on sources of interstate differences in fertiliser use in India, Sharma (1993) finds that of the 86 per cent difference in fertiliser use between Punjab and all other states, 70 per cent can be explained by the following four variables: area occupied by HYVs, irrigation, retail outlets, and credit availability.

In other words, differences in rural institutional factors may determine the interstate differences in levels of technology adoption. In the process of development, rural institutions undergo change, which in turn alters incentives and access to factors of production, including innovative technological factors. The institutional characteristics considered by Zarkovic (1987) are (i) human capital, (ii) access to capital for innovation, (iii) price incentives, (iv) size of cultivated holdings, and (v) ownership of land.[8] We discuss each of these in turn.

(i) One of the prerequisites of technology adoption is that a farmer should be aware of the benefits the new technology may bring. Thus, a farmer should be able to understand potential benefits from change. He should be able to assimilate new techniques and adopt new practices. This ability develops with increased education. Economists (e.g. Evenson, 1974) have suggested that farmers with better education tend to be earlier and more efficient adopters of modern technologies. Global studies indicate that education plays an important role in agricultural development. For example, Rosenzweig (1978) found that the probability of adoption of HYV of seeds in Punjab was positively related to education. In contrast, Fleigel *et al* (1968) argued that literacy and not education is significant for village-level adoption, because literacy is a basic skill to decipher messages in written form where as education is a long conditioning process during which the individual acquires different attitudes.

Among indicators of education are literacy rates, government expenditure on education per capita, and class enrolment ratios. For the year 1981, compared to Punjab, literacy rates - both rural and effective - were higher in Gujarat, Maharashtra, Tamil Nadu, and Kerala, while state government expenditure on education per capita was greater in Kerala (Table 5). The enrolment ratios in classes 1-5 of Gujarat, Maharashtra, and Tamil Nadu were above that of Punjab for 1983-84, while the enrolment ratio in classes 6-8 were higher in Tamil Nadu and Kerala than in Punjab. In contrast, the levels of adoption of HYVs of seeds, chemical fertilisers, pesticides, tractors, and diesel pumpsets were much higher in Punjab as seen from Tables 3 and 4. Only in the case of the number of tubewells adopted was the level of adoption in Tamil Nadu in terms of number per lakh hectare of gross cropped area higher than in Punjab. Thus, an inference we may draw is that education in general and literacy in particular did not *by themselves* play a prominent role in promoting the adoption of technological innovations.[9]

Table 5: Levels of Education

State	**Literacy rate(%) 1981 Rural**	**Effective**	**State govt. exp. on education per capita (Rs) 1980-81**	**Enrolment ratios 1983-84 Class 1-5 (6-11 yrs)**	**Class 6-8 (11-14 yrs)**
Punjab	41.7	41	82.8	103.7	63.5
Haryana	37.3	36	56.5	88.9	54.9
Gujarat	43.6	44	53.1	111.7	55.3
U.P.	28.5	27	31.7	80.2	43.3
Rajasthan	22.5	24	42.6	74.8	36.8
Assam*	n.a.	n.a.	53.8	62.9	47.6
W.B.	40.2	41	45.6	96.0	54.5
Karnataka	37.6	38	46.6	86.9	59.9
A.P.	27.9	30	43.1	97.3	39.4
Orissa	37.8	34	41.0	89.5	36.5
M.P.	26.3	28	33.0	80.3	35.0
Maharashtra	45.7	47	60.8	125.9	59.9
Bihar	27.5	26	33.8	82.3	30.5
T.N.	45.0	47	50.0	129.8	65.3
Kerala	80.3	70	65.3	96.8	90.2
All India	**36.1**	**36**	**46.1**	**93.4**	**48.9**

Source CMIE, States 1993.
* Including Meghalaya and Mizoram
Effective literacy rates exclude 0-4 age group.

(ii) Financial constraints are a major impediment to adoption of technological innovations. Agricultural investments are financed through accumulated savings or capital markets. Differences in access to these could lead to differences in the levels of adoption of innovations. Although rural savings rates have been increasing, they are typically not sufficient for major innovations. Thus access to financial markets is critical to most farmers. The main sources of credit in rural India are loans advanced by agricultural co-operative societies and village moneylenders.

An indicator of the ease with which farmers had access to credit would be the number of lending institutions per individual. In 1985, Punjab had the greatest number (8.8) of bank offices of scheduled commercial banks per lakh population (Table 6). In 1984, the percentage of borrowing members in primary agricultural societies was the highest (61.9 per cent) in Punjab. The amount of institutional medium and long-term loans per operational holding was also the highest in Punjab in the years 1980-81 and 1984-85. However, in the same years, Kerala advanced more institutional medium and long-term loans per hectare of gross cropped area. Compared to all the other states (except Kerala), Punjab still had the highest amount of institutional medium and long-term loans per hectare of gross cropped area. This could imply that Kerala is just an outlier. The mere fact that there were more bank offices per lakh of population, a greater percentage of borrowing members in co-operative societies, and more institutional medium and long-term loans advanced indicates that credit was easily and abundantly available to Punjabi farmers. Case study evidence such as that of Leaf (1984), who describes how credit cooperatives completely replaced private moneylenders between 1965 and 1978 in a particular Punjab village, supports the importance of this factor in making rapid technological change possible in Punjab. Hamid (1981) makes a similar point about Punjab's general experience with credit cooperatives, citing Randhawa (1974) in tracing their development in Punjab back to the 1950s.[10]

Table 6: Indicators of Credit Availability

State	**1985(a)**	**1984(b)**	**1980-81(c)**	**1984-85(c)**
Punjab	8.8	33.7	396.53	475.2
Haryana	5.9	40.7	253.96	347.92
Gujarat	6.2	45.3	62.94	136.13
U.P.	5.0	48.4	107.7	171.10
Rajasthan	6.7	26.5	47.49	65.98
Assam	3.0	32.1	4.53	30.83
W.B.	3.6	31.3	43.27	60.45
Karnataka	8.0	20.7	79.35	209.10
A.P.	5.8	22.1	106.47	158.23
Orissa	5.2	27.0	122.60	129.60
M.P.	5.8	13.6	36.07	62.64
Maharashtra	5.1	36.5	70.28	125.24
Bihar	4.8	29.6	42.11	107.02
T.N.	5.2	37.2	100.38	296.62
Kerala	5.5	53.2	561.94	779.34
All India	**5.6**	**33.4**	**249.20**	**148.58**

Sources: CMIE, States, Sept. (1987) and Rath, N. (1989)
(a) Rural distribution of bank offices of scheduled commercial banks, Sept. 1985, per lakh of population.
(b) Primary agricultural co-operative societies percentage of borrowing members, June end 1984.
(c) Total institutional medium and long-term loans (Rs. per hectare of gross cropped area).

Table 7: Credit Subsidy

	Rs. per ha. of GCA		**As per cent of SDP**		**Rs. Per operational holding**	
States	**1980-81**	**1985-86**	**1980-81**	**1985-86**	**1980-81**	**1985-86**
Punjab	43.12	89.41	1.26	1.57	283.12	587.17
Haryana	38.54	85.89	1.29	1.84	208.42	356.33
Gujarat	33.33	67.92	1.48	3.04	121.64	238.62
U.P.	26.07	53.82	0.93	1.3	35.95	71.68
Rajasthan	16.35	37.76	1.43	1.95	63.20	143.86
Assam	4.75	23.31	0.14	0.41	6.96	36.55
W.B.	28.61	62.30	0.88	1.04	37.07	80.90
Karnataka	36.68	98.88	1.63	3.12	90.72	224.00
A.P.	46.37	104.55	1.80	2.68	74.34	153.72
Orissa	18.53	42.23	0.99	1.34	48.66	108.9
M.P.	17.38	37.30	1.29	1.82	58.04	112.95
Maharashtra	34.44	76.42	1.85	2.91	100.78	193.44

Source: As Table 6.

Financial constraints can be encountered not only in the form of lack of access to lending institutions, but also in the form of low incentives or high costs of undertaking loans. Incentives that encourage farmers to seek credit can be provided by schemes that reduce the cost of loans, such as credit subsidies. In the years 1980-81 and 1985-86, the Punjab government advanced the most credit subsidy per operational holding (Table 7). However, in the same year, several other states offered a higher credit subsidy per hectare of gross cropped area and as percentage of state domestic product. These mixed findings, when put together with consistently high level of adoption of technological innovations per operational holding as well as per hectare of gross cropped area, suggest that credit subsidies alone may not have played an important role in reducing financial constraints in Punjab.[11] However, this does not imply that such incentives did not and will not motivate investments in other states, especially in combination with other favourable conditions. Punjabi farmers, with a large investible surplus resulting from the high rate of agricultural growth, may have had less need for investment-encouraging credit subsidies. The availability of a relatively large investible surplus to Punjabi farmers is evident from the high per capita income from agriculture in Punjab. In the period 1979-80 to 1981-82, this per capita income from agriculture was Rs. 1759 in Punjab, and Rs. 1463 in Haryana, while the all India average was Rs. 710 (CMIE: States, Sept. 1987).

(iii) Price incentives in the form of price subsidies can stimulate the adoption of technology. Direct price subsidies set by the central government are the same across states. Thus, this variable does not explain the interstate differences in the technology adoption levels. However, interstate variation in the responsiveness to price incentives may partially determine the state difference in the levels of technology adoption. Zarkovic (1987) found that the price had a greater positive influence in the adoption of the HYV package of technology, especially in the wheat and rice regions of Punjab. However, this explanation just leads us to rephrase the basic question posed, regarding higher rates of innovation in Punjab: what were the special characteristics of Punjab that led to greater price responsiveness?

Price incentives could also be offered indirectly through schemes like special tax concessions, credit subsidies on the adoption of a particular innovation, or greater availability of and subsidies on complementary goods and services, e.g. power supply and irrigation facilities. Since 1960-61, per capita power consumption has been the greatest in Punjab (Table 8) among all the states. The high consumption of power could reflect greater availability. According to the National Sample Survey, all villages in Punjab were electrified in 1976-77 (CMIE, States, Sept. 1987). Higher consumption could also be a direct result of lower costs of consumption. Punjab has been heavily subsidising electricity. Even in 1985, the average electricity rate in Punjab (13.5 paise per KWH) was less than half of that in Haryana (28.7 paise KWH), though Andhra Pradesh, Karnataka and Tamil Nadu had even lower rates. Similarly, among those states without all (or most of) their net sown area falling in high rainfall regions Punjab had the greatest percentage of net sown area with assured sources of water in 1978-79 (CMIE, States, 1987).

Table 8: Agriculture, per capita utilities power consumption (KWH)

States	**1960-61**	**1970-71**	**1980-81**	**1985-86**
Punjab	6.7(a)	34.7	112.0	165.2
Haryana	(b)	30.3	74.9	105.7
Gujarat	1.0	5.4	39.7	50.7
U.P.	2.7	8.2	25.2	33.7
Rajasthan	0.2	4.4	30.0	40.1
Assam (c)	n.a.	n.a.	0.2	0.4
W.B.	n.a.	0.5	1.3	2.3
Karnataka	1.2	6.2	10.7	33.2
A.P.	1.5	9.5	18.4	51.9
Orissa	n.a.	0.5	2.3	4.2
M.P.	0.1	1.6	6.7	14.8
Maharashtra	0.4	7.2	27.7	58.3
Bihar	0.4	1.2	6.3	11.4
T.N.	11.4	31.4	49.2	58.3
Kerala	1.1	2.0	3.2	3.9
All India	**1.9**	**8.3**	**21.4**	**34.3**

Source: CMIE: States Sept. 1987.

(a) Includes Haryana and Chandigarh

(b) Included under Punjab
(c) Includes Meghalaya and Mizoram

Inter-state differences in such indirect price incentives could be partly responsible for the different levels of technology adoption across states. As already discussed above, credit subsidies by themselves did not seem to have played a critical role in promoting investments on agricultural innovations in Punjab.

(iv) With respect to farm size, HYVs of seeds are scale neutral and high yields can be realised on any size farm.[12] However, the supporting technologies in the form of irrigation and machinery, i.e., fixed cost inputs, do lead to economies of scale.[13] Thus only farms of at least a particular size are capable of reaping the greatest benefits from the new technology. Farmers with farms this size or larger may have more incentive to adopt supporting technology. The appropriate size of operational holdings undertaking innovations associated with the Green Revolution ranges from 3 to 10 hectares.[14] The Indian government classifies farms of these sizes as medium and large. The 1971 Agricultural Census indicates that 48.5 per cent of the cultivated area in Punjab and Haryana fell in this category, compared to 38.2 per cent in Uttar Pradesh.[15]

Data from the All India Report on Inputs Survey of 1976-77 also lends support to the hypothesis that medium to large size farms were more likely to adopt technological innovations than smaller size farms.[16] In 1977, medium and large size farms in all states used greater numbers of pumps and tractors than smaller size farms. However, Punjab farms in every size category used the greatest number of pumps and tractors (per thousand hectares and per thousand operational holdings), among all the Indian states. Thus, the greater number of medium to large size farms in Punjab can only partially account for the inter-state differences in adoption levels. What still remains unanswered is the question of the reasons for greater adoption of technology by all farmers in Punjab.

(v) Economists have also suggested that it is the ownership of land rather than the size of the operational holding that motivates the adoption of innovations. For instance, Hamid (1981) found that it was the difference in the structure of land ownership inherited by Punjab which was the primary cause of differences in agricultural development. Hamid argued that, under tenancy or sharecropping, increases in production benefit the landowner, while the cost of production is disproportionately borne by the cultivators. These conditions of tenancy or sharecropping provide little incentive to adopt new techniques whose outcome is often unknown to the cultivator. The decision to innovate also depends on the distinction between pure tenants and tenant owners. Hamid supported this argument by showing that under colonial rule, when landlord-sharecropper relationships were encouraged, farmers adopted fewer innovations. The imposition of land reform acts, such as ceilings on land ownership, encouraged rich peasants and small landlords[17] to adopt more Green Revolution technology. In empirical studies, Parthasarthy and Prasad (1978) showed that owners of land were more likely to adopt HYVs of seeds than tenants because of the risk factor,[18] while Bhadhuri (1973) also found lower rates of adoption among tenants.

In contrast, Vyas (1979) found that the adoption rate in India has been the same among owners and tenants with respect to the HYVs of wheat. In fact, in some regions, tenants used more fertiliser per hectare than owners. In particular, Punjab had the lowest percentage of owned farms of marginal and small size, and among the lowest in the medium and large categories.

If land ownership is responsible for the interstate differences in technology adoption levels, than Punjab should have had the highest or amongst the highest percentage of wholly owned and self-operated operational holdings. However, among the major states, the percentage of wholly owned and self-operated operational holdings was the lowest in Punjab in 1985-85 (Table 9). In contrast, the levels of adoption of technological innovations per operational holding without regard to the title, legal form, size or location[19] were the highest in Punjab. Thus, land ownership by itself does not seem to have been important in motivating Punjabi farmers to invest in land improvements and adopt technological innovations that require purchased inputs.

Table 9: Land Ownership

States	**Wholly owned and self-operated holdings as percentage of total number of operational holdings under all size groups (1985-86).**
Punjab	84.9
Haryana	95.2
Gujarat	99.9
U.P.	98.2
Rajasthan	98.2
Assam	89.9
W.B.	88.5
Karnataka	99.8
A.P.	99.5
Orissa	91.4
M.P.	89.2
Maharashtra	98.3
Bihar	98.6
T.N.	99.4
Kerala	95.5
All India	**95.9**

Source: All-India Report on Agricultural Census 1985-86.

A final factor that has been frequently posited as a reason for higher levels of adoption of technological innovations in Punjab is appropriate adaptation of Green Revolution technology to local conditions. During the 1960s, the nature of mechanical inputs supplied to the market was altered. Pumpsets, automatic threshers, and tractors became smaller in scale and more appropriate for local conditions. Irrigation facilities and tractors are two technological inputs associated with the Green Revolution whose form and size are most appropriate for middle size farms. Private tubewells were best for irrigating farms between 10 to 25 acres in size. Thus, smaller as well as larger farms would find it less profitable to adopt technologies requiring intensive water use. However, in Punjab, 44.1 per cent of the irrigated area was covered by tubewells in 1970-71.[20] Tractors of the kind widely used in Punjab were appropriate for farms smaller than 25 acres. Threshers were produced with locally available technology and inputs. They sufficed in capacity for small farms prevailing in Punjab. HYVs of wheat and rice were adapted to suit local conditions such as soil, climate, and taste[21] prior to their widespread introduction to farmers in the mid 1960s. The adaptation of the Green Revolution technology to suit local conditions was facilitated by the close proximity of the farms to the research institutes such as the Punjab Agricultural University in Ludhiana, which enabled rapid feedback between research and practice. Thus, the nature of the inputs made the new technology suitable for adoption by farmers prevailing in Punjab.

IV. Punjab-Specific Studies

Although agricultural machinery was reduced in scale and made more suitable for local conditions, in some cases, their adoption was still not justifiable on economic grounds. For instance, in an early study, Sidhu (1972) argued that tractors were often bought mainly for prestige reasons.[22] His econometric evidence suggested that the productivity of tractor and non-tractor operated farms was the same for the period he considered. The unit cost of producing wheat at their respective mean output levels of tractor and non-tractor operated farms was also the same. Wheat production functions faced by both types of farms were the same as well. Thus, these farms did not differ in overall economic efficiency. Wheat farming exhibited constant returns to scale regardless of the type of farm, i.e. for both tractor and non-tractor operated farms. This implies that in the wake of rapidly changing agricultural technology, tractor and non-tractor operated farms were equal in economic performance. All the same, the per cent share of tractors in the change in the composition of agricultural implements and machinery of Punjab increased steadily from 5.22 in 1951 to 51.14 in 1972.[23] Tractorisation may have helped large farmers in increasing the possibility of multiple cropping. However, it seems that the adoption of tractors by small and marginal farmers was not always economically justifiable.

Most classes of cultivators gained from the Green Revolution. However, at least initially, the benefits were heavily weighted in favour of the very large farmers, i.e. farmers with operational holdings of 25 to 35 acres or more. Although, the larger farmers experienced an absolute increase in their output, the gap between large and medium farmers widened. Till 1971, smaller farmers with 10 to 15 acres or less made only marginal gains. It was hypothesized that ultimately they could find their farm operations overcapitalised and uneconomical. Then, why did these farmers adopt the Green Revolution technology?

Herdt (1983) found that the same or similar technological innovations were available to farmers of all states in India. Thus, 'extensive observations farmers made of other farmers resulted in efficient judgement about selection of factors and their use.'[24] In 1961, all categories of farmers were quickly convinced of the superiority of modern technology by observing crop demonstrations showing increased yields of 40 to 65 per cent per acre with the application of improved 'package of practices'.[25]

In another study, Day and Singh (1977) showed that a farmer responded to prices, revenue, quotas, and the past behaviour of his neighbours. He based his decision on his past experience and on the past actions of his neighbors. The farmer reacted to the past behaviour of other farmers because their actions in the aggregate had had an impact on the market situations prevailing at the time. Thus a farmer imitated his neighbour and this imitation, at least partially, conditioned the diffusion of technology. We shall explore this characterization further in the next, concluding section.

Hamid (1981) provided an overview of Punjab's performance in agriculture, in a comparison with its Pakistani counterpart. We have alluded to some of Hamid's observations in the previous section. A more recent, and detailed comparison was undertaken in Sims (1988). Sims noted several factors similar to those discussed by Hamid. For example, she noted that procurement prices as well as market prices were higher in Indian Punjab than in its counterpart. She discussed the broader distribution of resources, including credit and fertilizer, in India, and related it to the political economy of India, where policies were more responsive to small and medium farmers. Sims emphasized the very important role played by irrigation, in particular, the spread of private tubewells in Punjab, India. On the other hand, her field surveys suggested that agricultural extension, while active in Indian Punjab, had a limited direct impact on new technology adoption. However, she found that the availability of HYV seeds did matter, and farmers were heavily influenced by their neighbours' actions, corroborating Day and Singh's earlier study. Again, we return to this in the final section. Sims also noted the importance of the development of infrastructure such as a network of rural roads and rural electrification for Punjab's exceptional performance.

A detailed empirical study by McGuirk and Mundlak (1991, 1992) supports the conclusions of Hamid and Sims. They used twenty years of district level data, covering 10 of present-day Punjab's 12 districts for the period 1960-1979. They used a choice-of-technique/production-function approach that separates the decisions on area allocated to different crops and subsequent decisions that affect yield. They also estimated long run effects, in which factors such as irrigation, fixed in the short run, were modelled as responding to economic conditions. McGuirk and Mundlak's results are striking. They found that in the short run, the transition to HYVs of wheat and rice was strongly positively influenced by increases in irrigated area, miles of roads, and availability of fertilizer. Drawing a conclusion similar to those of Hamid (1981) and Leaf (1984), they note that the 'importance of roads indicates that linking rural areas to markets strongly affected technique choice.'[26] McGuirk and Mundlak also found that, conditional on crop/technique choice, yield response elasticities in the short run were low. In the long run, the quasi-fixed input most responsive to economic stimuli was found to be private irrigated area. This in turn led to increases in net cropped area as well. There was some government response for fertilizer availability. The response of roads was not modelled, and data were not available on electricity, but other evidence suggests that these grew in extent or availability, so that overall, the government was responsive to economic incentives over the period. We now turn to our overall assessment of these results.

V. Infrastructure, Information and Incentives

Many agricultural economists have suggested that instead of an individual factor determining technology diffusion, the combined effect of several factors is responsible for high levels of adoption of technology in Punjab. This emphasis on the complementarity of several factors is supported by our review in sections III and IV. In particular, the cross-state comparisons along individual potential causal factors did not reveal any striking differences for Punjab. The adaptation of the Green Revolution technology to suit local conditions in Punjab reinforces the explanation that there was a general thrust to promote the adoption of technological inputs in the state. By removing financial constraints and by making the technological innovations and their complementary inputs more easily and cheaply available, Punjab farmers were provided with an environment conducive to the extensive adoption of new technology. These factors, along with a literacy rate greater than the all-India average, may have enabled farmers in Punjab to adopt higher levels of technological inputs. An overall favourable atmosphere for the diffusion of technological innovations is reflected by the consistently high index of development of infrastructure in Punjab (Table 10). This index includes power, irrigation, transportation, communications, education, and credit as components, either through availability or use. While there is not a tight correlation between state per capita income levels and their infrastructure indices, Punjab's index is strikingly higher than other states throughout the surveyed period (and into the 1990s). Thus, while individual factors do not distinguish Punjab, this index combining many important dimensions, does single out the state.[27]

Table 10: Index of Development of Infrastructure

States	1966-67	1976-77	1980-81	1985-86	1996-97
Punjab	201	216	215	218	186
Haryana	129	151	154	150	137
Gujarat	111	122	125	132	122
Uttar Pradesh	107	112	107	108	104
Rajasthan	59	81	77	79	84
West Bengal	152	133	132	123	91
Karnataka	90	105	101	100	94
Andhra Pradesh	93	97	98	105	93
Orissa	69	79	82	81	99
Madhya Pradesh	53	61	62	71	74
Maharashtra	117	111	118	119	111
Bihar	98	109	97	98	78
Tamil Nadu	171	152	153	142	139
Kerala	135	167	137	140	155

Source: CMIE, States, Sept. 1987.All India = 100. Index components are: (1) Per capita consumption of electricity (KWH), (2) Per capita industrial consumption of electricity (KWH), (3) Percentage of villages electrified to total number of villages, (4) Percentage of net/gross area irrigated to total net/gross cropped area, (5) Road length in km. per 100 sq. km. of area, (6) Number of motor vehicles per lakh population, (7) Length of national highways in km. per 1000 sq. km. of area, (8) Railway route length in km. per '000 sq. km. of area, (9) Number of post offices per lakh population, (10) Number of letter boxes per lakh population, (11) Literacy percentage, (12) Number of hospital beds per lakh population, (13) Per capita deposits (Rs.), (14) Per capita bank credit (Rs.), (15) Number of bank offices per lakh population.

The role of infrastructure has also been stressed by Leaf (1984), in comparing a particular Punjabi village between 1965 and 1978. He comments on improvements in transportation and communication over this period, and points out how such improvements can reduce costs in ways that make innovation more profitable. He also comments on improvements in marketing and water availability. Hamid (1981) makes similar points in a more general overview. He emphasizes, in addition to all the above factors, the importance of the growth of small towns, aided by the development of infrastructure. These towns essentially became growth poles, with supporting light industry such as repair services and manufacture of some agricultural implements. Chadha (1986), Sims (1988) and McGuirk and Mundlak (1992), with different methods and emphases, make similar points about infrastructure. Thus, in our view, the first of the 'three I's' is critical in explaining Punjab's agricultural performance in the Green Revolution period.

The fact that Punjabi farmers with holdings of all sizes, regardless of title and legal form, used greater amounts of technological inputs suggests that these variables, i.e. farm size and land ownership, were not important by themselves in motivating them to adopt technological innovations. Small farmers were almost in pace with larger farmers in their willingness to adopt new technology. Frankel (1971) found that all classes of cultivators in the Ludhiana district of Punjab were participating equally in the Green Revolution, for example 'in 1963-64, 60 per cent of farmers with holdings of more than ten acres, 60 per cent of the farmers with holdings between five and ten acres, and 50 per cent of the farmers with holdings as small as five acres were applying fertilizers.'[28] In fact, the majority of loan applications received for tractors by the Pilot Officer in Ludhiana in March 1969 came from small farmers. According to Frankel, easy credit tempted small farmers to purchase machines, and they paid little attention to their ability to repay their loans. Such adoption incidences indicate that the general thrust in Punjab to promote the adoption of new technology may have aided the emergence of imitative behaviour among the Punjabi farmers. Initially, farmers were stimulated to adopt by the technology promotion schemes and other favorable conditions discussed above, while the rest based their adoption decisions on favorable information imparted by the actions of the first few, which outweighed their own information that the technology might not be profitable. Thus, informational cascades[29] or bandwagon effects may have partly driven the technology diffusion process in Punjab.

The informational cascades model, with its emphasis on rational decision-making by individuals absent any social constraints, is complemented by sociological theories that have also emphasized the role of information. In particular, Rogers (1983) developed a framework for describing innovations in terms of five attributes: (1) relative advantage (including profitability), (2) compatibility, which is defined to be consistency with 'existing values, past experience and needs of adopters', (3) complexity, (4) trialability, and (5) observability. Except for the first of these attributes, all the others stress some aspect of information regarding the new technology or innovation. Formal economic approaches[30] do not make quite the same categorization. In particular, they recognize that gains are uncertain and depend on various facets of information, so that attribute (1) above is interrelated with the other four. In any case, formal and informal empirical studies suggest that information of all four kinds embodied in attributes (2)-(5) has also been critical in the case of the Green Revolution in Punjab. In addition to the work of Day and Singh (1977), this is borne out by observations on the role of Punjab Agricultural University, agricultural extension, and learning made by Randhawa (1974), Hamid (1981) and Leaf (1984) among others, though – given the responses collected by Sims (1988), suggesting that the direct role of conventional agricultural extension was small – this may bear further analysis. In any case, information, the second of our 'three I's', was also crucial in our view.

The final 'I', incentives, one almost takes for granted. The usual focus of analysis of economic decision-making is on private profit. While direct incentives in terms of input subsidies and so on were not markedly different for Punjab versus the rest of the country, they were certainly not adverse. Furthermore, the provision of infrastructure and information would have had a positive effect on incentives as well: the availability of roads and electricity making investment and innovation more profitable in expected terms. Since it has been argued[31] that disincentives were also present, in the form of below-market government procurement prices, two points should be recognized. First, positive input and infrastructure subsidies are still likely to have implied a net positive incentive. Second, farmers were able to get market prices for some output (more so than their counterparts in Pakistani Punjab, for example). It is also possible to maintain the position that Punjabi farmers adopted new technology quickly in spite of disincentives: this would further emphasize the role played by the first two 'I's'.

In conclusion, for understanding the nature of technological change in Punjab agriculture, the threefold classification of (1) infrastructure, (2) information, and (3) incentives, seems to be a useful framework. It was the congruence of favorable conditions with respect to the first two of these, and probably the third as well, that made Punjab special. Some of the groundwork was laid before independence, and some was the result of slow and fortuitous historical developments. However, the successful role played by contemporary state government policies should not be undervalued.

It is also useful to consider the political economy of the policies that supported innovation in Punjab agriculture.[32] Decentralization with respect to agriculture and responsiveness of government to its constituents were important political preconditions for these policies. However, in the 1990s these kinds of policies appear to have been carried to extremes with respect to incentives, while neglecting infrastructure and information. Thus, while power and water have been ever more heavily subsidized, distorting cropping patterns and straining the state's environment,[33] the infrastructure (storage, air transportation, marketing support, power) and information (seeds, irrigation technologies, market needs) required for diversification into higher value-added crops have not kept pace. This paper suggests a conceptual framework for guiding a restoration of the policy balance, necessary for sustained growth as well as avoidance of environmental harm.

Notes

[1]Zarkovic, M. (1987), p. 36.
[2] In presenting data in these two sections, we focus on the 1960s through 1980s, when the Green Revolution and its effects were greatest in Punjab. More recent data on Punjab agriculture is compiled in Singh (2001), who also considers the rural Punjab economy more broadly than this paper.
[3] Sharma, A.K. (1993).
[4] A lakh is 100,000
[5] Similar rankings hold for tractors, diesel pumpsets, and energised tubewells per operational holding: those data are available from the authors.
[6] See Sims (1988), Figure 4, p. 60, and Singh (2001), Table 4.2, p. 83.
[7]Figures in this paragraph are from CMIE States 1993.
[8] A similar analysis may be found in Chadha (1986).
[9]Perhaps, this variable (human capital) in conjunction with other variables may have a greater influence on the adoption of innovations. We take up this issue again in the concluding section.
[10] This point is also elaborated by Chadha (1986)
[11] A high level of credit subsidy per operational holding may imply high levels of adoption of technological innovations per operational holding. But high levels of credit subsidy per hectare of gross cropped area do not seem to be related to high levels of adoption of technological innovations per hectare of gross cropped area in this data.
[12]For evidence see Sidhu (1972).
[13] See, for example, Feder and O'Mara (1981) on this point.
[14] Zarkovic (1987), page 45.
[15] Ibid.
[16] The complete statewise data is available from the authors on request.
[17] Small landlords had little monopolistic control over the tenant farmers or sharecroppers. Thus, there was more equal share in both costs and benefits of adopting innovations.
[18] The risk factor arises because often the outcome of adopting is aggravated even more under the conditions of tenancy or sharecropping where the cost of adopting a

new innovation is disproportionately borne by the cultivator, while the benefit from adoption is disproportionately obtained by the landlord.

[19] This is as defined in the Agricultural Census.

[20] Zarkovic (1987), p. 45.

[21] In the eyes of the consumer, the traditional variety of wheat was superior to that of the HYV only because the HYV of wheat was brown in colour as opposed to amber. In all other aspects the HYV of wheat was appropriate for local tastes.

[22] However, Leaf (1984) in his village case study that post-dates Sidhu's work, argues that tractor purchases are typically part of rational long run strategies.

[23]Chaudhri and Dasgupta (1985) p. 33.

[24]Sidhu (1972), p. 76.

[25]Frankel (1971), p. 20.

[26] McGuirk and Mundlak (1992), p. 137.

[27] Of course no index can be perfect, and in this case the data used to construct it also have flaws. But there seems to be no reason this would bias the index. Another issue could be causality: a high index is also a result of development. But the high value for Punjab in 1966-67 supports the view that favorable and critical investments were made prior to the Green Revolution. Hamid, Sims and others note that the groundwork was laid starting in the 1950s.

[28]Frankel (1971), p. 21.

[29] This term has been used recently in the economics literature to describe situations where later decision-makers are completely swayed by inferences drawn from observing previous decisions of others. See, for example, Bikhchandani, Hirshleifer and Welch (1992) and Kohli (1996). Precursors of this model in somewhat the same spirit include Feder and O'Mara (1982) and Feder and Slade (1984a).

[30] Surveys of economic approaches to technology adoption and diffusion may be found in Feder, Just and Zilberman (1985), Thirtle and Ruttan (1987), and Alauddin and Tisdell (1991). These surveys focus on situations where decision-makers are atomistic. Baldwin and Scott (1987) survey the same issues for strategic decision makers such as firms in a concentrated industry. Singh (1994) examines Indian agricultural experience in the light of economic models of innovation.

[31] This point was made to us by B. S. Mann, who has headed an important Punjabi farmers' organization.

[32] Again, Hamid (1981) and Leaf (1984) are good complementary references, the first being a broad conceptual overview, and the second incorporating detailed microlevel observations.

[33] See, e.g. Singh (1991).

Bibliography

All-India Report on Agricultural Census 1985-86, Department of Agriculture and Co-operation, Ministry of Agriculture, Govt. of India, New Delhi, 1992.

All India Report on Input Survey 1976-77, Vol. I, Government of India, Department of Agriculture and Co-operation (Agricultural Census Division), Ministry of Agriculture, New Delhi.

Allaudin, M. and C. Tisdell, (1991) *The 'Green Revolution' and Economic Development: The Process and its Impact in Bangladesh*, Macmillan, London, England.

Baldwin, W.L. and J.T. Scott, (1987*) Market Structure and Technological Change*, Fundamentals of Pure and Applied Economics, v.17, Harwood Academic Publishers, Chur, Switzerland

Bhaduri, A.R., (1973) 'A Study in Agricultural Backwardness under Semi-Feudalism,' *Economic Journal*, 23, 1, 313-332.

Bikhchandani, S., D. Hirshleifer and I. Welch, (1992) 'A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades', Journal of Political Economy, v. 100, 992-1026.

Centre for Monitoring Indian Economy, *Basic Statistics Relating to the Indian Economy*, *Vol. 2: States*, 1985-87, 1993-94.

Chadha, G. K., (1986) *The State and Rural Economic Transformation: the Case of Punjab, 1950-85*, Sage Publications, New Delhi.

Chaudhri, D.P. and A.K. Dasgupta, (1985) *Agriculture and Development Process, A Study of Punjab*, Croom Helm, New Hampshire.

Dadibhavi, R.V., (1988) 'Dimensions of Regional Disparities Institutional Credit to Agriculture,' *Indian Journal of Agricultural Economics*, vol. 43 (3).

Day, R.H. and I. Singh, (1977) *Economic Development As An Adaptive Process, the Green Revolution in the Indian Punjab*, Cambridge University Press, Cambridge, England.

Evenson, R., (1974) 'Education and Rural Development,' in *World Year Book of Education 1974*, eds. P. Foster and J.R. Sheffield, Evan Brothers, London.

Feder, G., R. Just and D. Zilberman, (1985) 'Adoption of Agricultural Innovations in Developing Countries: A Survey', *Economic Development and Cultural Change*, v. 33, 255-298.

Feder, G. and G.T. O'Mara, (1981) 'Farm size and the Diffusion of Green Revolution Technology', *Economic Development and Cultural Change*, v. 30, 59-76.

Feder G., and G.T. O'Mara, (1982) 'On Information and Innovation Diffusion: A Bayesian Approach', *American Journal of Agricultural Economics*, v. 64, 145-147.

Feder, G. and R. Slade, (1984) *Aspects of the Training and Visit System of Agricultural Extension in India*, The World Bank, Washington, DC., USA.

Feder, G. and R. Slade, (1984a) 'The Acquisition of Information and the Adoption of New Technology', *American Journal of Agricultural Economics*, v. 66, 312-320.

Feder, G., Slade, R.H., and A.K. Sundaram, (1985) *The Training and Visit System An Analysis of Operations and Effects*, The World Bank, Washington, DC., USA.

Fleigel, F.C., Kivlin, J.E., Roy, P., and L.K. Sen, (1968) *Agricultural Innovations in Indian Villages*, National Institute of Community Development, Hyderabad.

Frankel, F.R., (1971) *India's Green Revolution: Economic Gains and Political Costs*, Princeton University Press, Princeton.

Hamid, N., (1981) *Process of Agricultural Development- A Case Study of The Punjab*, University Microfilms International.

Herdt, R.W., (1983) *Adoption, Spread, and Production Impact of Modern Rice Varieties in Asia*, International Rice Research Institute, Manila, Philippines.

Kohli, D.S., (1996) 'Using Informational Cascades to Stimulate the Diffusion of Technology', processed, National Council of Applied Economic Research, New Delhi, India.

Leaf, M.J., (1984) *Song of Hope: The Green Revolution in a Panjab Village*, Rutgers University Press, New Jersey.

McGuirk, A.M. and Y. Mundlak, (1991) *Incentives and Constraints in the Transformation of Punjab Agriculture*, IFPRI Research Paper No. 87, Washington, D.C.

McGuirk, A.M. and Y. Mundlak (1992), 'The Transition of Punjab Agriculture: A Choice of Technique Approach', American *Journal of Agricultural Economics*, 74, 1, 132-143.

Parthasarthy, G. and D.S. Prasad, (1978) *Response to the Impact of the New Rice Technology by Farm Size and Tenure: Andhra Pradesh, India*, International Rice Research Institute.

Randhawa, M.S., (1974) *Green Revolution: A Case Study of Punjab*, Vikas Publishing House, Delhi.

Rath, N., (1989) 'Agriculture Growth and Investment in India,' *Journal of the Indian School of Political Economy*, vol. I, no.1.

Rogers, E.M., (1983) *Diffusion of Innovations*, 3rd ed. Macmillan, New York, New York.

Rosenzweig, M.R., (1978) 'Schooling, Allocative Ability, and the Green Revolution,' *Eastern Economic Association*, Washington, D.C.

Sharma, A.K., (1993) 'Sources of Differences in Input Use: The Case of Fertilisers in India,' *Journal of the Indian School of Political Economy*, vol. V, no. 2.

Sharma, R. and T.T. Poleman, (1993) *The New Economics of India's Green Revolution: Income and Employment Diffusion in Uttar Pradesh*, Cornell University Press, Ithaca, New York.

Sidhu, S.S., (1972) Economics of Technical Change in Wheat Production in Punjab (India), University of Minnesota, Ph.D. dissertation, University Microfilms, Ann Arbor, Michigan.

Sims, H., (1988) *Political Regimes, Public Policy and Economic Development: Agricultural Performance and Rural Change in the Two Punjabs*, Sage Publications, New Delhi.

Singh, G., (1991) *Environmental Deterioration in India: Causes and Control: with special reference to Punjab*, New Delhi, Agricole Pub. Academy.

Singh, H., (2001) *Green Revolutions Reconsidered: The Rural World of Contemporary Punjab*, Oxford University Press, New Delhi.

Singh, N., (1994) 'Some Aspects of Innovation and Technological Change in Agriculture', in *Agrarian Questions*, ed. K. Basu, Oxford University Press, New Delhi.

Thirtle, C.G. and V.W. Ruttan, (1987) *The Role of Demand and Supply in the Generation and Diffusion of Technical Change*, Fundamentals of Pure and Applied Economics, v.21, Harwood Academic Publishers, Chur, Switzerland.

Vyas, V.S., (1979) 'Some Aspects of Structural Change in Indian Agriculture,' *Indian Journal of Agricultural Economics*, vol. 34, no. 1.

Zarkovic, M., (1987) *Issues in Indian Agricultural Development*, Westview Press, Boulder, Colorado.