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9. ABSTRACT
The focus of the paper is on tracing the direct and indirect implications of technological change in agriculture in a dynamic framework with an emphasis on feedback and growth linkages among different sectors and economic variables. Both positive and negative aspects of the green revolution have been analyzed. Finally, it develops the conceptual framework to analyze the implications of the dynamic interdependence between technological change, income distribution and employment.

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- THE CASE OF PUNJAB, INDIA -

By

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DYNAMIC ANALYSIS OF DIRECT AND INDIRECT IMPLICATIONS OF TECHNOLOGICAL CHANGE IN AGRICULTURE - THE CASE OF PUNJAB, INDIA - *

By

Mohinder S. Mudahar

1. INTRODUCTION

In general, agricultural production is a function of farm inputs, weather, government programs, and technological change. However, in many Asian countries the most important single factor which led to a substantial increase in agricultural productivity in recent years has been the introduction and adoption of new farm technology. The use of these farm innovations have set into motion a sequence of events which have had varying degrees of multiplier effects and many direct and indirect implications for different sectors of these countries. The adoption of new farm technology has been mainly responsible for taking the agricultural sector out of the low level and stable economic equilibrium trap. Rural incomes and savings are steadily increasing and are instrumental in changing the consumption patterns of the farm population. The demand for durable and non-durable farm inputs; marketing, storage and transportation facilities; and agricultural credit are steadily increasing over time. The demand patterns for human and bullock labor are rapidly changing. New agro-industries are being set up which are creating new off-farm employment opportunities. However, these benefits of new farm technology are, to some extent, being offset by the creation of some social problems such as the distribution of incremental farm incomes in favor of already rich and big farmers.

The direct and indirect implications of new farm technology are analyzed by using data from Punjab agriculture. Punjab has experienced a major revolution in its agricultural sector in the last decade. Consequently, it provides an excellent case study for such an analysis. As compared to some other states in India, Punjab is very small. During 1971, Punjab comprised approximately 1.54 percent of the Indian geographical area and 2.46 percent of the Indian population. Agriculture is the predominant occupation although small-scale industries are rapidly increasing in number all over the state. The non-agricultural sector is growing at a rapid rate, partly in response to developments in the agricultural sector.

The technological change in agriculture is discussed in Section 2 and the dynamic implications of technological change are analyzed in Section 3. The dynamic interdependence and feedback analysis of modernizing agriculture is discussed in Section 4. The final section deals with a summary and conclusions.

*Paper presented at the annual conference of the Western Agricultural Economics Association, University of Idaho, Moscow, July 24-26, 1974. (Forthcoming in the annual conference proceedings.)

2. TECHNOLOGICAL CHANGE IN AGRICULTURE

In general, technological change refers to changes in the input-output coefficients resulting in more output with the same input levels, or the same output with lower input levels. In the neo-classical framework, technological change refers to changes in the parameters of the production function. In the mathematical programming framework, however, technological change can be viewed as not only changes in the magnitude of the input-output coefficients but also changes in the size of the technology matrix. The change in the size of the technology matrix results from (1) the replacement of old techniques with new techniques over time, (ii) the concurrent use of both old and new techniques, and (iii) the introduction of new operations and new activities. Above all, technological change is not just the invention of new machines in the industrial sector, the discovery of new materials, or the creation of new innovations on agricultural experimental stations, but it also includes actual adoption and diffusion of these innovations among farmers.

Farm innovations can be classified into three different categories: (i) new methods, (ii) new materials, and (iii) new machines. These innovations are grouped under "3-M's" of technological change. New methods include various improved agronomic practices such as crop rotations, improved cultural practices, timely farm operations, use of proper doses of various farm inputs, etc. New materials consist of chemical and biological innovations which include high yielding crop varieties, chemical fertilizers, insecticides, herbicides, etc. Finally, new machines include mechanical innovations such as the tractor, diesel engine, cane-crusher, wheat-thresher, harvesting combine, seed-drill, etc. These three components of technological change in the farm sector are factor non-neutral and embodied in the respective innovations.

At the empirical level, the derived magnitude and direction of implications of technological change in agriculture depend, to a great extent, on the methodological approach used to measure them, for example, the neo-classical production function approach or the mathematical programming approach. This differential impact is mainly due to differences in the underlying assumptions of these two approaches and their ability to incorporate complex farm technology. The mathematical programming approach allows for several farm commodities as farm activities, several kinds of investment goods, seasonal labor and land constraints, more than one production technique, land-labor-capital substitution, etc. Furthermore, it allows for a choice among several farm activities which are subject to different economic, resource and behavioral constraints. All of this is not possible in the neo-classical production function framework. However, the analysis in this paper is not derived from any particular methodological approach; rather it is based on a comprehensive set of micro and macro data from the ex post experience of Punjab agriculture.

The extent of utilization of new technologies depends upon their payoffs, resource restrictions, farmers' financial position, risk component, institutional factors and government programs. Technological change, on the other hand, is determined by various economic and institutional factors. The economic factors include changes in the relative price ratios of farm inputs such as land, labor, investment goods, money capital, etc., and

resource restrictions such as land, seasonal labor shortages, etc. In the early stages of U.S. agriculture, the main emphasis was on the use of labor-saving technology, i.e. mechanical innovations, whereas in Japanese agriculture, the main emphasis was given to land-saving technology, i.e. agronomic, biological and chemical innovations. However, in Punjab agriculture, all of these innovations were introduced and adopted more or less at the same time and with more or less equal emphasis.

The adoption of new farm innovations has been very rapid in Punjab agriculture. The area under high yielding wheat varieties has increased from 3.51 percent in 1966-67 to 72.56 in 1971-72. For rice, it has increased from 1.54 percent in 1966-67 to 69.11 percent in 1971-72. The use of chemical fertilizers has increased by over ten-fold in the ten year period from 1961-62 onward. The proportion of area under irrigation has increased from 52 percent in 1961-62 to 72 percent in 1971-72. The number of tubewells for irrigation has increased from 26 thousand in 1965-66 to 114 thousand in 1971-72. The number of tractors has increased from five thousand in 1961 to 40 thousand in 1972. During 1972, more than 25 percent of the total number of tractors in India were in Punjab. The use of other biological, chemical and mechanical innovations has also been increasing at a very rapid rate. The existence of favorable physical, institutional and human factors laid the groundwork and made it possible to adopt modern farm technology at a rapid rate and on a large scale.

3. DYNAMIC IMPLICATIONS OF TECHNOLOGICAL CHANGE

Since the introduction of high yielding crop varieties in Asian countries, many excellent studies have appeared describing the 'green revolution.' This includes Day and Singh (2), Falcon (3), Johnston and Cownie (9), Ladejinsky (13, 14), Lele and Mellor (15), Randhawa (19), Wharton (22), and many more. All of these studies have acknowledged the positive contributions of the green revolution on agricultural growth. However, these studies have also warned us about the negative contributions and social polarization which is supposedly the direct consequence of the green revolution. The issues raised by various scholars are far from settled. The purpose of this section is not to review or criticize these studies. Rather, the purpose is to present facts from the Punjab experience which may support or contradict the conclusions arrived at in earlier studies.

It is very difficult to classify these implications into (i) primary, secondary, and tertiary, or (ii) first, second and third generational. This difficulty arises mainly because (i) these implications are not static but dynamic and lead to dynamic consequences through various multiplier effects; (ii) these implications are not entirely independent, rather they are highly interdependent and lead to all kinds of feedback effects; and finally (iii) these implications do not take effect at different points in time but occur simultaneously. Consequently, no attempt is made to classify them based on any of the above criteria. Rather, the dynamic implications of technological change are classified into (i) direct implications, and (ii) indirect implications through various feedback effects. The direct and indirect implications of technological change in agriculture are analyzed on ten different variables which are outlined in Table 1.

Table 1. Direct and Indirect Implications of Technological Change in Agriculture*

No.	Implications	Direct	Indirect
1.	Agricultural Production	**	
2.	Marketable Surplus	**	
3.	Income & Income Distribution	**	**
4.	Consumption Patterns		**
5.	Physical & Financial Inputs	**	**
6.	Savings & Investment	**	**
7.	Employment	**	**
8.	Prices and Wages	**	**
9.	Energy	**	**
10.	Institutions	**	**

*The direct and indirect implications are not necessarily mutually exclusive. Furthermore, technological change in agriculture has far reaching implications for socio-political and governing institutional structures. None of this is discussed in this paper. However, interested readers are suggested to refer to Frankel (4) and Johl and Mudahar (8).

A. Agricultural Production

The introduction and adoption of new farm technology has led to a direct increase in agricultural production. Punjab has achieved a remarkable growth in foodgrains production since the mid-sixties. The average annual growth rate of foodgrains production has been 15.2 percent from 1961-62 to 1971-72 and 24.9 percent from 1965-66 to 1971-72. On the other hand, growth in non-foodgrains production has been relatively slower. This is partly due to a shift in acreage away from nonfoodgrains to foodgrains. Nevertheless the overall performance in agricultural production has been quite impressive. Among individual crops the average annual growth rate was 35.1 percent for rice and 32.6 percent for wheat from 1966 to 1972. The growth in foodgrains production has been due to increase in per acre yields, cropping intensity and shifts in acreage.

In the agricultural sector, Punjab did remarkably better as compared to the corresponding Indian performance. The relative share of Punjab in India's total production of foodgrains was 4.91 percent during 1966 and 7.6 percent during 1972. Wheat was mainly responsible for this spectacular growth. Since Punjab has been a food surplus state, the growth in marketable surplus of foodgrains has been much larger than the corresponding production. During 1972, Punjab contributed 28 percent of rice and 64 percent of wheat to the total Indian procurements of rice and wheat, respectively.[1/] In the case of the total procurements of all the foodgrains in India, Punjab contributed 11 percent in 1966 and 51 percent in 1972. Considering the size of the state in relation to the rest of India, these performances are no less than spectacular by any criteria.

B. Marketable Surplus and Marketing Behavior

As indicated above, production of foodgrains has increased manyfold over the past few years. However, there has been very little change in the total consumption of foodgrains by farmers. Consequently, almost all the incremental foodgrains production resulting from technological change has been marketed, leading to a substantial increase in marketed surplus. This is especially true for wheat and rice. The total production and marketed surplus for wheat in Punjab over time is reported in Table 2. [2/]

[1/] During 1970, Punjab contributed 74 percent of the total procurement of wheat in India. The fall in Punjab's share in the total wheat procurement in India from 1970 to 1972 was mainly due to price disincentive since the wheat price was fixed by the government at a level which was much lower compared to the open market price for wheat.

[2/] The results dealing with the marketing of wheat are based on Gill (5).

Table 2. Production and Marketed Surplus for Wheat in Punjab (million tons)

Year	Production		Marketed Surplus		
	Quantity	Percent Increase over 1967-68	Quantity	Percent Increase over 1967-68	Percent
1967-68	2.45	--	0.82	--	33.46
1968-69	3.34	36.33	1.64	100.00	49.10
1969-70	4.49	83.87	2.32	182.93	51.67
1970-71	4.92	100.82	2.80	241.46	56.91

Source: Gill (5).

It is clear from the table that both the production and marketed surplus of wheat have been increasing rapidly but at a diminishing rate. The production doubled in a three year period from 1967-68 to 1970-71. However, the marketed surplus more than tripled over the same period. The proportion of total wheat production marketed increased from 33.46 percent in 1967-68 to 56.91 percent in 1970-71. Furthermore, the post-harvest (15th April to 15th July) market arrivals increased from 54.9 percent in 1967-68 to 84 percent in 1970-71. Although this post-harvest increase was partly due to quick threshing of wheat by power threshers and combines, according to Gill it was mainly due to the farmers' fear of a crash in wheat prices after procurement targets were met by the government (5).

This led to post-harvest gluts in most wheat markets in Punjab. During peak periods the marketed arrivals increased as much as five-fold in certain markets. This happened despite the fact that the geographical area and population served by each grain market in Punjab is lowest among the major states of India (8), and the government opened up many new procurement centers to reduce heavy arrivals in certain markets. Nevertheless new and serious problems resulted. The market yards were not large enough to handle daily arrivals. On an average during the peak period, 25 to 29 percent of daily arrivals in Khanna market (an important wheat market) were sold outside the market. Despite substantial increase in the market labor force there was still shortage of labor. Sometimes farmers had to wait hours to sell their produce. Commission agents and traders made windfall profits. Due to shortages of storage facilities, produce was occasionally left in the market for days, exposing it to all kinds of natural hazards. During 1970-71, 25-30 percent of the total arrivals were affected by rain, causing 10-12 percent partial damage and 2.5-5.0 percent severe damages. Transport facilities were inadequate to haul the produce to its destination.

Small farmers and consumers with low income levels were most severely affected due to lack of facilities. Farmers suffered not only physical losses due to rain and exposure, but also financial losses since they were paid much lower prices for their rejected or damaged produce. Consumers suffered (and still do) because they had to pay exorbitant prices and there were insufficient supplies.

C. Income Level and Income Distribution

The average annual per capita income in Punjab has increased from 374 rupees in 1960-61 to 945 rupees in 1969-70, the highest among all Indian states. The real per capita annual income (at 1960-61 prices) was 470 rupees in 1969-70, which was very low according to international standards but still the highest in India. Although the use of modern technology has certainly increased average per capita income in Punjab and elsewhere, there is a lot of controversy with respect to its distributive effects. It is generally claimed that big and already rich farmers are benefitting from new technology while landless laborers, tenants and small farmers have gained very little or not at all. Consequently, income distribution is becoming much more inequitable over time.

The level and distribution of income among sample farmers in Ludhiana district of Punjab is reported in Table 3. 3/ The table clearly indicates that (i) the annual average income of all the farming households has gone up from 1038.34 rupees in 1967-68 to 1422.32 rupees in 1969-70, implying an 18.48 percent annual growth rate; (ii) a significant proportion of farmers have moved up the ladder to higher income groups; (iii) the annual average income levels of lower income groups have increased within those groups; and (iv) the farmers in the higher income groups have gained relatively more than lower income groups. These results strongly indicate that small and marginal farmers have benefitted from the new technologies, though proportionally less than the large farmers.

During 1967-68, 58.74 percent of the sample farmers had incomes less than or equal to 1000 rupees. This proportion was reduced to 53.98 percent in 1968-69 and to 42.87 percent in 1969-70. During 1967-68, none of the sample farmers had an income of more than 3000 rupees. However, during 1969-70, 11.11 percent of sample farmers had incomes of more than 3000 rupees. During 1967-68, 19.05 percent of the farmers belonged to the 400-600 rupee income group with average income equal to 461.35 rupees. However, during 1969-70, this reduced to 11.11 percent with average income equal to 530.49 rupees.

The distribution of per capita income also varies among farmers belonging to the same farm group (small, medium or large) and over time. The distribution of farm income for sample farmers in Punjab as represented by the gini ratios is reported in Table 4.

It is clear from the table that the income distribution within each farm category has been fluctuating over time, and the income distribution patterns vary among different farm categories. However, these results do not provide any conclusive evidence on the effects of technological change on income distribution patterns. Income distribution among farmers in the large farm category have widened over time. By contrast, income distribution seems to have become more equitable within each small and medium farm category over time, as indicated by the lower gini ratios during 1968-69 and 1969-70 as compared to 1967-68. However, annual differences in gini ratios may or may not be statistically significant. As indicated by Singh (21), there has

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3/ Based on a study conducted by Singh and Sandu (20). The empirical results are based on randomly selected 126 representative farm holdings which were evenly divided into small, medium and large sized farm groups.

TABLE 3 : DISTRIBUTION OF SAMPLE FARMERS BY PER CAPITA FARM INCOME GROUPS IN LUDHIANA DISTRICT, PUNJAB*

Per Capita Income in Rupees.

Income Group	1967-68			1968-69			1969-70		
	Percent	Cumulative Percent	Average Income	Percent	Cumulative Percent	Average Income	Percent	Cumulative Percent	Average Income
< 400	6.35	6.35	291.24	4.76	4.76	335.93	1.59	1.59	333.70
400- 600	19.05	25.40	461.35	14.29	19.05	502.38	11.11	12.70	530.49
600- 800	17.46	42.86	712.48	15.88	34.93	681.69	15.88	28.58	691.14
800-1000	15.88	58.74	858.96	19.05	53.98	874.52	14.29	42.87	906.32
1000-1200	7.94	66.68	1120.77	11.11	65.09	1126.41	12.70	55.57	1061.63
1200-1400	14.29	80.97	1276.23	7.94	73.03	1293.64	3.17	58.74	1261.58
1400-1600	4.76	85.73	1518.44	4.76	77.79	1464.60	12.70	71.44	1474.68
1600-1800	3.17	88.90	1759.43	4.76	82.55	1770.67	6.35	77.79	1665.87
1800-2000	-	88.90	-	4.76	83.31	1868.71	4.76	82.55	1813.46
2000-2200	3.17	92.07	2167.04	4.76	92.07	2195.94	-	82.55	-
2200-2400	3.17	95.24	2353.24	-	92.07	-	-	82.55	-
2400-2600	3.17	98.41	2560.73	3.17	95.24	2554.06	3.17	85.72	2525.67
2600-2800	-	98.41	-	1.59	96.83	2706.92	3.17	88.89	2702.25
2800-3000	1.59	100.00	2961.00	-	96.83	-	-	88.89	-
> 3000	-	100.00	-	3.17	100.00	3065.08	11.11	100.00	3588.23
Overall	100.00		1038.34	100.00		1160.29	100.00		1422.32

* The farm income figures as used in this table have been arrived at by adding rent, interest, wages, salaries and gifts obtained by the farm family and subtracting production expenditure and depreciation from the gross farm income.

Source: This table has been derived from figures reported in Table 2 of Singh, G. and H. S. Sandhu [20].

Table 4. Gini Ratios of Per Capita Farm Income Distribution for Different Farm Size Groups, Ludhiana District, Punjab

Farm Category	Farm Size in Hectares	1967-68	1968-69	1969-70
Small	≤ 3.64	0.27	0.22	0.26
Medium	3.65-6.48	0.30	0.27	0.28
Large	> 6.48	0.25	0.25	0.31

Source: Singh, G. and H. S. Sandhu (20)

also been a decline in farm income inequality in Aligarh district of Uttar Pradesh from 1963-64 to 1968-69. Furthermore, the table indicates that the range of income distribution is relatively higher in the medium farm category and lower in the small farm category, with no consistent pattern over time. These estimates of gini ratios are, however, lower than all-India estimates, implying that Punjab people are enjoying relatively more equitable income distribution.

It has been argued that modern technology is mainly responsible for unequal distribution of income. As has also been pointed out by Johl (7), this criticism is partly misplaced. New Technology has changed the rural scene and given renewed hope to solve the chronic food problem in India. It has tentatively delayed the catastropic effects of population explosion and has given some more breathing time to make a dent in the population problem. There has been an increase in the standards of living of all in Punjab as a result of new technology, though as noted above, the rich have gained more than the poor. In the absence of modern farm technology everyone would have suffered and the poor people would have suffered more than the rich.

Unequal benefits of new technology depend on the nature and degree of its use, which in turn depends upon (i) the initial distribution of farm assets, including land, (ii) ability to purchase complementary inputs, and (iii) attitudes towards risk. In general, new technology involves high risks. A farmer who is a risk averter and operates a large farm will not gain much from new technology. On the other hand, a small farmer who is willing to take risks has a better chance to benefit from new technology. Similarly, a farmer without a source of irrigation and/or financial resources to purchase fertilizer cannot gain much from high-yielding varieties.

In general, farm size, ability to take risks (attitudes towards risk) and financial base are positively correlated. As a result, small and marginal farmers are in relatively unfavorable positions (both financially and psychologically) to fully utilize all the potentials of new technology. The Government of India has initiated new programs to help weaker sections by establishing Small Farmers Development Agency and the Agricultural Laborers and Marginal Farmers Development Agency. These agencies are already in

operation on an experimental scale. In addition, the government should also use various fiscal, welfare and employment programs to correct the unequal distributive effects of new farm technology in favor of the weaker sections. The adoption of new farm technology has also indirectly influenced the income levels and income distribution of laborers, artisans, traders, and commission agents.

D. Consumption Patterns

The change in consumption patterns caused by rising incomes is quite visible throughout rural Punjab. Consumption items can be divided into (i) foodgrains, (ii) nonfoodgrain farm commodities, (iii) agro-industrial commodities, and (iv) nonagro-industrial commodities and services. The incremental consumption patterns for various types of consumer goods by various farm size groups are represented in Table 5 by the incremental consumption matrix. The incremental consumption coefficients (C_{ij}'s) indicate incremental budget shares for different consumption commodities from the incremental household income.

It is clear from the table that the incremental budget share for foodgrains goes down as farm size increases. This has important implications for (i) the potential demand for foodgrains by the landless laborers and small farmers, and (ii) the potential supply of marketable surplus of foodgrains from medium and large sized farm groups. There is also a tremendous potential for incremental demand for nonfoodgrain farm commodities such as vegetables, fruits, milk and other livestock products, as income and farm size increases. This is a very healthy trend because (i) all of these commodities are nutritionally superior, and (ii) the production of these commodities is highly labor intensive and hence promises a great potential for new employment opportunities. The production of these commodities is also appropriate for landless laborers, marginal and small farmers since they have relatively abundant supplies of labor and the production process creates relatively little demand for land. These enterprises can also be undertaken as supplemental activities by small and marginal farmers.

There is not much difference in the incremental budget share for agro-industrial commodities among different farm size groups. However, the incremental budget share goes down as farm size increases. A major change occurs in the demand for nonagro-industrial commodities and services. The incremental budget share increases rapidly as the farm size increases. The demand for services such as education, health facilities, recreational facilities, transportation, etc. increases at a very rapid rate. Again, the production of these commodities and the furnishing of these services is quite labor intensive. Finally, one can conclude that (i) consumers with higher income levels have a tendency to spend a large part of their incremental income on nonfoodgrains and nonagro-industrial commodities and services; and (ii) that consumers with low income levels spend a major part of their incremental incomes on greater quantity and/or better quality foodgrains.

Table 5. Farm Size and Incremental Consumption Patterns*

Farm Size (Acres)	Agricultural Commodities		Nonagri. Commodities & Services		Total
	Foodgrains	Nonfoodgrains	Agro-industrial	Nonagro-industrial	
No land	$C_{11} = 55$	$C_{12} = 14$	$C_{13} = 18$	$C_{14} = 13$	$C_1 = 100$
$0 < \text{Small} \leq 5$	$C_{21} = 30$	$C_{22} = 24$	$C_{23} = 18$	$C_{24} = 28$	$C_2 = 100$
$5 < \text{Medium} \leq 15$	$C_{31} = 13$	$C_{32} = 26$	$C_{33} = 15$	$C_{34} = 46$	$C_3 = 100$
$15 < \text{Large} \leq 30$	$C_{41} = 7$	$C_{42} = 28$	$C_{43} = 13$	$C_{44} = 52$	$C_4 \doteq 100$

*The values of C_{ij} are compiled from Mellor and Lele (16) and the division of farms into small, medium and large farms is quite arbitrary.

Notes: 1. $\sum_j C_{ij} = 100$

2. $C_{ij} > C_{i+1,j'}$ $j = 1,\ i = 1,\ldots,3$

$C_{ij} < C_{i+1,j'}$ $j = 2,\ i = 1,\ldots,3$

$C_{ij} \geq C_{i+1,j'}$ $j = 3,\ i = 1,\ldots,3$

$C_{ij} < C_{i+1,j'}$ $j = 4,\ i = 1,\ldots,3$

E. Physical and Financial Inputs

The use of high-yielding crop varieties is productive only if it is adopted as a package. This involves improved seeds, chemical fertilizers, irrigation water, insecticides, etc. Most of these new varieties require new and more farm operations. Consequently, the demand for farm labor is also quite high and increasing over time. In Punjab, the area under high yielding crop varieties has increased from 1.5 percent in 1966-67 to 70 percent in 1971-72 for rice; from 0.3 percent in 1966-67 to 48 percent in 1971-72 for hybrid bajra; and from 3.5 percent in 1966-67 to 73 percent in 1971-72 for wheat. This indicates a significant increase in demand for improved seeds. The use of chemical fertilizers has increased from 49 thousand metric tons in 1961-62 to 569 thousand metric tons in 1968-69 (almost an 11-fold increase) and declined to 475 thousand metric tons in 1971-72. The proportion of cultivated area under irrigation has increased from 52 percent in 1961-62 to 59 percent in 1966-67 to 72 percent in 1971-72. More than half of this area is irrigated by private tubewells. Finally, the use of insecticides is also increasing rapidly.

In reality a shortage exists of all these inputs in Punjab, implying that supply of these inputs is an effective constraint to their use. The effective demand for these inputs is determined by farmers' ability to purchase them. While large farmers have purchasing ability, small and marginal farmers have quite inadequate resources to make these purchases. Consequently, the demand for short, medium and long term loans is rapidly increasing. In the absence of credit facilities, small farmers cannot purchase complementary farm inputs and hence cannot really adopt or benefit from new technology.

All the modern farm inputs are produced in the nonfarm sector, implying an increase in the degree of interdependence between the farm and nonfarm sectors. Furthermore, this interdependence is creating a large indirect and derived demand for raw material, labor and other physical inputs which are essential for the production of modern farm inputs in the nonfarm sector. Consequently, demand for financial resources is also increasing. Since demand for financial resources is growing in both the farm and nonfarm sectors, the linkages between these and the banking sectors are quite significant and increasing rapidly.

F. Savings and Investment Patterns

An increase in savings and investments is quite visible on Punjab farms. Despite an increase in production expenditure, the increase in marketable surplus has resulted in a positive increase in savings over time. This is partly reflected in a substantial increase in savings deposits in cooperatives and commercial banks by farming households. According to Kahlon and Bal, net savings per rural household in Punjab have increased from 1363.09 rupees in 1966-67 to 5181.96 rupees in 1969-70, an almost four-fold increase (10). Net savings were either low or negative on small farms prior to 1967-68, but they are now making positive savings.

These savings have been and are being used to make investments in quasi-fixed and fixed farm machinery. The number of versatile (fixed and mobile) and specialized farm machinery has been growing in the last few years in Punjab. The number of tubewells has increased from 26 thousand in 1965-66 to 114 thousand in 1971-72 (more than a four-fold increase). The number of tractors has increased from 1100 in 1951 to five thousand in 1961 to almost 40 thousand in 1972. During 1972, approximately 27 percent of the total number of tractors in India were in Punjab. There are over 80 thousand power wheat threshers. Almost all of the wheat crop is threshed by power threshers. The number of sugarcane-crushers, maize-shellers, rice-hullers, chaff-cutters, hydraulic land-levellers, cultivators, seed-drills and plant protection equipment is increasing rapidly over time. The sight of traditional farm equipment is becoming more uncommon everyday.

Currently, most farms in Punjab are either partially or fully mechanized. Some of the major reasons which led to this mechanization are (i) the need for timeliness of farm operations, (ii) a shortage of labor (human and bullock) during peak periods, (iii) the need for leveling sand dunes and bringing previously uncultivated land under cultivation, and (iv) an increase in savings and relatively easy availability of farm loans. Since heavy farm equipment, mainly tractors, is not being fully utilized, it indicates that social factors, such as status, might have outweighed economic considerations in some cases.

In order to meet the increased demand for farm machinery and equipment in the agricultural sector, its production and supply has also increased in the nonagricultural sector. However, the supply is still lagging far behind the actual demand. Consequently, there has been a tremendous increase in investment in the nonagricultural sector. Given a significant increase in the volume of business of those firms which produce agricultural equipment, the overhead costs are declining and the economies of scale are increasing. Since demand exceeds supply, the per unit price for this machinery is increasing quite rapidly. All these factors have led to a significant increase in profits and savings for these firms which quite often plow them back into their own business.

G. Labor Utilization and Employment Patterns

The impact of new technology on employment depends upon the stage of development, pattern of mechanization, mode of technology, and cropping pattern. It is hypothesized that with the possible exception of tractors the impact of technological breakthroughs on overall employment has been positive in Punjab agriculture. Let us now examine this proposition in the light of a few empirical studies. In a careful analysis of Punjab agriculture Johl has concluded that the direct and indirect effects of mechanization, along with elements of improved farm technology, have been positive not only on employment and labor productivity but also on returns to various factors of production (6).

According to Billings and Singh, the average demand for labor was 51 man days per care on a ten acre irrigated farm in the Punjab with a typical cropping pattern and using traditional technology (1). With the introduction

of high yielding crop varieties along with complementary farm inputs, the labor demand increased to 61 man days per acre. With the introduction of all the farm machinery (including tractor, tubewell, thresher, sheller, cane crusher and wheat reaper) and 220 percent cropping intensity, the labor demand declined to 49.4 man days per acre. This indicates only a marginal decline in labor demand compared to completely traditional technology. At this stage only a small percentage of the farms are fully mechanized.

Based on a farm mechanization study of Punjab agriculture, Kahlon and Grewal conclude that "in the case of human labor it was replaced by tractors only to the extent of 4.25 man days per acre per year. This loss, if one chooses to call it a loss, should be judged against the gain of the much higher productivity of land on tractor operated holdings and off-farm employment generated in agro-industries. The additional income per acre on tractor operated farms compared to bullock farms was 388.00 rupees." (11)

All these studies support the hypothesis of an increase in per acre labor use with the introduction of modern technology, including farm machinery except tractors. 4/ However, even with the introduction of tractors there is only a marginal decline in labor use which is offset by substantial gains in the form of increases in off-farm employment and farm productivity. An increase in labor demand with the introduction of modern technology is caused by (i) an increase in cropping intensity through multiple cropping, (ii) an increase in the number of existing farm operations per acre, (iii) the introduction of new farm operations, and (iv) an increase in the intensity of each farm operation. Furthermore, the use of new technology makes it possible to grow those crops which are highly labor intensive and could not be grown previously due to shortages of labor during peak periods. Finally, the introduction of new farm technology has reduced severe shortages of labor during peak periods and created more demand for labor during slack seasons, hence reducing seasonal variations in employment.

As reported in Table 6, the displacement of labor depends on which farm operation is mechanized. With the introduction of tractors, labor required per cropped hectare declined for preparatory tillage and increased for hoeing and threshing. Labor required for sowing, application of fertilizer, irrigation and harvesting did not change significantly. Furthermore, that part of labor which was supplied by outside labor increased since some operations are traditionally performed by hired labor. On a pure bullock farm, 56 percent of the labor is supplied by family and 44 percent by hired (casual + permanent) labor. On the other hand, on a fully mechanized farm only 24 percent of the labor used is supplied by family and 76 percent by hired labor. Consequently, the results indicate that farm mechanization in Punjab has provided more and better opportunities for employment of landless laborers and farm operators gain more time to participate in farm management and off-farm activities or consume more leisure.

The demand for labor also depends on the cropping pattern. Gram and barley, which require much less labor on a per acre basis, are being replaced

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4/ Combines are certainly labor displacing. At this stage, however, there are only very few combines in Punjab. Our analysis assumes the absence of combines.

Table 6. PATTERN OF EMPLOYMENT DURING DIFFERENT STAGES OF MECHANIZATION ON SAMPLE FARMS, PUNJAB, 1971-72

Hours per Cropped Hectare

Mechanization Stages*	I				II				III				IV			
	Family labour	Permanent hired labour	Casual hired labour	Total	Family labour	Permanent hired labour	Casual hired labour	Total	Family labour	Permanent hired labour	Casual hired labour	Total	Family labour	Permanent hired labour	Casual hired labour	Total
1. Preparatory tillage	111.23	44.93	0.88	157.04	111.36	27.27	8.28	146.91	84.70	48.18	7.22	140.08	24.59	24.36	2.32	51.27
2. Sowing	40.75	14.32	30.62	85.69	37.83	6.33	30.52	74.68	35.27	13.03	51.58	99.86	14.27	16.36	63.81	94.44
3. Manuring and fertilizers	17.18	7.93	0.44	25.55	16.23	2.44	2.27	20.94	9.63	7.08	6.66	23.37	8.82	7.08	2.78	18.18
4. Hoeing and interculture	78.19	48.46	29.07	155.72	76.14	6.49	31.66	114.29	57.22	30.88	48.16	136.26	37.01	42.46	107.31	186.78
5. Irrigation	85.68	56.30	—	141.98	120.62	22.57	2.44	145.63	102.12	58.50	5.38	166.00	54.76	80.27	4.41	139.44
6. Harvesting	108.59	41.19	67.62	218.40	89.61	7.47	53.90	150.98	79.46	34.99	94.33	208.78	34.57	30.05	142.69	207.31
7. Threshing	60.57	22.69	31.06	114.32	42.7	7.31	41.56	91.57	53.96	25.07	5.43	114.49	23.67	27.84	75.64	127.15
8. Plant protection	—	0.44	—	0.44	0.65	—	2.27	2.92	0.14	—	0.14	0.28	1.74	1.62	0.46	3.82
9. Miscellaneous	5.73	0.88	—	6.61	5.36	0.46	0.44	8.26	1.70	0.71	0.99	3.40	1.51	1.74	1.39	4.64
Total	508.92	237.14	159.69	905.75	500.50	80.34	175.34	756.58	424.20	218.42	269.90	912.52	200.94	231.78	400.81	833.53
Percent	56	26	18	100	66	11	23	100	46	24	30	100	24	28	48	100

*Different mechanization stages include the following: I = pure bullock farms
II = pure bullock farms + tubewell/oil engine
III = pure bullock farms + tubewell/oil engine + other farm machinery
IV = tractor + tubewell/oil engine + other farm machinery

Source: Compiled from data provided by Professor S. S. Johl in a seminar at Cornell University in January, 1974

by more productive and labor intensive wheat crop. Maize local and bajra local are being replaced by maize hybrid, bajra hybrid and rice which are relatively more productive and labor intensive. The area under vegetable crops, which are highly labor intensive as compared to general crops, is increasing rapidly over time. Furthermore, the proportion of total labor supplied by the family is going down and the demand for hired labor is going up.

The use of new farm technology is creating tremendous possibilities for indirect employment in the nonagricultural sector through various linkages and multiplier effects caused by (i) increase in demand for industrial inputs and farm machinery, (ii) increase in demand for infrastructure and agricultural services, (iii) increase in sale and distribution operations of farm inputs, (iv) creation of maintenance facilities for farm machinery, (v) increase in marketable surplus, and (vi) increase in demand for nonfarm produced consumer goods. From 1965-66 to 1970-71, the average annual growth in employment has been six percent in cotton textiles; 11.5 percent in woolen textiles; 11.2 percent in power loom weaving; 27.7 percent in cotton ginning and pressing; 16.6 percent in the manufacture of sewing machines; and four percent in the manufacture of agricultural implements. The small-scale industries are booming all over Punjab and are creating tremendous demand for skilled and unskilled labor.

The dynamic implications of new farm technology on employment in the agricultural and nonagricultural sectors are summarized in Table 7. The use of new technology has positive effects on employment in the nonagricultural sector at all levels of farm technology. The partial farm mechanization along with the use of biological, chemical and agronomic aspects of technological change has positive effects on employment in the agricultural sector also. The fully mechanized farms (excluding combines) have marginally negative effects on farm employment. However, the number of these farms in Punjab is still very small. Furthermore, its negative farm employment effects are offset by (i) an increase in nonfarm employment, (ii) a substantial increase in agricultural productivity, and (iii) an increase in returns to other factors of production. The net effects of new farm technology on overall employment are positive. In fact, a tremendous shortage of labor exists in Punjab. These shortages are partly met by an inflow of migrating labor from neighboring states, namely Rajasthan and Uttar Pradesh.

Table 7. Technological Change and Employment

Farm Category*	Agricultural Sector	Nonagricultural Sector
I	+	+
II	+	+
III	+	+
IV	-	+

*All these farm categories use the seed-fertilizer technology and include the following mechanization levels:

I = Pure Bullock Farm II = Pure Bullock Farm + Tubewell
III = Pure Bullock Farm + Tubewell + Other Farm Machinery
IV = Tractor + Tubewell + Other Farm Machinery

The use of tubewells, tractors and other farm machinery has greatly reduced demand for bullock labor. According to Kahlon, Gupta and Sondhi, the overall seasonal demand for bullock power has gone down from 76.17 hours per cropped acre in 1966-67 to 23.06 hours in 1969-70 (12). This is quite a healthy trend for the Punjab economy. Land previously used to grow fodders to feed bullocks can now be used either to feed more milch cattle or to grow nonfodder crops such as foodgrains and nonfoodgrains.

H. Wages and Prices

The annual income of agricultural labor households depends on both annual employment and wage rates. As discussed in preceding sections, the use of new farm technology has created an overall increase in demand for laborers in both the agricultural and nonagricultural sectors. In fact, a tremendous seasonal shortage of labor exists in both sectors. These labor shortages have resulted in wage increases. These increases, however, vary from one region to another and from one part of the year to another. As reported by Johl, the real daily wages in Punjab from 1966 to 1971 have increased by 29.06 percent for ploughing, 32.17 percent for sowing, 33.33 percent for weeding, 50.25 percent for harvesting, 37.04 percent for other agricultural operations, 39.84 percent for blacksmiths, and 50.82 percent for carpenters (7). In addition, laborers are often provided with daily meals by the farming households.

The effect of new farm technology has been to dampen the increase in main farm product prices and to accelerate the increase in farm input prices and nonfarm consumer goods prices. The harvest prices for various crops from 1964-65 to 1971-72 have increased at an average annual rate of approximately 20 percent for rice, five percent for barley, nine percent for gram, nine percent for gur (raw brown sugar), six percent for local cotton, and ten percent for American cotton. The price declined in the case of bajra. However, cotton and rice are not the major crops of Punjab and the area under barley, sugarcane and gram is declining. This leaves maize and wheat as two important crops. The price for maize did not change. The average annual increase in wheat price was seven percent from 1964-65 to 1971-72, four percent from 1965-66 to 1971-72, and no change from 1966-67 to 1971-72.

On the other hand, fertilizer prices are among the highest in the world and were increasing at eight percent average annual rate from 1965 to 1972. Tractor prices have almost doubled over the past decade. Diesel fuel and oil prices are very high and are increasing rapidly. Wage rates have more than doubled. The prices of nonfarm consumer goods are skyrocketing. These conditions certainly do not provide production incentives to farmers. All these inflationary conditions most severely affect small and marginal farmers whose financial base is relatively low and who therefore cannot afford to pay exorbitant black market prices for both farm inputs and consumer goods.

In response to increase in land productivity due to new farm technology, and inflationary pressure due to more or less fixed supply and increasing demand for farm land, the land prices have doubled and tripled in the last decade in different parts of Punjab. Consequently, there has been a tremendous increase in the real value of the assets of large landholders. The landless laborers

and small farmers are the obvious losers in this respect. This has important implications for social justice through land reforms in those areas where the land is highly unequitably distributed. However, one must weigh the long-run economic implications of such a reform in Punjab where the land is relatively more equitably distributed than in India as a whole.

I. Energy Requirements

Farming in Punjab is becoming more and more mechanized over time, mainly in response to shortages of labor during peak periods to perform crucial farm operations, such as sowing, irrigation and harvesting, at the optimal time. The number of diesel engines, electric motors and tractors has increased manyfold in the last few years. Consequently, demand for energy in the form of gasoline, diesel oil and electricity has also increased manyfold. The proportion of total annual electricity supply in Punjab used for agricultural purposes has increased from 22 percent in 1968-69 to 41 percent in 1971-72. The per capita annual consumption of electricity for irrigation alone has increased from 15 KWH in 1968-69 to 41 KWH in 1971-72.

Gasoline and diesel oil have always been in short supply. The energy crisis of 1973-74 only worsened the situation. Consequently, gasoline and diesel prices have risen; the length of lines of farmers waiting to get gasoline or diesel are increasing everyday; and the amount of time spent in search of gasoline -- which otherwise could be spent for more productive purposes -- is also increasing. The supply of electricity for agricultural purposes is also more or less following the same pattern. The uncertain monsoons and hence always uncertain supply of water to the hydro-electric plants is further aggravating the energy situation. Consequently, the on-going process of mechanization is suffering. Total agricultural production has already started showing signs of decline with no bright hopes in the future, at least not in the short-run.

Since farm demand for those products which are produced in the nonagricultural sector has increased manyfold and is still increasing, energy requirements for this sector are increasing even faster than in the agricultural sector. Consequently, competition for the allocation of limited energy supply between the agricultural and nonagricultural sectors is increasing, which, in turn, may lead to a severe setback to development of small-scale industries.

J. Institutional Development

The development of institutions is endogenous to the economic domain and hence it responds to the environmental change in both the agricultural and nonagricultural sectors, through various feedback processes. The interdependence between institutional and agricultural development is dynamic and sequential. The introduction of new farm technology has created an increasing demand for the development of new marketing, financial and delivery institutions. This, in turn, has facilitated the process of adoption of new farm technology and hence the agricultural transformation process. The role of agricultural research and extension institutions in agricultural growth is becoming increasingly important. The government has initiated special programs for the weaker

sections which are benefitting relatively less from the new farm technology as compared to big farmers. The new demands and problems arising from the green revolution are, to some extent, instrumental in establishing new and more efficient institutions in the nonagricultural sector. These, in turn, are promoting a smoother transition from traditional to modern agriculture. As the agricultural and nonagricultural sectors are being modernized, the institutional network is becoming more and more complex and interdependent. 5/

4. DYNAMIC INTERDEPENDENCE AND FEEDBACK ANALYSIS

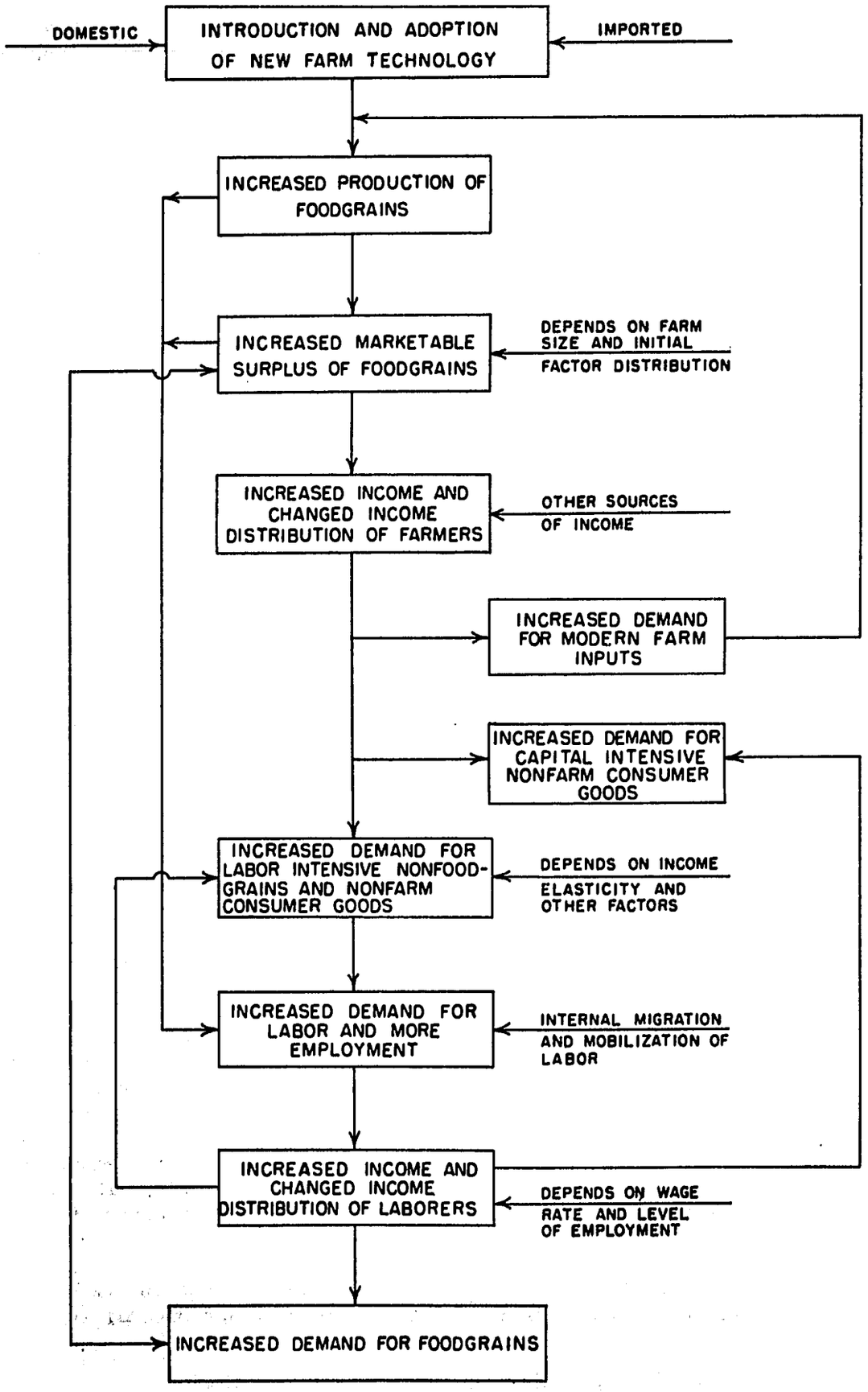
The direct and indirect implications of new farm technology are dynamic, highly interdependent, and sequential in nature. The dynamic interdependence between technological change, income distribution and employment through various feedback processes is presented in Figure 1. The most significant impact of new farm technology has been on the production and marketable surplus of foodgrains. Given the initial farm size and factor distribution among farmers, the marketed surplus has led to increased incomes and changed income distribution. Since the consumption patterns differ among different income groups, demand has increased for those consumer goods which can be produced with labor intensive techniques. This has created more employment opportunities and demand for labor. Increased wages and employment have led to increase in the income of the laboring class and hence increased demand for foodgrains, leading to a consistency between incremental supply and demand for foodgrains. However, if the initial source of increased farm income is other than the increased marketable surplus of foodgrains, the foodgrains supply may serve as an effective constraint to sustain more employment in both the agricultural and the nonagricultural sectors.

Mellor and Mudahar have developed and estimated a simulation model which emphasizes the dynamic interdependence between the implications of new farm technology on employment, income distribution and economic growth (17, 18). The model has been estimated by using aggregate data from India. The preliminary findings suggest that the undesirable consequences of new farm technology (mainly unequal income distribution) are offset by much better prospects for employment and economic growth. The supply of foodgrains (wage goods) does serve as an effective constraint to create and sustain new employment opportunities without creating undesirable inflation. The use of new farm technology has not only increased foodgrains production and thus increased the supply of wage goods but also has created demand for nonfoodgrains and industrial goods through income effects, which, in turn, has created demand for labor and employment.

As has been shown in the preceding discussion, differences exist in the production, consumption, marketing and investment patterns among different farm size groups. It is these differences and their dynamic interdependence which led to (i) increased marketable surplus of foodgrains, (ii) increased demand for those commodities which can be easily produced with labor intensive techniques, (iii) increased demand for labor and hence employment, and (iv) increased demand for foodgrains in the form of wage goods. This has important implications for land reform programs in different parts of India.

5/ The dynamics of institutional change and rural development in the context of Punjab is analyzed in great depth and detail by Johl and Mudahar (8).

FIGURE I. DYNAMIC INTERDEPENDENCE BETWEEN TECHNOLOGICAL CHANGE, INCOME DISTRIBUTION AND EMPLOYMENT



During 1961, the proportion of owner cultivators was more than 80 percent among the total cultivators in Punjab. Only 5.96 percent of the cultivators had land below 2.5 acres. Approximately 52 percent of the farmers had land between 2.5 and 15 acres. Only 2.4 percent of the farmers had more than 50 acres of land. Since then the land distribution is believed to have become more equitable through land ceiling legislation. The argument that small farmers are more efficient is based on studies conducted prior to the introduction of new farm technology. This no longer appears true. Consequently, except for extremely large farms, there is very little economic logic to further reduce the farm size. Certainly further reduction would increase the social justice, but only in the short-run. However, it might reduce (i) the production and marketable surplus of foodgrains, (ii) the derived demand and linkages between farm and nonfarm sectors, and (iii) hence employment. In other words, the long-run effect of further land redistribution rules may not be an increase in social justice.

The development experience of other countries suggests that the role of agriculture declines as development accelerates. As a result, population moves out of the agricultural sector. Reduction in farm size under these circumstances will only lead to absentee landlordism, fragmentation and unproductive use of land. Instead, government should pursue various fiscal programs such as agricultural taxation and create more employment opportunities in the agro-industrial and industrial sectors. However, land reform programs are needed in those parts of Punjab and states in India where land is highly unequitably distributed and the owner-tenant ratio is quite unfavorable.

5. SUMMARY AND CONCLUSIONS

Some of the major findings of the study can now be summarized as follows:

(i) The total production of foodgrains in Punjab has increased at an average annual growth rate of 25 percent from 1965-66 to 1971-72. During 1970, Punjab contributed 74 percent of the total wheat procurements and 45 percent of the total procurements of all foodgrains in India.

(ii) The marketed surplus of wheat increased at an average growth rate of 47 percent annually from 1967-68 to 1970-71. However, existing marketing facilities were quite inadequate to cope with the increased market arrivals. Since more than 90 percent of wheat was purchased by government or government agents for procurement purposes, it created all kinds of market inefficiencies. However, the marketing system and institutions are adapting rapidly to new challenges.

(iii) Landless laborers; marginal and submarginal farmers; tenants, and small, medium and large farmers have all benefitted from the agricultural revolution. However, the large farmers benefitted proportionately more than the small farmers. Income disparities are widening among different farm size groups.

(iv) The consumption demand for nonfoodgrain farm commodities, nonfarm consumer goods, and services is increasing rapidly in response to increased incomes. Production of these commodities is creating more and more employment in both the agricultural and nonagricultural sectors.

(v) Demand for variable farm inputs, durable farm machinery and energy is increasing rapidly but at a diminishing rate. The use of these farm inputs is constrained, not by lack of effective demand but by lack of supply. These investments are financed mainly from increased savings. However, small farmers have a relatively weak financial base and their savings must be supplemented with cheap and timely credit facilities.

(vi) In general, the adoption of modern farm technology, including farm machinery except tractors and combines, led to increased labor use and employment in both the agricultural and nonagricultural sectors. The introduction of tractors has marginally displaced farm labor. However, this has been offset by substantial gains caused by the tractors in (a) increase in off-farm employment, (b) increase in farm productivity, and (c) increase in productivity of labor and other factors of production. The use of family labor is declining. Consequently, the demand for hired labor is increasing more rapidly than the total demand for labor. This is creating shortages of both farm and nonfarm hired labor, which is being partly met by an inflow of migratory labor from adjoining states. Furthermore, farm mechanization is displacing bullocks as a source of draft power quite rapidly. This has made it possible to either use that fodder land to raise milch cattle or grow more nonfodder crops or both.

(vii) Wages have more than doubled. The prices of other farm inputs have increased manyfold. However, the output prices did not increase that rapidly. Consequently, the gap between total revenue and total cost (on per acre basis) for various crops is narrowing over time. The prices for consumer goods are also increasing very rapidly. This is creating economic disincentives to produce more foodgrains. The situation can be corrected through less discriminatory price policies.

(viii) Finally, the preliminary findings from the simulation model indicate that the supply of wage goods is an effective constraint both in creating and sustaining employment in the economy. The adoption of modern farm technology has made it possible to increase the supply of wage goods and hence employment. The lack of use of modern technology and the simultaneous provision of title ownership of a small uneconomic piece of land to everyone may not only reduce production, marketable surplus and employment, but may also lead to inflation. Land redistribution does provide social justice in the short-run. However, it may lead to lack of growth and social justice in the long-run. Consequently, along with devising more equitable distribution methods we must also devise methods to increase the total production of what is being distributed, especially when population pressure is increasing every day.

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