AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY: Agriculture — AE30-0000-G635

B. SECONDARY: Development--India

2. TITLE AND SUBTITLE

The transformation of traditional agriculture,a case study of Punjab,India

3. AUTHOR(S)

Singh,Inderjit

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1971	10p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Ohio State

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)

(In Am.j.of agr.economics,v.53,no.2,p.275-284)

9. ABSTRACT

10. CONTROL NUMBER	11. PRICE OF DOCUMENT
PN-RAA-345	

12. DESCRIPTORS

India
Models
Punjab?

13. PROJECT NUMBER

14. CONTRACT NUMBER

CSD-2501 Res.

15. TYPE OF DOCUMENT

AID 890-1 (4-74)

PAU

ocd 250 /

Reprinted from
AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS
Vol. 53, No. 2, May, 1971

The Transformation of Traditional Agriculture: A Case Study of Punjab, India*

I. J. SINGH

THE PURPOSE of this paper is to report the results of a dynamic regional model of agricultural production response, developed and applied to traditional agriculture, which (1) is based on the already tested notions of economic rationality and price responsiveness in traditional agriculture; (2) incorporates several categories of response forces already studied in the case of developed agriculture; and (3) includes in an essential way the features of subsistence production and household-firm interdependence that are central to the study of production response in traditional agriculture. Specifically, recursive linear programming and activity analysis are used to analyze and simulate the production, consumption, and investment decisions of subsistence farmers in a given region. The result is an improved understanding of the process of agriculture in transition and an operationally tested method for projecting future development.

There is growing evidence of the recent transformation of the agricultural sectors of such diverse economies as Israel, Nigeria, West Pakistan, India, the Philippines, Tanganyika, and Thailand [18]. These vast agricultural transformations offer an excellent opportunity to enhance our understanding of the process of development. The purpose of this study was to investigate some of the factors and conditions responsible for one of these transformations, not in its generality, but in great detail.

While agricultural development remains at the center of development theory and policy, only recently has attention been given to the empirical investigation of its role in the LDC's. Though some investigations stress the importance of agricultural exports as a point of departure in the LDC's, the more fundamental problems are those associated with agricultural production response, since agricultural exports, whatever their role, cannot increase without an increase in agricultural production.

A large part of the empirical work done so far on production response in the LDC's touches on a very important aspect: whether peasants in traditional or near-traditional agriculture respond to market opportunities. These studies have shown that agricultural production of specific commodities in specific LDC's is price responsive, especially when account is taken of adjustment lags due to uncertainty and the quasi-fixity of capital stocks. They show that the form and direction of this response is consistent with price theory, so that we can expect market incentives to play an important role in the transformation of traditional agriculture. These empirical findings clearly refute those who believe that cultural and institutional restraints limit to insignificance any responsiveness to market incentives and that the accepted notions of "economic" behavior cannot be applied to traditional agriculture.[1] This study shows that it is possible to explain production response in traditional agriculture within the accepted framework of economic rationality.

There are many detailed elements of production response that have already been incorporated in regional production models. Among these are the interdependence of outputs using common inputs, technological change, changes in yield and acreage components in crop production, uncertainty and adjustment over time, the relative interaction of inputs and output prices, the rates of investments in factors fixed in the short run, the aggregate supply of production inputs, and planned or programmed policy actions [2, 4]. The relevance of these factors for the study of production response in traditional agriculture has not been fully appreciated. It is one of the purposes of this study to correct this shortcoming. In addition it incorporates features of traditional agriculture: "subsistence production" and the critical household-firm interdependencies, a recognition of which is necessary to give a complete picture of production response in traditional agriculture.

* The research for this paper was supported by the Agricultural Development Council and the National Science Foundation under grants to Richard H. Day of the University of Wisconsin, to whom I am indebted for his continual support.

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[1] See [1] for references and summary of price response studies in the LDC's.

Activities of a Subsistence Production Farm

The notion of subsistence production

It has long been recognized that the farm combines two fundamental units of microeconomic activity, the household and the firm. The resulting interdependence has been analysed for developed agriculture [2, 5, 10]; but while this is clearly of the essence in the analysis of traditional agriculture, its implications, with a few exceptions, have not been understood. Traditional agriculture is distinguished by the predominance of farms whose main characteristics are (1) the dependence of the household upon the output of the farm to maintain family and animal labor and (2) the dependence of the farm upon the household for its labor requirements. The former determines the degree of subsistence production (commercialization), that is, the proportion of production consumed or sold by the farmer; the latter, the degree to which a farm is a family farm, that is, the proportion of family (or hired labor) in the total labor input on the farm [13].

This interdependence has several implications: (1) Production and consumption decisions are interdependent, since subsistence requirements modify cropping patterns, prevent specialization, and affect the amount and composition of the marketable surplus, thereby dampening response to market profitability; (2) consumption and investments decisions are interdependent since the former, through savings and the marketable surplus, affect cash flows and determine the latter; (3) the availability of family labor plays an important role in the choice of technique, thus determining the composition and amount of investment and the path of technological change. These considerations suggest that in the study of production response in traditional agriculture, an appropriate starting point for analysis is t' activity of the subsistence production farm.

The farming household in traditional agriculture can be said to be engaged in a number of general economic activities throughout the year, such as purchasing, production, consumption, sales, investment, and financial activities. These include "traditional" as well as "new" activities which we wish to consider for analysis. Let us examine these activities in greater detail.

Purchasing activities

Purchasing activities include the use of hired labor, animal draft, and tractor hours on the farms in the region. These activities are associated with the use of variable inputs, which may be purchased but are not likely to be unless near-perfect owned substitutes are exhausted (as in the case of labor), or with the use of owned inputs that require complementary cash inputs for their use (as in the case of tractors and animal draft). The use of these inputs depends upon (1) their relative prices, (2) their relative productivities in the alternative uses, (3) their aggregate regional supply, and (4) the availability (existing capacity) of owned substitutes.

Production activities and technological change

Production activities are those that transform owned and purchased inputs into outputs and are measured in acreages sown to important crops in the region. They include: (1) crops grown during two seasons in the cropping year —Rabi (winter) and Kharif (summer); (2) crops grown on irrigated and unirrigated soil conditions; (3) both traditional and new high-yielding crop varieties; (4) crops grown for fodder purposes; and (5) production under two technologies for each crop activity—traditional (bullock-operated) and modern (tractor-operated). These production activities use variable inputs, quasi-fixed capacities, and land of different qualities, and yield final crop outputs measured in yields per acre.

Since crop production is carried out by the performance of agricultural tasks, these are represented by "intermediate production" activities in the present model. Each intermediate production activity has associated with it the use of various inputs, the cost of performing a standard unit of a task, and an intermediate output of a unit of the standard task. The production of final crop outputs then involves the use of several intermediate task outputs by the production activities.

Intermediate production activities provide a quantitative dimension that allows us to view technological change as incorporating (1) the inclusion (or exclusion) of certain agricultural tasks, (2) a change in the way in which tasks are performed, and (3) a change in the level of input use by the tasks. In this manner it is possible to examine the impact of strategic inputs such as water (through irrigation task activities); inorganic fertilizers (through fertilizing activities); the use of new power sources (by incorporating the different ways in which task activities produce intermediate outputs); and the adoption of new high-yield varieties (by considering

them as separate production activities).[2] The process of technological change is viewed not as a replacement of a traditional technology by a new, modern technology but as a task-by-task choice by farmers in the region over time.

Another crucial feature that has to be incorporated is the seasonal use of various inputs, since agricultural operations are time inelastic. A given input available at two different times of the cropping season has to be considered as several different inputs. This feature is included by giving the purchasing activities a time subscript and considering labor, animal draft, and machine capacities during different periods in the cropping year.

Consumption activities

Consumption activities incorporate the nature of subsistence production in terms of the amount of foodgrains and partly processed outputs (sugar) retained for consumption by the household and fodders planted for the maintenance of livestock and draft animals. These consumption requirements are exogenously estimated[3] and are viewed as a constraint in terms of the minimum amounts of certain final crop outputs that have to be grown in any region. Consumption activities have no direct costs, but have opportunity costs in terms of possible profitable crop outputs foregone.

Investment activities

Investment activities are associated with investments in quasi-fixed inputs leading to the replacement and additions to the capital stock. They consist of the purchase of new power sources whose profitability is based upon a net cost calculated on a payback principle [6]. Investments then become profitable if additions to capacity generate enough cost savings in terms of the production or intermediate production activities that use these capacities. Investments also involve a cash outlay for their purchase.

Sales and financial activities

Sales activities involve the sale of marketable surplus for cash when outputs are sold at harvest prices. The cash generated from current sales is then available to meet jointly the requirements of activities in the following year. The decision to sell is viewed as the outcome of two decisions, the decision to produce and the decision to consume out of production with no inventories other than those in the form of crop outputs retained for annual consumption.

The financial activities include (1) a banking activity that allows farmers to "save" excess cash available over cash used at a nominal interest rate which is then available with the accrued interest in the following year and (2) a borrowing activity that allows farmers to borrow working capital at the going interest rate, which then has to be repaid along with the accrued interest in the following year. Other financial cash transactions such as nonfarm cash incomes and cash expenditures for consumption are estimated exogenously and are added to or subtracted from the cash available for the following year.

These activities are incorporated in a recursive programming framework in which decisions are presented as maximizing an objective function each year, subject to a set of constraints that partly depend upon previous year's decisions. The next two sections briefly describe the objective function and the constraint structure.[4]

The Objective Function

The subsistence farmers in a relatively homogeneous farming region carry out their activities with two ordered objectives in mind, the foremost objective being to meet family requirements for food and animal requirements for fodder; once these have been met, to minimize short-run cash costs. This decision rule differs from that of a firm minimizing cash costs in three instances: (1) The first-order consumption requirements act as a constraint upon cost minimization; (2) the use of family labor is given a zero cost in the function, its annual costs of maintenance being fixed; and (3) the use of animal draft includes only variable costs (concentrates and additional fodder given when animals work), since annual maintenance costs are also fixed.

The cost coefficients for the objective function include the variable cash costs for labor hired (if any), tractor hours used (fuel and other costs), and animal draft used (variable cash costs) for the purchase activities; the costs

[2] For a detailed exposition of the notion of intermediate outputs, standardized agricultural tasks, and technological choice, see [17]; to see how these are incorporated into a regional programming model, see [16].

[3] The main determinants of the consumption of subsistence crops were found to be the size of the household and the amount of the output of the crop [15].

[4] For a detailed exposition of the model, see [16].

of seeds and manure for the final production activities; the costs of performing a given standard task for the intermediate production activities; costs estimated on a payback principle for the investment activities; harvest prices of crop outputs for the sales activities; and the appropriate interest rates for the savings and borrowing activities—all lagged one year to represent simple price expectations on the part of the farmers.[5]

The Constraint Structure

The constraint structure includes three broad categories: (1) resource constraints, (2) behavioral constraints, and (3) financial constraints.

Resource constraints

Resource constraints include constraints upon the regional availabilities of (1) variable inputs such as family labor, hired labor, fertilizers, and animal draft; (2) quasi-fixed inputs in the form of available capacities of various power sources such as tractors, tubewells, threshers, cane crushers, which change with both investments and physical depreciation; and (3) fixed inputs of various qualities of land and the amount of canal irrigation available in the region.[6] The strong seasonal use of inputs is accounted for by considering labor, animal draft, and quasi-fixed capacities during seven different periods in the cropping year, while land and canal irrigation availabilities are considered for the summer (Kharif) and the winter (Rabi) cropping seasons.

Behavioral constraints

Behavioral constraints describe the elements of response to uncertainty, adjustment through time, adoption, and learning behavior that modify the response to economic opportunity, and include three broad categories: (1) flexibility constraints, (2) adoption constraints, and (3) consumption constraints.

The flexibility constraints place both an upper and lower limit on the extent to which subsistence farmers are willing to change their output of any given crop in response to profitability in any one year. This cautious response to changes in profitability may be due to (a) expectations that the changes may be short-lived; (b) a desire to diversify crop portfolios to avoid risk, given the nature of subsistence. Flexibility constraints express the farmer's response to risk and uncertainty and can also be viewed as an approximation of a nonlinear objective function in a linear model.[7]

The adoption constraints account for the fact that when a new activity is introduced, even if it is profitable and remains so, it is not adopted immediately. Both the investment in new power sources and growth in the acreage of new crop varieties are constrained by an upper limit to express factors such as learning, experience, cautious behavior, and innovative leadership. The adoption constraints describe an s-shaped path and depend recursively upon the previous year's level of adoption. Such adoption paths are not peculiar to traditional agriculture but are also evident in modern agriculture and industry [6, 11].

The consumption constraints describe the limitation imposed by the need to produce family and livestock requirements on a subsistence farm and are included in the form of lower constraints upon the amount of output for certain crops.[8] These consumption constraints are peculiar to subsistence agriculture and limit specialization and response to market profitability.

Financial constraints

Financial constraints are of two types: (1) an upper limit upon the total amount of short-term working capital available from various sources and (2) the constraint upon cash available for carrying out the activities that use cash by the total cash generated in the previous year through sales, savings, and nonfarm cash incomes, less any cash consumption expenditures and the repayment of previous years' borrowings of working capital.

Model Summary

The model is computed by setting up a linear programming problem for a given initial year and a solution that maximizes the objective function obtained. The results from this solution are then used to estimate a new set of con-

[5] The use of a more complete price expectation model is also possible and is under investigation.

[6] Canal irrigation is an example of fixed regional resources available to farmers that can be changed by policy decisions with regard to infrastructure.

[7] For the use of flexibility constraints, see [4], [12], and [14]; for a theoretical justification of their use, see [3].

[8] This is only one way to include subsistence production. An alternate formulation involving a recursive dependence on endogenous levels of outputs and incomes generated by the model is being investigated.

straints for the objective function, constraints that depend recursively upon the previous year's decisions; and along with exogenous information on input and output prices, the problem is set up for the next year and new objective function maximized. Certain activities and constraints are introduced only when they become available to farmers in the region (such as new varieties, inorganic fertilizers, and new power sources).[9]

Summary Results for Central Punjab, India (1952–1965)

The tremendous growth during the past two decades in total output and productivity in East Punjab (India) and especially the central five districts—Central Punjab—has been widely and repeatedly reported [7, 8, 9]. What has not been reported are the tremendous structural changes that have accompanied this growth and have slowly but surely transformed the traditional agricultural economy. The r.l.p. model described here has made it possible to explain precisely this structural transformation in terms of the economic variables and the environmental conditions that operate at the farm level.

During the 14 years for which the model was computed, four aspects of this transformation are clearly delineated: (1) investments in new power sources; (2) the consequent change in farm technology; (3) structural shifts in labor use; and (4) commercialization of the subsistence production sector. These results are now briefly reviewed.[10]

Investments in new power sources

The traditional inputs of peasant agriculture, labor and animal draft, are being complemented by the use of new power sources. Tremendous investments in tractors, tubewells, and power threshers are predicted by the model and are partly shown in Figure 1. According to the model, the number of tractors in use has increased sevenfold, the number of tubewells in use nearly twelvefold, and the number of threshers over fourfold, even though the last were introduced only in 1963. Investments in power cane crushers increased between 1952 and 1955; but no additional investment occurred again until 1959–60, after which investments again fell to zero. The index of use showed a similar trend, with an increase in the first three years followed by a continual decline almost to zero by 1965. This indicates that the adoption of labor-saving power sources has not been across the board and that in some cases their use has actually declined. This has a bearing on the choice of technique, since power cane crushers are profitable to use only when labor has to be hired during the period of cane crushing (November to March). With the growth in population and availability of family labor and a decline in the total amount of cane crushed, there has actually been a reversal in the adoption of labor-saving technology and the mechanization of this task.

Change in farm technology

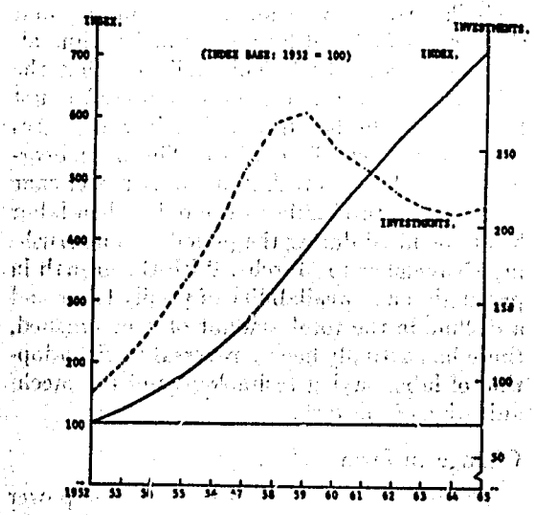
The investments and the use of new power sources predicted by the model show that the trend in mechanization does not lie on a balanced growth path. The choice with regard to technique is made task by task. During the period studied, this choice led to an investment pattern oriented towards the performance of specific tasks—tractors for land preparation, sowing, and transportation; tubewells for irrigation; and threshers for threshing.

Figure 1 shows the indices of total gross area sown, and Figure 2 shows total standard units of land preparation, irrigation, cane crushing, and transportation used in the region, and the indices of the performance of these tasks by labor-saving technologies along with the percentage of the total task use mechanized (1952 is the base year).

The index of the total gross area sown has increased by 37 percent in the period, but the index of area sown by tractors has increased by 363 percent while the percentage of total gross area sown by tractors has increased from 7.7 percent in 1952 to 25.6 percent in 1965. The indices of total land preparation, irrigation, and transportation increased by 46 percent, 39 percent, and 396 percent, respectively, while the indices of the performance of these tasks by mechanized means increased 384 percent, 501 percent, and 336 percent, respectively. The percentages of land preparation and irrigation performed by mechanized means increased from 11.3 percent to 37.3 percent for land preparation and from 15.8 percent to 68.3 percent for irrigation from 1952 to 1965, in the latter case totally replacing the traditional Persian wheel as a means of irrigation by tubewells. The in-

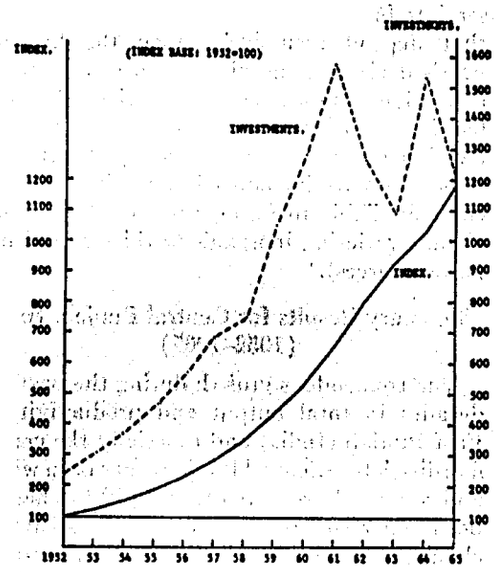
[9] For a detailed exposition of the methodology of recursive linear programming, see [4].

[10] For details, see accompanying charts; for detailed model results, see [16].



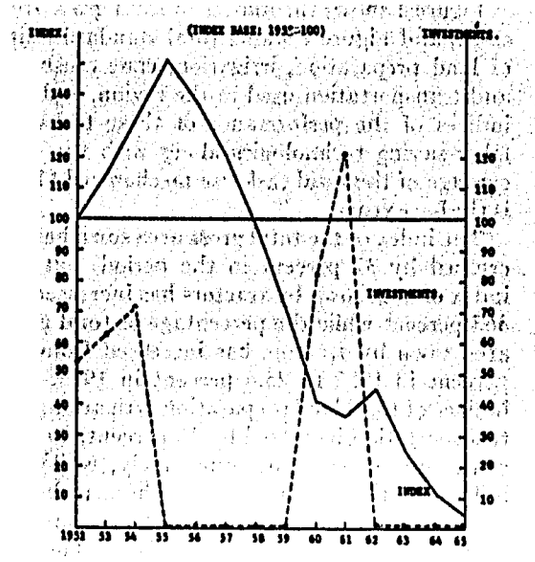
INDEX OF NUMBER OF TRACTORS IN USE & ANNUAL INVESTMENTS IN TRACTORS (NUMBER PURCHASED) IN CENTRAL PUNJAB. (1952 - 1965).

SOURCE: MODEL RESULTS.



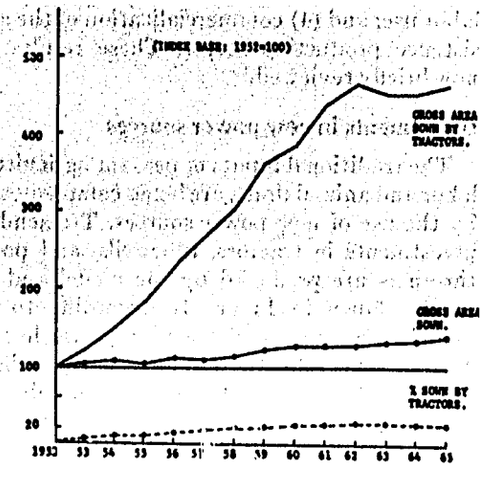
INDEX OF NUMBER OF TUBEWELLS IN USE & ANNUAL INVESTMENTS IN TUBEWELLS (NUMBER PURCHASED) IN CENTRAL PUNJAB. (1952 - 1965).

SOURCE: MODEL RESULTS.



INDEX OF NUMBER OF DIESEL POWERED CANE CRUSHERS IN USE & ANNUAL INVESTMENTS IN POWERED CANE CRUSHERS (NUMBER PURCHASED) IN CENTRAL PUNJAB. (1952 - 1965).

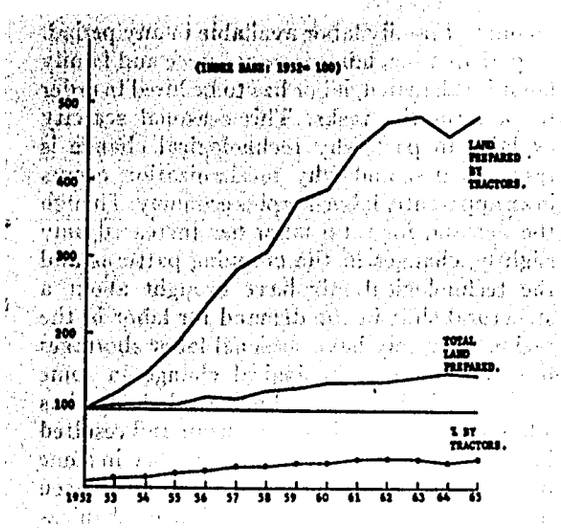
SOURCE: MODEL RESULTS.



INDEX OF GROSS AREA SOWN & GROSS AREA SOWN BY TRACTORS AND GROSS AREA SOWN BY TRACTORS AS A PERCENTAGE OF TOTAL GROSS AREA SOWN IN CENTRAL PUNJAB. (1952-1965).

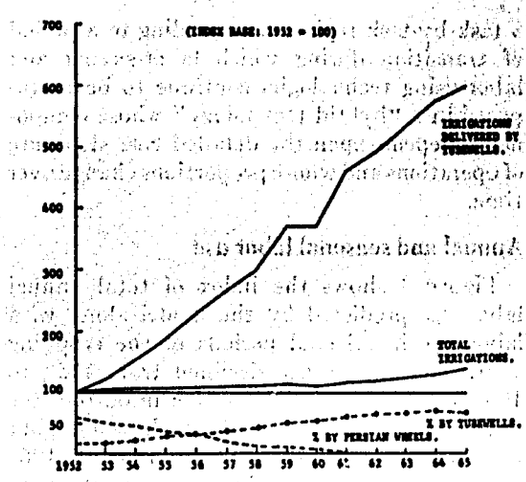
SOURCE: MODEL RESULTS.

FIGURE 1



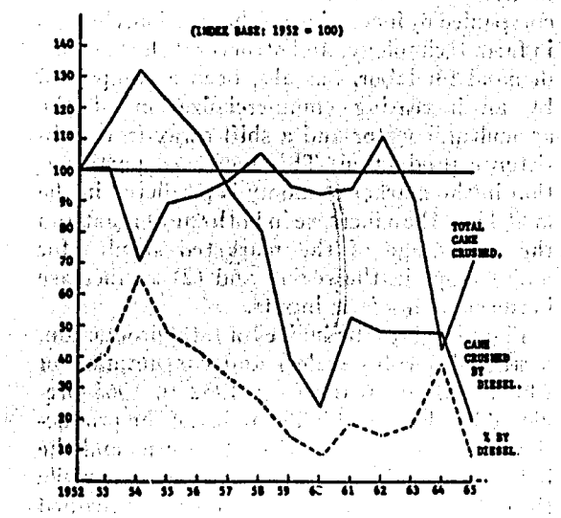
INDICES OF TOTAL LAND PREPARATION (TASK) & LAND PREPARED BY TRACTORS AND LAND PREPARED BY TRACTORS AS A PERCENTAGE OF TOTAL LAND PREPARED IN CENTRAL PUNJAB. (1952 - 1965).

SOURCE: MODEL RESULTS.



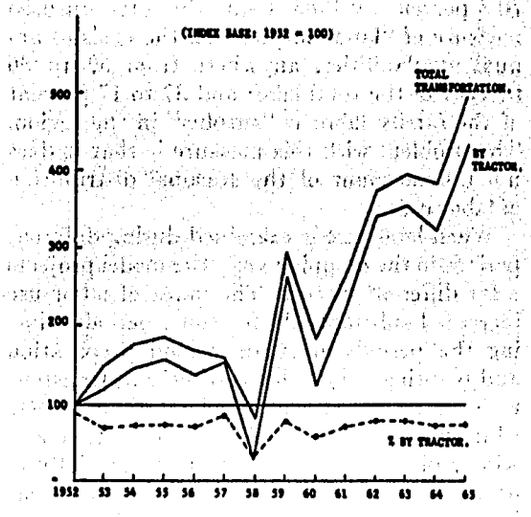
INDICES OF TOTAL IRRIGATIONS, & IRRIGATIONS DELIVERED BY TUBEWELLS AND IRRIGATIONS DELIVERED BY TUBEWELLS & PERSIAN WHEELS AS A PERCENTAGE OF THE TOTAL IN CENTRAL PUNJAB. (1952 - 1965).

SOURCE: MODEL RESULTS



INDICES OF TOTAL CANE CRUSHED & CANE CRUSHED BY DIESEL POWERED CANE CRUSHERS AND CANE CRUSHED BY DIESEL AS A PERCENTAGE OF THE TOTAL IN CENTRAL PUNJAB. (1952 - 1965).

SOURCE: MODEL RESULTS.



INDICES OF TOTAL TRANSPORTATION (TASK) & TRANSPORTATION BY TRACTORS AND TRANSPORTATION BY TRACTORS AS A PERCENTAGE OF THE TOTAL TRANSPORTATION IN CENTRAL PUNJAB. (1952-1965).

SOURCE: MODEL RESULTS

FIGURE 2

dex of total cane crushing declined, as less sugarcane output is being processed on the farms and more being taken to sugar mills; but the percentage of cane crushed by diesel declined from 35 percent in 1954 to 5.2 percent in 1965.

To summarize, the pattern of change in farm technology predicted by the model indicates that technological change is task oriented; that it does not consist of the total replacement of a traditional technological set (bullock-labor intensive technology); that it consists rather of

a task-by-task replacement leading to a period of transition during which labor-saving and labor-using technologies continue to be juxtaposed in a "hybrid technology" whose components depend upon the detailed cost structure of operations and whose proportions change over time.

Annual and seasonal labor use

Figure 3 shows the index of total annual labor use predicted by the model along with labor use in selected periods of the cropping year. Total labor use declined from 1952 to 1961, during a period of growth in output due to the adoption of labor-saving technologies, but has shown some increase from 1962 to 1965 because of an increase in total output at an even higher rate. Annual labor use as a percentage of total labor available declined from 63.4 percent in 1952 to 48.6 percent in 1962, but increased to 54.4 percent by 1965. Similarly, annual labor use as a percentage of family labor available declined from 82.2 percent in 1952 to 63 percent in 1962, but increased to 70.5 percent by 1965. Using the often misused measure of "labor surplus" on the basis of annual availabilities, anywhere from 52 to 36 percent of the total labor and 37 to 17 percent of the family labor is "surplus" in the region. The problem with this measure is that it does not take account of the seasonal distribution of labor use.

When labor use is examined during different periods in the cropping year, the model projects a far different picture. The index of labor use increased substantially for some periods (during the periods of summer land preparation and planting, winter harvesting, and transportation), increased only moderately in others (during the period of summer irrigation and winter planting), but declined substantially in others (during the periods of summer harvesting, winter irrigation, and sugarcane harvesting and processing), even though total output and acreage sown increased substantially. (Figure 2 shows indices for period V (winter irrigation) and period VI (winter harvesting) and for total annual labor use.)

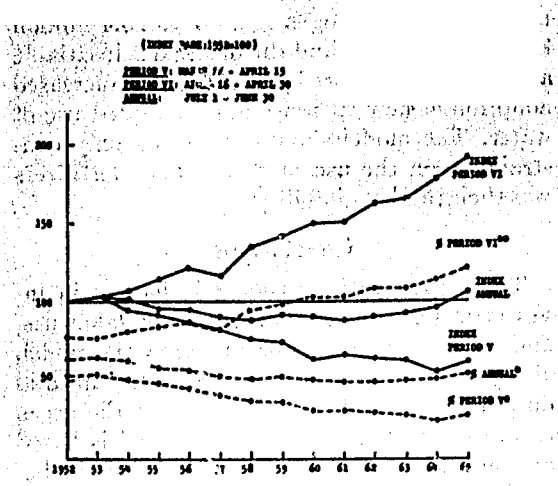
If we examine seasonal labor use in relation to total and family labor availabilities, we do not get the same results as those predicted by annual labor use. The model shows labor is "very scarce" in some periods. "occasionally scarce" in others, "slack" in some, and "very slack" in others, when measured in terms of the amount of family labor available in any period. In periods when labor is very scarce and family labor is exhausted, labor has to be hired in order to perform the tasks. This seasonal scarcity explains in part why technological change is task oriented and why mechanization occurs in an apparently labor-surplus economy. Though the demand for total labor has increased only slightly, changes in the cropping patterns and the technological mix have brought about a structural shift in the demand for labor in the region. Not only have seasonal labor shortages brought about technological change in some cases, but in its turn technological change has allowed an increase in total output and resulted in an increase in the demand for labor in some periods that would otherwise not have been possible. In the period of transition, mechanization per se does not imply a reduction in the demand for labor.

The commercialization of traditional agriculture

The growth in total output and productivity in the last two decades, which has been accompanied by increasing mechanization, changes in farm technology, and structural shifts in the demand for labor, has also been accompanied by an increasing commercialization of the agricultural sector and a shift away from subsistence production. This increased participation in the market economy is predicted in the model by (1) an increase in both the amount and the percentage of the marketed surplus for major crops in the region and (2) an increase in the use of nonfarm inputs.

Figure 3 gives the indices of total production, marketed surplus (sales) and consumption of wheat and sugarcane from 1952 to 1965 predicted by the model.[11] The index of the production of wheat increased by 14 percent and the index of sales increased by 273 percent, while the index of the consumption of wheat remained fairly constant. The marketed surplus of wheat as a percentage of total production increased from 53.4 percent in 1952 to 80.3 percent in 1965, indicating that whereas 47 percent of the production of wheat was for subsistence in 1952, only 18 percent of the production was for the same purposes in 1965. The predicted results for sugarcane are more dramatic, for while the index of production increased by 138 percent,

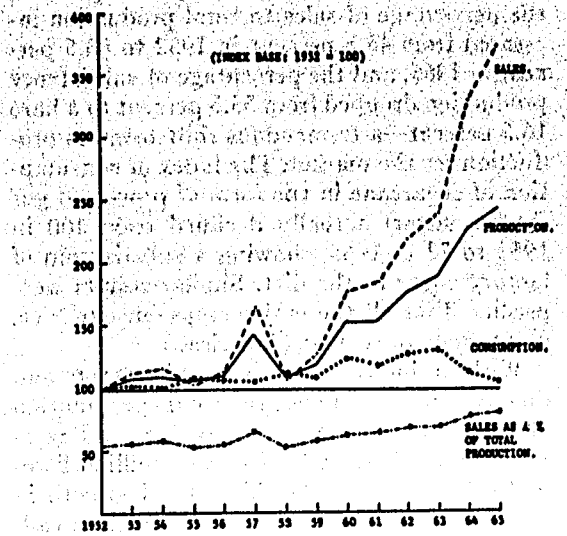
[11] The model included all major crops in the region—wheat, gram, barley, winter fodders, maize, rice, groundnut, cotton, millets, and sugarcane.



INDICES OF ANNUAL & SEASONAL LABOUR USE & LABOUR USED AS A PERCENTAGE OF TOTAL & SEASONAL LABOUR AVAILABLE IN SELECT PERIODS IN CENTRAL PUNJAB. (1952 - 1963).

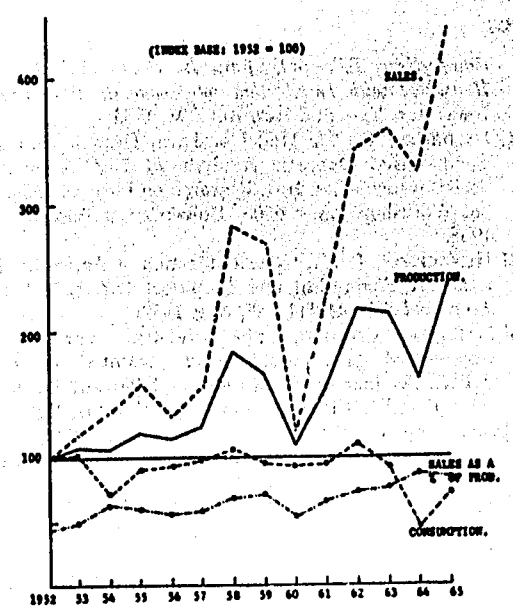
* ESTIMATED ON THE BASIS OF AN 8 HOUR WORK DAY.
** ESTIMATED ON THE BASIS OF A 10 HOUR WORK DAY.

SOURCE: MODEL RESULTS



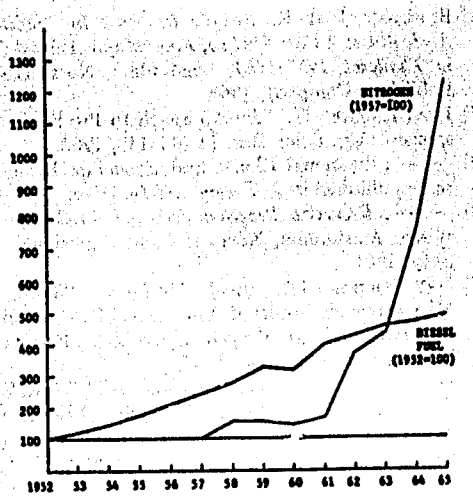
INDICES OF TOTAL PRODUCTION, MARKETED SURPLUS(SALES), & CONSUMPTION AND SALES AS A PERCENTAGE OF TOTAL PRODUCTION OF WHEAT IN CENTRAL PUNJAB. (1952 - 1963).

SOURCE: MODEL RESULTS



INDICES OF TOTAL PRODUCTION, MARKETED SURPLUS (SALES), & CONSUMPTION & SALES AS A PERCENTAGE OF TOTAL PRODUCTION OF SUGARCANE IN CENTRAL PUNJAB. (1952 - 1963).

SOURCE: MODEL RESULTS



INDICES OF TOTAL ANNUAL CONSUMPTION OF DIESEL FUEL (BY TRACTORS & DIESEL ENGINES) AND NITROGENOUS FERTILIZERS IN CENTRAL PUNJAB. (1952 - 1963).

SOURCE: MODEL RESULTS

FIGURE 3

the index of sales increased by 336 percent, the percentage of sales to total production increased from 45.5 percent in 1952 to 83.5 percent in 1965, and the percentage of subsistence production dropped from 55.5 percent to a bare 16.5 percent—a tremendous shift towards production for the market. The index of consumption of sugarcane in the form of processed gur (brown sugar) actually declined from 100 in 1952 to 72 in 1965, showing a substitution of factory sugar in the diet. Similar results were predicted for all the major crops—maize, rice, groundnut, and cotton (American).

With an increase in the use of tractors and diesels as power sources, the total consumption of diesel fuel increased nearly five fold from 11.4 million litres in 1952 to 55.5 million litres in 1965 (Figure 3). At this rate of growth in consumption, in the years to come the availability of petroleum products could act as a serious constraint upon the adoption of these power sources, since India is short on petroleum resources and has to import them.

Another component of the increased use of nonfarm inputs predicted is the increase in the consumption of nitrogenous fertilizers, whose consumption increased twelvefold (Figure 3) from a mere 1.6 million kilograms of nutrient equivalents of nitrogen in 1957 to 20.4 million kilograms in 1965; and the demand is insatiable at currently subsidized prices, with the increased adoption of new varieties and increased use of water. The model showed that the only constraint upon the use of nitrogenous fertilizers was their total availability.

Conclusions

These substantial structural changes in investment patterns, farm technology, labor use, and market orientation predicted by the model, along with the unprecedented increases in total output, have spelled the content of the green revolution in the Punjab. The model is based on the assumption of rational economic behavior and uses the standard tools of economic analysis to generate the past development of the agricultural sector in a selected region, and is able to explain observed phenomenon of the transformation process. It is reasonable to expect that the model will also be capable of projecting possible future transformations under alternative policy assumptions.

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