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

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revised September 1997

* This is a revised version of a paper presented at a conference on Agriculture of the Punjab at The Southern Asian Institute, Columbia University, April 1, 1995.
We are grateful to Sunil Ashra for useful comments and guidance and the UCSC Endowment Fund for Studies of the Punjab State in India for funding this research. We also benefited from the helpful comments of the conference participants. However, remaining shortcomings are our responsibility. The views expressed here are not those of NCAER or other institutions.

1. Introduction

The state of Punjab in India has, in the last three 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 (HYV's) of wheat, rice and other food crops. The astounding agricultural growth in Punjab is exemplified by the increase in Punjabi wheat production from 1.9 to 5.6 million tons during the years 1965 through 1972.[1] Growth in rice production has been equally impressive.

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 try and construct an answer to this question, this paper reviews studies that have attempted to explain the pattern of rapid innovation in Punjab agriculture over the last three decades. We suggest that there is no single explanatory variable that stands out in comparing Punjab with other Indian states. However, we think 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 may 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

[1]Zarkovic, M. (1987), page 36.

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. 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.

II. Rapid Growth and High Levels of 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 II.1. During this time frame, 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 rate of food grain production resulting from these high 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.

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 (see Table II.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 is not justifiable, as some states included are not comparable with Punjab in terms of size, climate, development, and other such factors. However, even when compared to similar states, such as Haryana, Punjab has fared far better. Moreover, even in the case of rice, which occupied only about 29 percent of the total cropped are in Punjab in 1981-82, the percentage of area under HYV's of rice in the total cropped area was 95.[2] In comparison, in states like Assam, Orissa, and West Bengal where rice covered 50 per cent or more of the total cropped area, the percentage under HYV's of rice was less than 50.[3]

As in the case of the adoption of HYV's 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 (see table II.3). In the latter year Punjab was also the highest consumer of pesticides both in terms of tonnes per lakh hectares of gross cropped area and in terms of tonnes per lakh operational holdings (see table II.4). Even Haryana, which is very similar in terms of size, climate, and development and is second only to Punjab in the consumption of both fertilisers and pesticides, has consumed much lower levels than Punjab. In the years 1979-80 and 1984-85, Punjab had the most number of registered tractors per lakh hectare of gross cropped area and per lakh operational holdings (table II.5).

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 and per lakh operational holdings were installed in Punjab than in any other state. However, as seen from table II.6, 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 in terms of installations per lakh operational holdings, by Tamil Nadu in terms of installations per lakh hectares of gross cropped area, and by Maharashtra in terms of installations per lakh operational holdings. The shift in position from being amongst the highest in 1968-69 to the highest in 1984-85, in terms of both installations per lakh hectares of gross cropped area and installations per

[2] Sharma, A.K. (1993).
[3] Ibid.

lakh operational holdings, reflects the high level of technology diffusion in Punjab. In 1968-69, Tamil Nadu had a greater number of tubewells per lakh gross cropped area and per lakh operational holdings than Punjab. In the same year, Haryana had more tubewells per lakh operational holdings than Punjab (table II.7). 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, table II.2 to II.7 support the statement that Punjab has experienced high levels of technology adoption.

III. Possible Reasons for Interstate 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 HYV of wheat in Punjab have been attributed to two factors. Sen (1974) claims that (1) wheat seeds responded better than rice or jowar 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 HYV's in total cropped area under different food grains, but the higher level of adoption of all the HYV's 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[4].

As noted earlier, of the 29 per cent of the gross cropped area in Punjab occupied by rice in 1981-82, 95 per cent was under HYV's of rice. In the same year, of the total area covered by bajra (millet), 61.67 per cent was under HYV's 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 9.33 per cent, respectively, of total area covered by bajra

[4] See Sims (1988), Figure 4, p. 60.

was under HYV of bajra. Thus, perhaps, other factors, such as levels of supporting inputs, infrastructural development, credit availability, etc., may help determine the interstate differences in the levels of adoption of technological innovations[5]. 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: (1) area occupied by HYV's, (2) irrigation, (3) retail outlets, and (4) 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 (1) human capital, (2) access to capital for innovation, (3) price incentives, (4) size of cultivated holdings, and (5) ownership of land[6]. We discuss each of these in turn.

(1) One of the prerequisites of technology adoption is that a farmer should be aware of the benefits the 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. Several economists, including 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, Fliegel et. al. (1968) argued that literacy and not education is significant for village-level adoption because literacy is a basic skill to

[5]Figures in this paragraph are from CMIE States 1993.
[6] A similar analysis may be found in Chadha (1986).

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. The enrolment ratios in classes I-V of Gujarat, Maharashtra, and Tamil Nadu were above that of Punjab for 1983-84, while the enrolment ratio in classes VI-VIII were higher in Tamil Nadu and Kerala than in Punjab. In contrast, the levels of adoption of HYV's of seeds, chemical fertilisers, pesticides, tractors, and diesel pumpsets were much higher in Punjab as seen from tables II.2 to II.6. Only in the case of the number of tubewells adopted do we find that the level of adoption in Tamil Nadu in terms of number per lakh hectare of gross cropped area was higher than the adoption level 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[7].

(2) 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 source 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 III.2). In

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[7]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.

1984, the percentage of borrowing members in primary agricultural societies was the highest (61.9%) 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 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 1950's[8].

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, as seen from table III.3. 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

[8] This point is also elaborated by Chadha (1986)

financial constraints in Punjab[9]. 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 was Rs. 1759 in Punjab, and only Rs. 1463 in Haryana, while the all India average was Rs. 710 (see Table III.4).

(3) 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 wheat and rice regions of Punjab. This explanation just makes us rephrase the basic question posed, regarding higher rates of innovation in Punjab, to: what are the special characteristics of Punjabi farmers that have 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 III.5) among all the states. The high consumption of power could reflect greater availability. According to the NSS report all the villages in Punjab were electrified

[9] 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 1976-77 (table III.6). 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 (Paise 13.5 per KWH) was less than half of that in Haryana (Paise 28.68 KWH) (see table III.7). Similarly, Punjab had the greatest percentage of net sown area with assured sources of water in 1978-79 (table III.8)[10].

Interstate 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 an important role in promoting investments on agricultural innovations in Punjab. A more comprehensive study would be required in order to conclusively say whether such indirect subsidies encouraged adoption of innovations in Punjab and whether similar incentive schemes will prove to be fruitful in other states.

(4) Farm size: HYV's of seeds are scale neutral and high yield can be realised on any size farm[11]. However, the supporting technology in the form of irrigation and machinery, i.e., fixed cost inputs, does lead to economies of scale[12]. Thus only farms of at least a particular size are capable of reaping the greatest benefits from the new technology. Farmers with this size or larger farms may have more incentive to adopt supporting technology. The appropriate size of operational holdings undertaking innovations associated with the Green Revolution ranges from 7.5 to 25 acres[13]. The Indian government classifies these size farms in the medium and large categories. The 1971

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[10]Note that only those states with all (or most of) their net sown area falling under high rainfall regions had 100 per cent (or above 90 per cent) net sown area with reasonably assured water supply. These states are not comparable to Punjab which has no net sown area in high rainfall regions.
[11](For evidence see Sidhu (1972).)
[12] See, for example, Feder and O'Mara (1981) on this point.
[13] Zarkovic (1987), page 45.

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[14].

Table III.9 lends further support to the hypothesis that medium to large size farms are more likely to adopt technological innovations than smaller size farms. As seen from the table, in 1977, medium and large size farms in all states used greater numbers of pumps and tractors than smaller size farms. However, Punjabi farms in all size categories 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 are the reasons for greater adoption of technology by all farmers in Punjab.

(5) Some economists have suggested that perhaps 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 the 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[15] to adopt more Green Revolution technology. Parthasarthy

[14] Ibid.

[15] Small landlords had little monopolistic control over the tenant farmers or sharecropper. Thus, there was more equal share in both costs and benefits of adopting innovations.

and Prasad (1978) also showed that owners of land are more likely to adopt HYV's of seeds than tenants because of the risk factor.[16] Bhadhuri (1973) , too, found lower rates of adoption among tenants.

In contrast, Vyas (1979) claimed that the adoption rate in India has been the same among owners and tenants with respect to the HYV's of wheat. In fact, in some regions tenants used more fertiliser per hectare than the owners. 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 the highest or amongst the highest percentage of wholly owned and self-operated operational holdings. However, as seen from Table III.10, the percentage of wholly owned and self-operated operational holdings is the lowest in Punjab. In contrast, the levels of adoption of technological innovations per operational holding without regard to the title, legal form, size or location[17] are the highest in Punjab. Thus, land ownership by itself does not seem to be important in motivating Punjabi farmers to invest in land improvements and adopt technological innovations that require purchased inputs.

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

[16] 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.
[17] As defined in the Agricultural Census.

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.[18] 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. The HYV's of wheat and rice were adapted to suit local conditions such as soil, climate, and taste[19] 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 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[20]. 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

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[18] Zarkovic (1987), page 45.

[19] 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 collar as opposed to amber. In all other aspects the HYV of wheat was appropriate for local tastes.

[20] 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.

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[21]. 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 technology was of stationary nature across all states, i.e. 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."[22] 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'.[23]

Day and Singh (1977), in an important study of the Green Revolution in Punjab, showed that a farmer responded to prices, revenue, quotas, and the past behaviour of his

[21] Chaudhri and Dasgupta (1985) page 33.
[22] Sidhu (1972), page 76.
[23] Frankel (1971), page 20.

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 notes several factors similar to those discussed by Hamid. For example, she notes that procurement prices as well as market prices were higher in Indian Punjab than in its counterpart. She discusses the broader distribution of resources, including credit and fertilizer, in India, and relates it to the political economy of India, where policies were more responsive to small and medium farmers. Sims emphasizes 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 neighbors' actions, corroborating Day and Singh's earlier study. Again, we return to this in the final section. Sims also notes the importance of the development of infrastructure such as a network of rural roads and rural electrification for Punjab's exceptional performance.

A recent, detailed empirical study by McGuirk and Mundlak (1991, 1992) supports the conclusions of Hamid and Sims. They use twenty years of district level data, covering 10 of present-day Punjab's 12 districts for the period 1960-1979. They use 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 modeled 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."[24] 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 modeled, 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. Concluding Remarks

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 seems to be supported by our review in sections III and IV. In particular, the cross-state comparisons along individual dimensions 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, the Punjabi farmers were provided with an environment conducive the

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

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 V.1). 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. Thus, while individual factors do not distinguish Punjab, this index combining many important dimensions, does single out the state[25]

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.

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

[25] 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 1950's.

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. "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."[26] In fact, the majority of loan applications received for tractors by the Pilot Officer in Ludhiana in March 1969 came from small farmers. Easy credit tempted small farmers to purchase machines. These farmers paid little attention to their ability to repay their loans. The demand for tractors and other machinery may have been unjustified on short-term economic grounds. 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. The first few farmers were stimulated to adopt by the technology promotion schemes and other favorable conditions discussed above, while the rest of the farmers based their adoption decision 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[27] 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

[26]Frankel (1971), page 21.

[27] 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).

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[28] 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[29] 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

[28] 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 strategic decision makers such as firms in a concentrated industry. Singh (1994) examines Indian agricultural experience in the light of economic models of innovation.

[29] This point was made by a participant in the conference who has headed an important Punjabi farmers' organization.

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 realize the political economy of these favorable policies[30]. Decentralization with respect to agriculture and responsiveness of government to its constituents were important political preconditions for these policies. This is an important general lesson.

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

<u>Table II.1</u>

State	**Annual rate of increase in production of food grains 1961-62 to 1985-86**
Punjab	6.4
Haryana	4.7
Gujarat	3.4
Uttar Pradesh (U.P.)	3.2
Rajasthan	2.4
Assam	2.3
West Bengal (W.B.)	2.2
Karnataka	2.1
Andhra Pradesh (A.P.)	2.0
Orissa	2.0
Madhya Pradesh (M.P.)	1.8
Maharashtra	1.7
Bihar	1.6
Tamil Nadu (T.N.)	1.0
Kerala	1.0
All India	2.6

* Source CMIE Vol. 2: States, Sept. 1987

Table II.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

Table II.3 Consumption of fertilisers (NPK)

	per ha. of GCA (kg)		per operational holding (kg)	
State	1971-72	1985-86	1971-72	1985-86
Punjab	73.05	157.4	210	
Haryana	24.06	65.5	91	275
Gujarat	18.2	40.5	75	167
U.P.	26.32	78.7	30	104
Rajasthan	3.49	11.6	19	46
Assam	3.12	4.7	4.6	7
W.B.	18.77	52.2	22	66
Karnataka	14.69	48.4	47	113
A.P.	21.87	66.3	55	108
Orissa	7.6	14.7	14.3	39
M.P.	5.57	19.1	22	57
Maharashtra	11.38	31.7	49	83
Bihar	9.4	48.8	14	42
T.N.	44.88	36.2	65	87
Kerala	40.37	49.8	23	29
All India	10.22	48.4	23	89

* 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 II.4 Consumption of Pesticides (1985-86)

States	Tonnes per lakh ha. of GCA	Tonnes per lakh operational holdings
Punjab	112.68	423.85
Haryana	97.25	267.26
Gujarat	45.73	144.28
U.P.	34.05	66.85
Rajasthan	11.82	51.34
Assam	25.63	33.47
W.B.	88.65	81.3
Karnataka	27.61	66.67
A.P.	101.69	174.97
Orissa	22.81	33.43
M.P.	15.34	44.74
Maharashtra	14.44	38.23
Bihar	17.09	14.83
T.N.	128.2	129.7
Kerala	64.57	23.11
All India	41	68.78

* Source CMIE Sept. 1993
GCA: gross cropped area

Table II.5 Registered Tractors

States	per lakh ha. of GCA		per lakh operational holdings	
	1979-80	1984-85	1979-80	1984-85
Punjab	2570	4642	9956	17459
Haryana	448	1897	1580	5212
Gujarat	322	624	1109	1968
U.P.	457	878	461	816
Rajasthan	196	190	869	825
Assam	148	199	201	260
W.B.	164	184	154	169
Karnataka	141	225	386	543
A.P.	75	160	140	276
Orissa	27	32	43	46
M.P.	36	152	125	442
Maharashtra	119	179	350	474
Bihar	82	165	81	143
T.N.	132	180	143	182
Kerala	233	232	101	83
All India	230	426	418	714

* Source CMIE Sept. 1993

GCA: Gross Cropped area

The operational holdings and gross cropped area figures of 1980-81 and 1985-86 are used to calculate the number of registered tractors per lakh ha. of GCA and per lakh of operational holdings for the years 1979-80 and 1984-85 respectively.

Table II.6 Installation of Diesel Pumpsets

	per lakh ha. of GCA		per lakh operational holdings	
States	**1968-69**	**1984-85**	**1968-69**	**1984-85**
Punjab	730	7512	2101	28257
Haryana	87	2507	330	6889
Gujarat	2150	7449	8848	23494
U.P.	468	6974	543	6482
Rajasthan	88	348	482	1513
Assam		32		41
W.B.	593	2376	711	2179
Karnataka	273	488	873	1179
A.P.	280	1250	701	2151
Orissa	78	361	147	529
M.P.	118	523	472	1526
Maharashtra	604	1159	2586	3069
Bihar	244	1689	369	1466
T.N.	869	1833	1262	1855
Kerala	310	2000	177	716
All India	445	2168	1017	3636

* Source CMIE Sept. 1993

GCA: Gross Cropped area

The operational holdings and gross cropped area figures of 1970-71 and 1985-86 are used to calculate the number of installations of diesel pumpsets per lakh ha. of GCA and per lakh of operational holdings for the years 1968-69 and 1984-85 respectively.

Table II.7 Energisation of Pumpset/ Tubewells

States	per lakh ha. of GCA		per lakh operational holdings	
	1968-69	**1985-86**	**1968-69**	**1985-86**
Punjab	1486	10756	4275	40459
Haryana	1304	7601	4945	20889
Gujarat	420	3221	1728	10160
U.P.	418	3054	486	2838
Rajasthan	88	1384	482	6008
Assam		127		165
W.B.	20	851	24	780
Karnataka	809	4124	2592	9959
A.P.	906	5198	2269	8943
Orissa	16	627	29	919
M.P.	118	2297	472	6697
Maharashtra	590	4740	2525	12550
Bihar	435	1973	660	1712
T.N.	5318	16769	7721	13930
Kerala	870	8646	496	2986
All India	672	3753	1534	6295

* Source CMIE Sept. 1993

GCA: Gross Cropped area

The operational holdings and gross cropped area figures of 1970-71 are used to calculate the number of installations of diesel pumpsets per lakh ha. of GCA and per lakh of operational holdings for 1968-69.

Table III.1 Level of education

State	Literacy rate (1981) Rural	Literacy rate (1981) Effective	State govt. exp. on education per capita (Rs) 1980-81
Punjab	41.7	41	82.8
Haryana	37.3	36	56.5
Gujarat	43.6	44	53.1
U.P.	28.5	27	31.7
Rajasthan	22.5	24	42.6
Assam*			53.8
W.B.	40.2	41	45.6
Karnataka	37.6	38	46.6
A.P.	27.9	30	43.1
Orissa	37.8	34	41.0
M.P.	26.3	28	33.0
Maharashtra	45.7	47	60.8
Bihar	27.5	26	33.8
T.N.	45.0	47	50.0
Kerala	80.3	70	65.3
All India	36.1	36	46.1

Source CMIE, States 1993.

* including Meghalaya and Mizoram

Effective literacy rates exclude 0-4 age group.

Table III.1 Level of education (continued)

State	Enrolment ratios 1983-84 Class I-V (6-11 yrs)	Enrolment ratios 1983-84 Class VI-VIII (11-14 yrs)
Punjab	103.7	63.5
Haryana	88.9	54.9
Gujarat	111.7	55.3
U.P.	80.2	43.3
Rajasthan	74.8	36.8
Assam	62.9	47.6
W.B.	96.0	54.5
Karnataka	86.9	59.9
A.P.	97.3	39.4
Orissa	89.5	36.5
M.P.	80.3	35.0
Maharashtra	125.9	59.9
Bihar	82.3	30.5
T.N.	129.8	65.3
Kerala	96.8	90.2
All India	93.4	48.9

Table III.2 Indicators of credit availability

	(a)	(b)	(c)		(d)	
State	**1985**	**1984**	**1980-81**	**1984-85**	**1980-81**	**1984-85**
Punjab	8.8	33.7	1536.09	1787.47	396.53	475.2
Haryana	5.9	40.7	869.15	956.12	253.96	347.92
Gujarat	6.2	45.3	216.96	429.32	62.94	136.13
U.P.	5.0	48.4	108.6	159.03	107.7	171.10
Rajasthan	6.7	26.5	210.80	286.52	47.49	65.98
Assam	3.0	32.1	6.14	40.26	4.53	30.83
W.B.	3.6	31.3	40.84	55.44	43.27	60.45
Karnataka	8.0	20.7	216.32	504.90	79.35	209.10
A.P.	5.8	22.1	199.17	272.25	106.47	158.23
Orissa	5.2	27.0	195.14	189.95	122.6	129.6
M.P.	5.8	13.6	123.41	182.66	36.07	62.64
Maharashtra	5.1	36.5	207.38	331.55	70.28	125.24
Bihar	4.8	29.6	41.51	92.88	42.11	107.02
T.N.	5.2	37.2	108.66	300.08	100.38	296.62
Kerala	5.5	53.2	243.33	278.9	561.94	779.34
All India	5.6	33.37	158.10	86.78	249.2	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 operational holding).

(d) Total institutional medium and long term loans (Rs. per hectare of gross cropped area).

Table III.3 Credit Subsidy

States	per ha. of GCA		as per cent of SDP		per operational holding	
	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	63.2	143.86
Assam	4.75	23.31	0.14	0.41	6.96	36.55
W.B.	28.61	62.3	0.88	1.04	37.07	80.90
Karnataka	36.68	98.88	1.63	3.12	90.72	224.0
A.P.	46.37	104.55	1.8	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
Bihar	20.14	55.27	0.74	1.09	19.99	49.26
T.N.	59.19	143.37	2.16	2.88	53.56	126.8
Kerala	84.65	221.17	1.87	3.09	57.96	129.4
All India	29.88	69.25	1.29	1.91	57.88	125.66

Source: Rath, N. (1989)

Table III.4 Per capita (rural) income from agriculture (net value added), Rs.

States	1979-80 to 1981-82	1982-83 to 1984-85
Punjab	1795	2325
Haryana	1463	1880
Gujarat	858	1210
U.P.	648	869
Rajasthan	771	1222
Assam	656	928
W.B.	686	1075
Karnataka	837	1074
A.P.	836	1093
Orissa	684	1017
M.P.	605	905
Maharashtra	922	1239
Bihar	450	590
T.N.	522	578
Kerala	631	933
All India	710	994

Source: CMIE: States, Sept. 1987.

Table III.5 Agriculture: per capita power consumption (utilities only) (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

Table III.6 Rural electrification

States	Percentage of villages electrified
Punjab	100
Haryana	100
Gujarat	40
U.P.	29
Rajasthan	25
Assam	9
W.B.	29
Karnataka	55
A.P.	50
Orissa	28
M.P.	20
Maharashtra	57
Bihar	27
T.N.	98
Kerala	95

Source: CMIE, States, Sept. 1987

Table III.7 Average electricity rates (paise per KWH)

States	1985
Punjab	13.50
Haryana	28.68
Gujarat	33.50
U.P.	41.36
Rajasthan	22.00
Assam	30.00
W.B.	35.00
Karnataka	7.66
A.P.	9.50
Orissa	22.22
M.P.	16.00
Maharashtra	22.98
Bihar	36.00
T.N.	11.49
Kerala	15.22

Source: CMIE, States, Sept. 1987

Table III.8 Availability of assured sources of water supply for agriculture: 1978-79

States	**percentage of net sown area with reasonably assured water supply**
Punjab	78
Haryana	53
Gujarat	24
U.P.	56
Rajasthan	19
Assam	100
W.B.	100
Karnataka	21
A.P.	32
Orissa	100
M.P.	63
Maharashtra	29
Bihar	94
T.N.	53
Kerala	100
All India	51

Source: CMIE: States, Sept. 1987.

Table III.9 Number of agricultural machinery per 1000 ha. of GCA (1977)

	Marginal		Small		Semi-Medium		Medium		Large		All Size Groups	
States	Pumps	Tractors	Pumps	Tractors	Pumps	Tractors	Pumps	Tractors	Pumps	Tractors	Pumps	Tractors
Punjab	735	108	685	45	257	47	191	44	91	29	229	42
Haryana	195	10	110	25	65	4	54	10	23	10	56	10
Gujarat	124	15	89		94	1	72	2	37	2	69	2
U.P.	51	1	69	3	87	4	86	10	35	13	70	5
Rajasthan	23	5	33	2	20	1	15	2	4	2	11	2
Assam	61		28		22		90		3		44	
W.B.	79	13	55		51		39		0.3		59	3
Karnataka	14		19	0.2	19	1	19	0.3	30	1	22	1
A.P.	38	1	43		57	1	54	2	32	3	43	2
Orissa	7	0.3	3	0.1	3	0.3	6	0.2	24	1	6	0.3
M.P.	9	0.1	11	1	15	0.4	15	0.4	15	1	15	1
Maharashtra	176		64	6	46		29	5	21	2	35	3
Bihar	50	2	37	1	32	1	40	4	23	2	38	2
T.N.	116	0.2	136	1	130	1	80	2	38	2	108	1
Kerala	103	2	76	52	46	4	48	7	29	6	77	15
All India	64	3	59	3	53	2	42	4	20	3	43	3

Table III.9 (continued) Number of agricultural machinery per 1000 operational holdings (1977)

Groups	Marginal		Small		Semi-Medium		Medium		Large		All Size	
States	Pumps	Tractors	Pumps	Tractors	Pumps	Tractors	Pumps	Tractors	Pumps	Tractors	Pumps	Tractors
Punjab	410	60	906	60	770	140	1200	278	1430	450	886	164
Haryana	89	5	156	36	188	10	334	64	374	163	197	36
Gujarat	62	7	130		268	3	449	14	549	28	256	
U.P.	18	0.2	96	4	237	12	486	59	535	200	74	5
Rajasthan	10	2	47	4	59	4	93	11	73	43	50	9
Assam	27		39		60		493		42		54	
W.B.	32	5	76		133		203		4		56	4
Karnataka	14		29	0.3	53	2	116	2	494	25	65	2
A.P.	18	0.3	64		158	3	260	12	549	50	99	4
Orissa	7	0.1	4	0.2	9	1	32	1	348	14	10	0.5
M.P.	4		16	1	42	1	95	2	259	24	52	3
Maharashtra	83		93	9	131		178	28	324	27	136	10
Bihar	18	1	49	2	86	3	224	22	398	38	42	2
T.N.	47	0.1	192	2	356	2	462	13	635	46	134	2
Kerala	124	1	105	71	123	11	266	40	552	117	38	7
All India	25	1	84	5	148	6	251	25	347	52	86	6

Source: All India Report on Input Survey 1976-77 Vol. I.

Note: The All India Report on Input Survey categorises operational holdings according to their size into five strata:

Strata I	Marginal	below 1.0 ha.
Strata II	Small	1.0 ha. to 1.99 ha.
Strata III	Semi-Medium	2.0 ha. to 3.99 ha.
Strata IV	Medium	4.0 ha. to 9.99 ha.
Strata V	Large	10 ha. and above

Table III.10 Land ownership

States	Wholly owned and self-operated holdings as percentage of total number of operational holdings under all size groups in the state (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.

Table V.1 CMIE's Index of Development of Infrastructure[31]

States	1966-67	1976-77	1980-81	1985-86
Punjab	201	216	215	218
Haryana	129	151	154	150
Gujarat	111	122	125	132
U.P.	107	112	107	108
Rajasthan	59	81	77	79
Assam	73	89	93	87
W.B.	152	133	132	123
Karnataka	90	105	101	100
A.P.	93	97	98	105
Orissa	69	79	82	81
M.P.	53	61	62	71
Maharashtra	117	111	118	119
Bihar	98	109	97	98
T.N.	171	152	153	142
Kerala	135	167	137	140

Source: CMIE, States, Sept. 1987.

[31]For the weights used in the computation of the CMIE infrastructure index refer to table V.2.

Table V.2: Weights used in the composition of the CMIE Infrastructure Index

Item	**Weight**
Power	20
(1) Per capita consumption of electricity (KWH)	10
(2) Per capita industrial consumption of electricity (KWH)	5
(3) Percentage of villages electrified to total number of villages	5
Irrigation	20
(4) Percentage of net/gross area irrigated to total net/gross cropped area.	20
Roads	15
(5) Road length in km. per 100 sq. km. of area	5
(6) Number of motor vehicles per lakh population	5
(7) Length of national highways in km. per 1000 sq. km. of area	5
Railways	20
(6) Railway route length in km. per '000 sq. km. of area	20
Post Offices	5
(9) Number of post offices per lakh population	2.5
(10) Number of letter boxes per lakh population	2.5
Education	10
(11) Literacy percentage	10
Health	4
(12) Number of hospital beds per lakh population	4
Banking	6
(13) Per capita deposits (Rs.)	2
(14) Per capita bank credit (Rs.)	2
(15) Number of bank offices per lakh population	2
Total	100

Source: CMIE: States, Sept. 1987.

References

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

Basic Statistics Relating to the Indian Economy, Vol. 2: States, Centre for Monitoring Indian Economy, Sept. 1994.

Basic Statistics Relating to the Indian Economy, Vol. 2: States, Centre for Monitoring Indian Economy, Sept. 1993.

Basic Statistics Relating to the Indian Economy, Vol. 2: States, Centre for Monitoring Indian Economy, Sept. 1987.

Basic Statistics Relating to the Indian Economy, Vol. 2: States, Centre for Monitoring Indian Economy, Sept. 1986.

Basic Statistics Relating to the Indian Economy, Vol. 2: States, Centre for Monitoring Indian Economy, Sept. 1985.

Bhaduri, A.R. (1973), "A Study in Agricultural Backwardness under Semi-Feudalism," *Economic Journal*, March.

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.

Blyn, G. (1966), *Agricultural Trends in India, 1891-1947: Output, Availability and Productivity*, University of Pennsylvania Press, Philadelphia, Pennsylvania.

Brown, D.D. (1971), *Agricultural Development in India's Districts*, Harvard University Press, Cambridge, Massachusetts.

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.

Desai, D.K. (1988), "Institutional Credit Requirements for Agricultural Production-2000 A.D.," *Indian Journal of Agricultural Economics*.

Evenson, R. (1974), "Education and Rural Development," *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.

Fleigel, F.C., Kivlin, J.E., Roy, P., and L.K. Sen (1970), *Agricultural Innovation Among Indian Farmers*, National Institute of Community Development, Hyderabad.

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

Gulati, A. (1990), "Incentives for Oilseed Cultivators: Implications for Efficiency," *Journal of Indian School of Political Economy*, vol. 11, 2.

Gulati, A. (1989), " Input Subsidies in Indian Agriculture- A Statewise Analysis," *Economic and Political Weekly*, June 24, 1989.

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.

Laxminarayan, H. (1990), "Performance of Indian Agriculture and Rural Sector in the Post Green Revolution Period," *The Indian Economy and Its Performance Since Independence*, ed. R.A. Chaudhury, S. Gamkhar, and Aurobindo Ghose, Oxford University Press, New Delhi.

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..

Shah, M. (1990), "Growth of School Enrolment in India," *Journal of Indian School of Political Economy*, vol. II, no. 2.

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 Preformance and Rural Change in the Two Punjabs*, Sage Publications, 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.