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FACTOR UTILIZATION AND SUBSTITUTION IN ECONOMIC DEVELOPMENT:

A GREEN REVOLUTION CASE STUDY

By

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I. INTRODUCTION

The onset of the green revolution in Asia and other parts of the world has brought about a significant shift in development strategy. Previously, the dynamic role of output and employment was assigned to the industrial sector. Development policies stemming from this viewpoint emphasized low food prices, heavy industry, import-substitution in industry under protective tariffs, with the direct or indirect consequence of subsidizing industry at the expense of agriculture. These policies found a rationale in the dualistic development models that emphasized the role of a growing industrial sector in providing employment opportunities as "surplus" labour from agriculture was absorbed. [Lewis (1954), Fei and Ranis (1961), Jorgenson (1961)].

These views are being reconsidered. Among the reasons are: growing food crises with consequent impact on domestic prices and imports; a higher rate of growth in the labour force than estimated; a growth of employment and output in the industrial sector far less than needed to prevent growing unemployment, and finally the advent of the green revolution with possibilities of high rates of growth in predominantly agricultural

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economies. This change in view is evident in the recent importance given to agriculture in development policies and in the development literature. [Healey (1972)].

Among other things, the green revolution has raised the hope that a solution to unemployment may be found in the countryside rather than in the overcrowded urban areas. In view of the capital-intensive development of the industrial sector and its low labour absorptive capacity, it has been emaphsized that "the most important single factor influencing a developing country's ability to absrob a growing labour force into productive employment is the type of strategy pursued for developing its agricultural sector" [Johnson and Cownie, p. 569]. For this a strategy emphasizing capital-saving, labour intensive techniques are advocated, and the green revolution seems to provide just the right solution. Thus empirical inquiry has shifted from concern with the production and output consequences of the green revolution to problems relating to unemployment, factor intensity and income distribution in agriculture. [Seers (1969)].

These issues are interrelated and the impact of the green revolution on these problems complex. [Falcon (1970)]. Whereas the impact upon employment and factor proportions was expected to be labour intensive, in some parts of the world, the Indian and Pakistan Punjab for example, the green revolution has been accompanied by high rates of mechanization. These trends provide cause for alarm on two accounts. First is the paradox of capital intensive development in a labour surplus environment with an implied use of inappropriate factor proportions. Thus it has been argued that in such cases the marginal productivity of investments in labour displacing mechanization far exceeds its social marginal productivity.

[Johnson and Cownie (1969), Bose and Clark (1969)]. Second, there is a concern that this tendency is abetted by factor price distortions and government policies that encourage a form of mechanization that is labour displacing rather than labour absorbing. [Ridker (1971)].

In spite of the importance of these issues, relatively little empirical information is available, especially on the long run trends in factor use and productivity, changing factor proportions and the process of factor substitution once the green revolution was under way. Although our ability to identify issues has been extended, our ability to develop empirical tools that can analyze these issues a- _ provide an insight useful for policy is woefully inadequate. The issues are complex and involve details of technological choice, on-farm decision making and farm policies. [Day and Singh (1972)]. The little empirical information available comes from extremely simple models that can often be misleading for policy purposes. [Gemmill and Eicher (1972)].

The purpose of this paper is to help fill these gaps in our understanding of economic development in five specific ways. 1) We examine the long-run trends in factor utilization and substitution for agriculture in the Indian Punjab during a period when it experienced both labour intensive and labour displacing changes in technology. 2) We project these trends to 1980. 3) We examine short-run factor substitution possibilities, particularly capital-labour substitution, in response to changes in factor pricing and factor supplies. 4) We draw broad policy implications that stem from the Punjabi experience in order to shed some light on the problem of unemployment with capital intensive development. 5) We use a methodology that explicitly incorporates important details strategic to these problems.

Our projections and comparative static results are derived from a simulation model of the farm sector, designed to track the course of agricultural development in the Indian Punjab. This approach was adopted partly because actual regional data on factor use are unavailable for aggregate and dynamic analysis and a well conceived model could be used to estimate them. We also used it because it allows us to analyze the impact on factor use of factor prices and resource availabilities other than those that existed historically. Activity analysis is used in the model to analyze changes in factor proportions. This contrasts with the more frequent use of production functions for such a purpose. We feel the activity analysis approach has many advantages in representing multiproduct, multiprocess technologies of the kind that typifies agriculture in a state of transition from traditional to modern methods.

A brief non-technical summary of the model is presented in the next section; model results are discussed in section III for four benchmark years, 1955, 1965, 1970 and 1975. Long-run trends in factor use and substitution are also analyzed. We examine the short run substitution possibilities using a comparative static framework in section IV and conclude our paper by returning to some policy implications.

II. A MODEL OF PUNJAB FARMING

The model used to represent farm decisions in the Indian Punjab is a recursive programming model that can be summarized by the following system of equations.[1]

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[1] This is a summary of a model for which a complete technical description is given in Singh [1971] and Day and Singh [1972].

(1) $$\max_{x} \quad \pi(t) = \Sigma_j \; a_j(t) X_j$$

subject to

(2) $$\Sigma_j \; b_{ij} X_j \leqq C_i(t)$$

$$i = 1, \ldots m, \; j = 1, \ldots n, \; t = 1, \ldots T.$$

Let $X(t) = (X_1(t), \ldots, X_n(t))$ be a solution to (1) and (2). Then write

(3) $$C_i(t) = {}_i[C(t-1), \; X(t-1), \; Z(t)]$$

where $C(t-1) = [C_1(t-1), \ldots, C_m(t-1)]$ and $X(t-1) = [X_1(t-1), \ldots, X_n(t-1)]$ and $Z(t)$ is a vector of exogenous variables.

The system of equations (1) and (2) describes a linear programming problem of a group of homogeneous farm-firms aggregated to the regional level. The $a_j(t)$ represent the exogenously determined net returns or costs per unit level of the jth activity. Farmers choice of activity levels X_j are constrained by resource, financial, subsistence and behavioral constraints. These are represented at the regional level by a system of inequalities (2) for each crop year, where b_{ij} are the input-output coefficients and $C_i(t)$ the ith limitation coefficient (resource level, behavioral bound, etc.) for year t.

Field crop production is described in the model by a sequence of tasks, each using a specific power-implement combination. Various alternative task sequences are allowed for by including a variety of specific alternative activities.[2] Alternative activities include land preparation by bullocks and tractors, irrigation by canal, persian wheel wells or tube-wells, harvesting and threshing by manual and bullock power or by tractor

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[2] See Singh, Day and Johl (1968) and Singh (1971).

powered harvesters and threshers, transportation by bullock cart or tractor-trailer, and sugarcane processing by bullock drawn or diesel powered cane crushers. The choice between alternative ways of performing tasks depends upon the relative costs of the operations, the relative availability of resources used by the operation and upon the adoption of new power sources and their availability. Several alternative levels of fertilizing are allowed for each crop variety and their activities compete for the regional supply of nutrients. The production activities as a group are structured to represent the double cropping system prevalent in the region, as well as to take into account both the biochemical and mechanical components of technological change. Detailed task specific data collected in the field allowed us to account for these strategic details.

Subsistence consumption activities describe the home consumption of farm produced commodities and fodder crops for maintaining and using draft animals. Financial activities allow saving, short-term borrowing, debt repayment and cash purchases of non-farm durable and non-durable goods and services.

Investment activities replace worn out machines and add to available capacities in new power sources such as tractors, tubewells, threshers, harvesters and cane crushers.

Resource constraints include seasonal restrictions on the supplies of family and hired labour, animal draft and various machine capacities that can be augmented by investments and regional supplies of chemical nutrients irrigated and rainfed land and canal irrigable area, for two cropping seasons.

Financial constraints restrict cash use to cash generated from sales, savings and non-farm incomes from the previous year, after cash outlays for production inputs, cash consumption expenditures and debt repayment have been met. Short term borrowings are also constrained by a four step staircase function which relates credit supplies to previous years' sales and operational expenses.

Subsistence constraints describe lower bounds on the amount of farm outputs required for household consumption, and a lower limit on the amount of fodder required for maintaining and using draft animals.

Behavioral constraints reflecting such factors as learning, experience and cautious adoption, place bounds on individual crop acreages in any given year and bounds on the adoption of new technologies that define S-shaped diffusion paths over time.

What distinguishes a "recursive" from an ordinary linear programming problem is the inclusion of feedback functions (3). These relate current machine capacities to past capacities and investments, current cash and credit availabilities to past sales, savings and debt repayment and current levels of the behavioral constraints to the past history of crop production and adoption of new technologies.[3]

The complete model then consists of a sequence of linear programming problems where parameters in each year in the sequence are related through feedback to the solutions to the proceeding problem in the sequence. The model is computed by setting up and solving a linear programming problem (1), (2) for a given initial year. The optimal solution vector X(t-1),

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[3]For a detailed description of the subsistence and behavioral constraints their form and estimation and the nature of the feedback functions used see Singh [1971] and Day and Singh [1971].

and the lagged resource constraint vector C(t-1) along with exogenous data Z(t) are used to estimate a new set of constraints through the feedback functions (3), and a new linear programming problem is set up and solved for the next year. Using exogenous data on input and output prices and regional land, labour and nutrient supplies allows us to solve the model.

The Punjab model was used to generate dozens of variables describing economic activity on farms in the Central Punjab for the period 1952-1965. Model results for field crop acreages were compared to available series for purposes of model evaluation. Testimony of regional experts was also used as a basis for determining goodness of fit.[4] Having it this way determined that the model tracked recent events closely, it was possible to use the model to examine analytically both the long run and short run implications for factor utilization and substitution.

What does the future hold for factor utilization and substitution in the Punjab? To answer this question, and to provide a basis for the comparative static analyses to follow, we projected the various exogenous variables (population, prices, etc.) for each year 1966 to 1980, using simple trend analyses and the judgement of regional experts. We then projected the endogenous variables by simulating the recursive programming model using the independently projected exogenous variables. To provide benchmarks for comparison we report model estimates for factor utilization for 1955, 1965 and 1970 in addition to 1980 and discuss their implications for long run substitution in the next section.[5]

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[4]A detailed model evaluation is available in Day and Singh [1971]. The model's detailed description of the green revolution in the Punjab for the period 1952-65 is the subject of another paper. Singh and Day [1972].

[5]The selection of ten year intervals would have sufficed for long-run analysis, but the period 1965-70 was of particular importance because of the technological breakthroughs in the adoption of new varieties and mechanization.

III. LONG TERM TRENDS IN FACTOR USE AND SUBSTITUTION

Model estimates of factor use for benchmark years are given in Table 1.

1. Land Use

The long run patterns in land use include i) an increase in multiple cropping (measured by the cropping intensity), ii) an increase in the irrigated area (to 93 percent of total area cropped by 1980), and iii) an increase in the irrigated area sown to new high yield varieties (to 98 percent of the total irrigated area cropped by 1980). These patterns for the period 1952-70 are in close conformity with the data, while the projected trends are similar to those estimated in other projections for the Indian Punjab.[6]

Over the 25 year period there has been a slow but steady increase in the new area brought under cultivation (about 1 percent per annum), while most of the increase has come through multiple cropping (a nearly 3.6 percent per annum increase in the area cropped). By 1980 increases at the extensive margin will no longer be possible, and increases will have to be confined to the intensive margin. Our model estimates a cropping intensity of 1.96 by 1980, that is an equivalent of a fully utilized double cropping system. This increase in intensity comes mainly between 1970-80 and we believe further increases in intensity, requiring a triple or multiple cropping system, will not be large before 1980.

2. Employment

Annual employment shows a slight increase between 1955 and 1965 mainly due to a 28 percent increase in cropped area. However between 1965 and 1980 the absolute level of employment declines by nearly 12 percent in

[6]See the Statistical Abstract of the Punjab, 1950 ... 1970. A confirmation of the model results on land use patterns. Our projected trends are similar though somewhat higher for areas devoted to new varieties than the projections by Billings and Singh [1971].

Table 1: Estimated and Projected Resource Use: Central Punjab, India

(MODEL RESULTS)

Resources	1955	1965	1970	1980
A. Land Use (millions of acres)				
1. Area Cultivated	2.5398	2.758	3.1729	3.248
2. Area Cropped*	3.3647	4.268	4.9218	6.370
3. Irrigated Area Cultivated	1.7568	2.082	2.7731	3.121
4. Irrigated Area Cropped	2.4017	3.214	4.0352	5.931
5. Area Sown to New Varieties	--	0.3042	1.8784	4.860
6. Cropping Intensity (2÷1)	1.325	1.547	1.551	1.960
B. Labor (millions of acres)				
1. Total Annual Labor	101.23	108.32	107.02	95.66
2. Total Hired Labor	3.411	4.248	5.127	--
3. Winter Harvest Labor	8.564	9.882	10.286	2.896
4. Labour Surplus (Annual Basis)	42.6%	50.9%	55.2%	65.3%
C. Animal Draft (millions of days)				
1. Annual Bullock Labor	50.169	29.684	25.03	5.243
D. Mechanical Power Use				
1. Tractors (millions of hours)	2.265	5.549	12.045	27.547
2. Diesels (millions of litres)	12.69	28.37	42.47	71.64
3. Electric Engines (million KWH)	18.69	111.98	218.67	442.06
4. Total Power Use (millions BHP hours)	116.74	349.17	646.12	1317.78
E. Nutrient Use (millions of kilograms)				
1. Nitrogen	--	57.02	156.65	309.08
2. Phosphorus	--	3.88	37.13	74.04
3. Potash	--	4.84	41.22	89.56
4. Total NPK	--	65.74	234.90	472.78
F. Capital Use (millions Rs. at constant 1970 prices)				
1. Total Outlays	273.29	510.47	893.0	1653.94
2. Outlays on Variable Inputs	264.02	479.17	829.0	1491.79
3. Outlays on Non-Farm Variable Inputs	76.30 (28.9)	307.78 (64.2)	625.36 (75.4)	1210.42 (81.9)
4. Outlays on Non-Farm Capital Inputs	9.26	31.29	63.32	162.15
5. Borrowing Working Capital	273.29	415.16	619.12	605.87
6. Outlays of Nutrients	--	188.99	468.22	868.45

*Cropped Area is a measure of multiple cropping while cultivates area is a measure of the physical area sown.

Figures in brackets are percentages of outlays on non-farm variable to total variable inputs.

spite of a nearly 50 percent increase in total area cropped, 85 percent increase in irrigated area cropped and a nearly sixteenfold increase in the area sown to new varieties.[7]

This decline in employment involves only employment associated with crop production. Farm employment opportunities in poultry, vegetable and dairy production and non-farm employment in the marketing, transportation and processing of farm products and the distribution of farm inputs, will no doubt offset some of this. Moreover, these opportunities will have to absorb not only the labour displaced by mechanization, but also approximately a 1.65 percent per annum increase in the rural labour force. Thus the model estimates that on an annual basis 65 percent of the labour force in agriculture will not be redundant from the point of view of crop production.

It is clear that at least in the case of the Indian Punjab, the increased labour absorbtive capacity released by the green revolution has been quickly dissipated by large increases in labour displacing technologies. Thus the positive impact upon employment of the green revolution is likely to be temporary and short lived and is swamped by mechanization in the long run.[8]

The model also revealed a picture of seasonal scarcity instead of a chronic labour surplus, particularly during the winter harvest months. We have argued elsewhere that this seasonal scarcity is partly responsible for the task specific nature of mechanization in the Indian Punjab.[9]

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[7]Billings and Singh [1971] arrive at similar results, predicting a 17 percent decline in the demand for total human energy by 1983/84, using similar assumptions.

[8]There is enough evidence on the basis of short run partial analysis that indicates substantial labour absorbtive capacity associated with the green revolution in the Indian Punjab. See Billings and Singh (1971) and the recent detailed study of new wheat technologies by S.S. Sidhu (1972).

[9]See Singh (1971) and Singh and Day (1972).

However if we assume as we do in the model that the rural labour force continues to increase at the same rate between 1970-80 as it did in the decade 1955-65 (1.65 percent per annum), the supply of regional labour increases faster than the demand, and seasonal labour shortages are eliminated. Thus in the decade 1970-80, what has been an apparent labour surplus economy is transformed into an actual labour surplus economy, but this does not abate the rate of mechanization. We have to look to other causes besides seasonal labour scarcity for an explanation of the capital-intensive development experienced in the Punjab.[10]

3. Capital Use

Capital use takes a variety of forms. Here we focus on non-farm produced capital goods (tractors, tubewells, power threshers and farm equipment) and capital intensive, non farm produced variable inputs (fuel, fertilizers, pesticides, herbicides, electricity and canal irrigation water).

Long run trends in capital use indicate a sevenfold increase in total capital outlays between 1955-80 (at constant 1970 prices); a slight decline in the percentage of total outlays devoted to variable inputs, and an increase in the percentage of non-farm to total variable inputs, from 29 percent in 1955 to nearly 82 percent in 1980. These trends show an increasing capitalization and commercialization on the input side.

The increased commercialization has been accompanied by a declining role of credit in financing farm production. Borrowings as a percentage of total capital outlays decline from 100% in 1955 to 81%, 69% and 37%

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[10]Billings and Singh (1971) also indicate seasonal shortages, but they predict that the greatest displacement of labour between 1968/69 and 1983/84 is expected to be during the harvest period. This is a result similar to ours, that would lead to an elimination of the shortages. This point is of some significance because seasonal labour shortages have been an important factor in the mechanization of specific tasks.

respectively in 1965, 1970 and 1980. This has been possible because the increased output and productivity generated have enabled the farm-firms to finance their own production to a greater degree. Thus although credit continues to play an important role in farm production, it is most crucial in getting the green revolution under way. After the initial take off, the cash flows become self generating, enabling higher cash requirements to be met out of increased sales.

Outlays on non-farm capital inputs have been devoted mainly to the purchase of tractors, harvesting equipment and tubewells for irrigation. This is reflected in the increase in the use of mechanical power to perform agricultural tasks, and the associated increase in the demand for fuel and electricity. As a consequence the use of animal draft has continued to decline, and will be virtually eliminated by 1980.

A large part of the increase in capital use is associated with the overwhelming adoption of yield increasing technologies and the outlays on nutrient use. The use of chemical nutrients is estimated to double between 1970 and 1980.

4. Factor Productivity, Factor Proportions and Factor Substitution

These long run changes are estimated to have involved a five and a half fold increase in total output (at constant 1970 prices), a ten fold increase in market sales, and a decline in subsistence production -- that is production retained for home consumption including fodder -- from 52.6 percent in 1955 to 10 percent in 1980. These and related model estimates are shown in Table 2.

The output per unit of labour doubled between 1965 and 1970 and will very likely double again between 1970-80. By 1980 it will probably be six times its value in 1955. A similar long run pattern is observed for

Table 2: Estimated and Projected Output, Factor Productivity and Factor Proportions: Central Punjab, India.

(MODEL RESULTS)

Item	1955	1965	1970	1980
(in millions of Rs. at 1970 prices)				
1. Total Output	1563.91	2729.94	5089.79	8703.38
2. Market Sales	741.23	1859.3	4211.55	7816.97
3. Subsistence Production	822.68	870.41	878.25	886.41
4. Degree of Subsistence (3)+(1)	52.6%	31.88%	17.26%	10.18%
Factor Productivity				
1. Labor (Rs./man day)	15.45	25.20	47.56	91.00
2. Land (Rs./acre)				
Per Cultivated Acre	615.76	989.82	1604.14	2678.87
Per Cropped Acre	464.80	639.63	1034.13	1366.11
3. Capital (Rs./Rs.)	5.72	5.35	5.70	5.26
Inputs Per Acre (per cropped acre)				
1. Labor (man days)	30.09	25.38	21.74	15.02
2. Animal Draft (days)	14.91	6.96	5.09	0.82
3. Tractor Use (hours)	0.67	1.30	2.45	4.32
4. Diesel Use (litres)	3.77	6.65	8.63	11.24
5. Electricity (KWH)	5.55	26.24	44.43	69.39
6. Mechanical Power (BHP hours)	34.69	81.81	131.28	206.85
7. Working Capital (Rs.)	78.47	112.27	168.57	234.16
Inputs Per Unit of Labor (per man day)				
1. Animal Draft (days)	0.496	0.274	0.14	0.055
2. Mechanical Power (BHP hours)	1.15	3.22	6.04	13.76
3. Land (cultivated acres)	0.0251	0.0255	0.0296	0.034
4. Working Capital (Rs.)	2.61	4.42	7.75	15.59
5. Outlays on Non-Farm Variable Inputs (Rs.)	0.75	2.84	5.84	11.61
Total Capital Use (in constant 1970 Rs.)				
1. Per Cultivated Acre	107.60	185.09	281.44	509.08
2. Per Cropped Acre	81.22	119.60	181.44	259.61
3. Per Man Day	2.70	4.71	8.34	17.29
4. Per Unit of Output	0.1747	0.107	0.1754	0.19

average land productivity, though increases in productivity begin to taper off as the new production boundaries extended by the green revolution are reached and spectacularly profitable investments decline. Average capital productivity has remained fairly constant even as total capital use per acre and per man day have continued to increase.

The substitution of capital for labour has been mainly in the form of mechanical power. This is reflected in the steady decline in the animal draft/labour, animal draft/land and a rise in the mechanical power/labour ratios. A steady and related increase in the land/labour ratio reflects the increased ability provided by mechanical power to crop more land.

It has been argued in the literature that seasonal bottlenecks in the supply of farm power can seriously deter multiple cropping. Mechanization is then seen as allowing total employment to actually increase. Johl (1971). This argument merits attention since our model results indicate a shortage in tractor capacity between October 16-November 15, a period during which land is prepared for winter planting, all through the decade of the seventies. Others have observed seasonal shortages of draft power [Billings and Singh (1972)], and the inability to use labour intensive methods to overcome them, due to the need for timeliness in farm operations. It is definitely true that during the coming decade attempts to slow down mechanization and increase employment can only be brought about at the cost of reduced output, unless the peak work load problem is solved.

The substitution of capital for labor is projected to continue as, for example, machines hours and the total working capital expended per man day are expected to more than double in the present decade. Over time, the longer run substitution effects are projected to be drastic. These trends indicate increased use of capital (of all kinds) and a declining use of labour per unit of land and capital.

However the process of substitution has been more complex than between labour and labour displacing capital. The real process has involved the choice of farm power -- a choice between human, animal and mechanical sources. The primary substitution has involved the displacement of animal by mechanical sources of power. This has been evident in the task specific nature of the mechanization process. Since mechanical power uses smaller amounts of complementary labour, it too has been displaced.

IV. FACTOR PRICING, FACTOR AVAILABILITY AND SHORT-RUN FACTOR SUBSTITUTION

There is some evidence to indicate that rapid mechanization that occurred in the decade of the sixties, in both India and Pakistan, may have been encouraged by relative factor prices favorable to the capital intensive development. Thus Billings (1972) shows that the real cost of a tractor in the Indian Punjab is half the cost to the farmer in the U.S., and a black market is developing, while Kaneda (1969) shows that in West Pakistan farmers had only to pay one half the amount of wheat needed on world markets to buy a tractor. Bose and Clark (1969) showed that social costs of tractorization in West Pakistan exceeded social benefits on the basis of similar arguments.

Using a comparative static, parametric programming analysis the initial base in each benchmark year for the exercises is the situation estimated by the dynamic model, whose results we reported in the last section. Six parametric changes, involving changes in both the supply and cost of labour, non-farm capital goods and credit are analyzed.

1. The Marginal Efficiency of Capital

Our first exercise in comparative statistics was to vary the supply of working capital, beginning with the amount estimated for the base year, to obtain the corresponding shadow price, or internal rates of return at various capital supplies, in this way tracing out the marginal efficiency of capital schedule for a given year. The schedules obtained are displayed graphically in Figure 1.

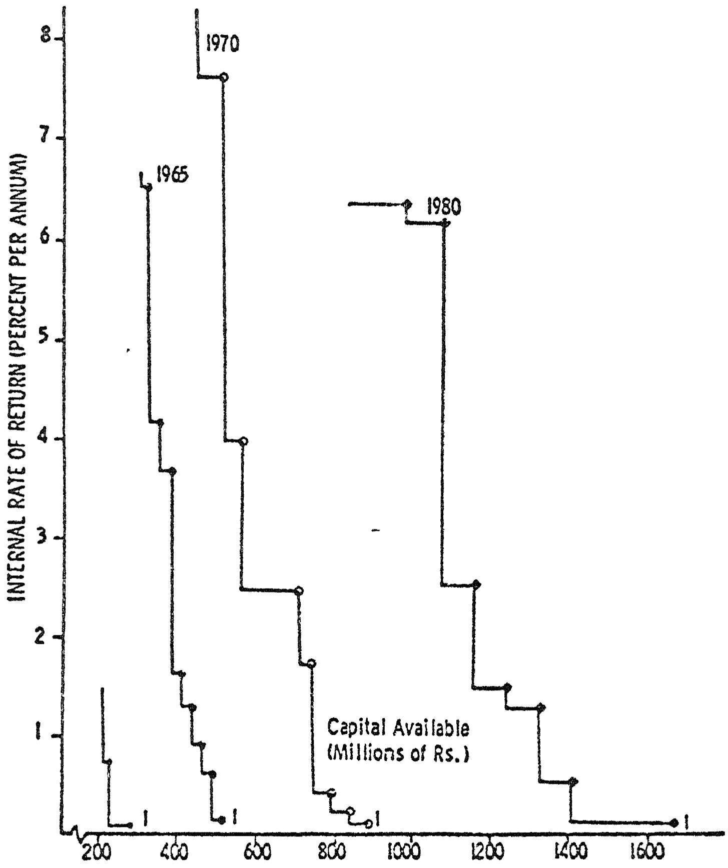
These derived demand curves for capital shift substantially over time. The schedules rise more steeply in the earlier years (1955, 1965) than in the latter years (1970, 1980), suggesting that over time the demand for liquidity has become and will become still more elastic.[11] This is no doubt due to the fact that especially after 1970 the marginal return from yield increasing inputs is quite low and increments of these inputs bring about smaller and smaller increases in output.

2. The Derived Demand for Nonfarm Capital Goods

The next exercise was to explore the possibility that investment in mechanical power and machinery was influenced by factor price distortions in favor of capital inputs. This was accomplished by varying the annual investment charges or depreciation allowances for their initial levels to three times that amount. The result is a derived demand curve for each capital good. These were aggregated by using 1970 constant prices. The resulting figures trace out derived demand curves for aggregate nonfarm

[11] The rates of return to liquidity are low initially because they are determined by the opportunity cost of borrowing working capital. This cost has been kept low by an expansion in the supplies of institutional credit significant enough to meet the rising demand.

FIGURE I: MARGINAL EFFICIENCY OF CAPITAL



capital goods in each year. They are displayed in Figure 2.

The extreme inelasticity of these schedules is evident, though in the middle years a doubling of farm machinery prices would have caused a substantial drop in annual capital investment. New power sources and machines are in fact highly cost effective.[12] They replace hired labor, relieve seasonal labor shortages and release land from fodder production for bullocks making possible its allocation to high yielding new varieties.

3. Demand for Debt

Debt is an important means of financing farm expenditures in Punjab agriculture. In our treatment all debt is assumed to be refinanced each year so that the borrowing activity for each year reflects the total demand for debt under existing economic conditions. Because previous debt must be maintained -- at least to the extent it cannot be retired -- the demand for debt over the period considered becomes inelastic at some interest rate. Below this rate the demand for loanable funds does respond in a few discrete steps to reductions in interest. By varying the interest rate this demand for loanable funds can be traced out.

Figure 3 shows these derived demand for indebtedness curves for each of the four years. As the sector becomes more commercialized, that is, as it becomes more intimately linked to the market economy the elasticity of demand for loanable funds increases. The large discrete steps may be expected to be much smoother in reality, so that the large inelastic segments might be expected to be broken down into a series of shorter steps.[13]

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[12] These results indicate the extent to which increased prices of farm machinery would have retarded mechanization. Aggregation however hides the fact that investments in tubewell irrigation is so cost effective that tripling of prices does not change the demand for tubewell equipment. The main decline occurs in investments in tractors, and powered cane crushers.

[13] Again aggregation hides the fact that the main decline occurs in the use of debt to finance the purchase of non-farm capital rather than non-farm variable inputs.

FIGURE 2: DERIVED AGGREGATE DEMAND FOR NONFARM CAPITAL GOODS

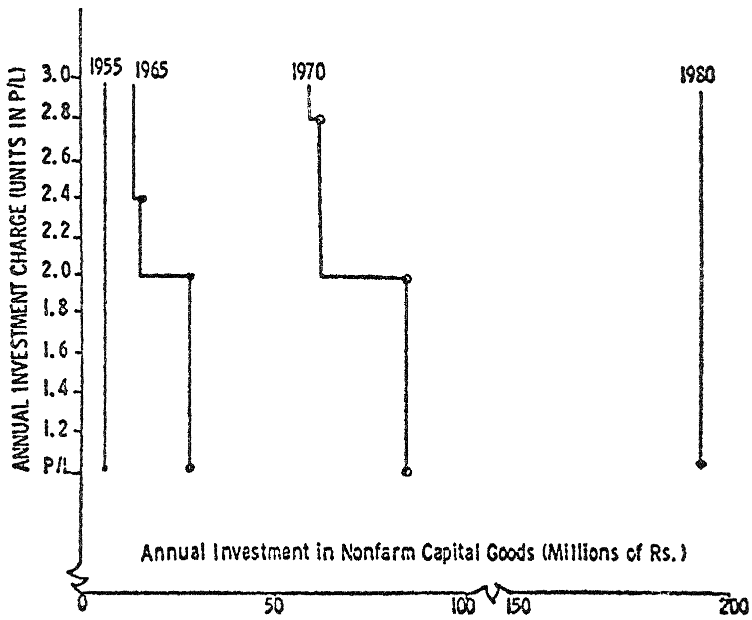
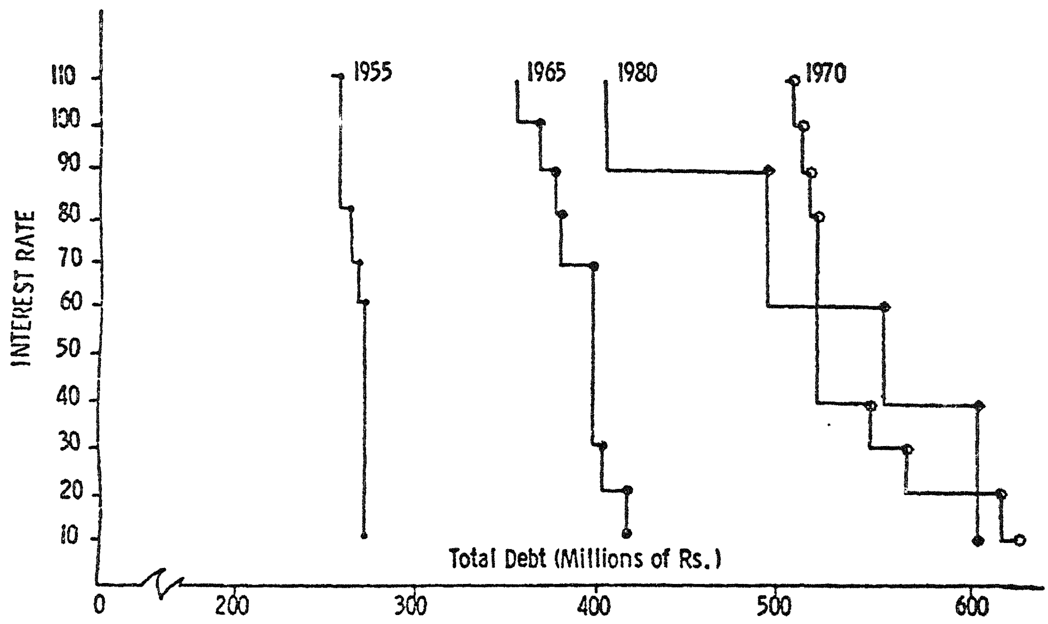


FIGURE 3: DEMAND FOR DEBT



4. The Derived Demand for Labor

A large proportion of the employment in the farm sector is accounted for by the use of family labor as shown by the results discussed in Part III. Only a small percentage of labor is hired (3-4 percent in 1955 to 1970, none in 1980) and that only for the peak periods in April and October-November. Therefore the main question of the impact of changing labor costs revolves around the opportunity cost assigned to the use of family labor.

The results in Part III are based on the assumption that family labor is a fixed farm resource in the short-run, and therefore it has a zero opportunity cost to the farmers.[14] We examine now the impact of increasing the opportunity cost of family labor and of hired labor as well. We first give family labor a wage equal to half the going local rate and regional (non-local) labor a rate half again as high as the local rate. We then vary these rates continuously. This parametric programming exercise then traces out derived demand curves for labor, one for each year, as shown in Figure 4.

As the opportunity cost is increased from zero to fifty percent of the market wage there is a decline of 4.5 percent, 8.5 percent, 8.4 percent and 3.3 percent in total employment from the level of employment at a zero opportunity cost for 1955, 1965, 1970 and 1980 respectively. The demand for labor is fairly inelastic for all the four years, though relatively less inelastic for 1965 and 1970 in this range. These results lend some evidence to the contention that wage subsidies are not a promising policy instrument for accelerating employment because of [Johnson and Cownie (1969)]. Besides wage rates affect only hired labour which accounts for only a small percentage of total employment.

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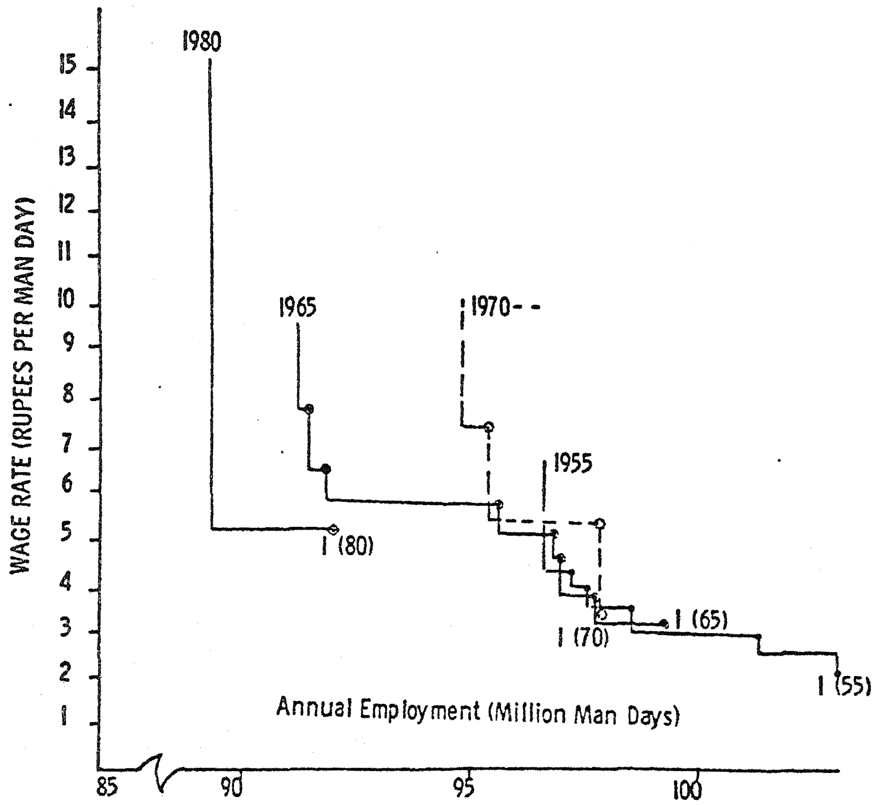
[14] Subsistence consumption constraints however take account of the fixed costs of maintaining the family labour force.

FIGURE 4: DERIVED DEMAND FOR LABOR



The drastic decline in the derived demand for labor after 1970 is expected from our earlier historical analysis and projections to 1980. Quite unexpected, however, is the shift in the general slope of the curve, especially for the year 1965 in which changes in wage rates would have had quite a substantial effect on labor use. The demand for labor actually rose in 1970, a period when high yielding varieties have already reached the most dramatic part of their impact, but in which mechanization of the labor intensive harvesting activities has only just begun.

The demand for labor in 1980 is extremely inelastic. By that time there will be left only a very small margin for labor displacement, at least on the basis of the present (1971) state of technology. This is because by 1980 most of the existing and known mechanical technologies will have been fully adopted and only new mechanical technologies such as mechanical harvesters, weeders and larger sized tractors could still further reduce the demand for labor.

To fully understand the prospects for farm employment these demand figures should be considered in conjunction with the labor supply. This supply has been increasing and as we pointed out already, by 1980 two thirds of the available annual labour supply will be unutilized. This projection uses a zero opportunity cost for family labour, an assumption most favorable to the use of labour intensive technologies.[15]

5. Capital-Labour Substitution

Capital-labour substitution possibilities at historical and estimated prices is estimated by decreasing the supply of labour and at the same time relaxing the annual constraints on investment. The curves in Figure 5

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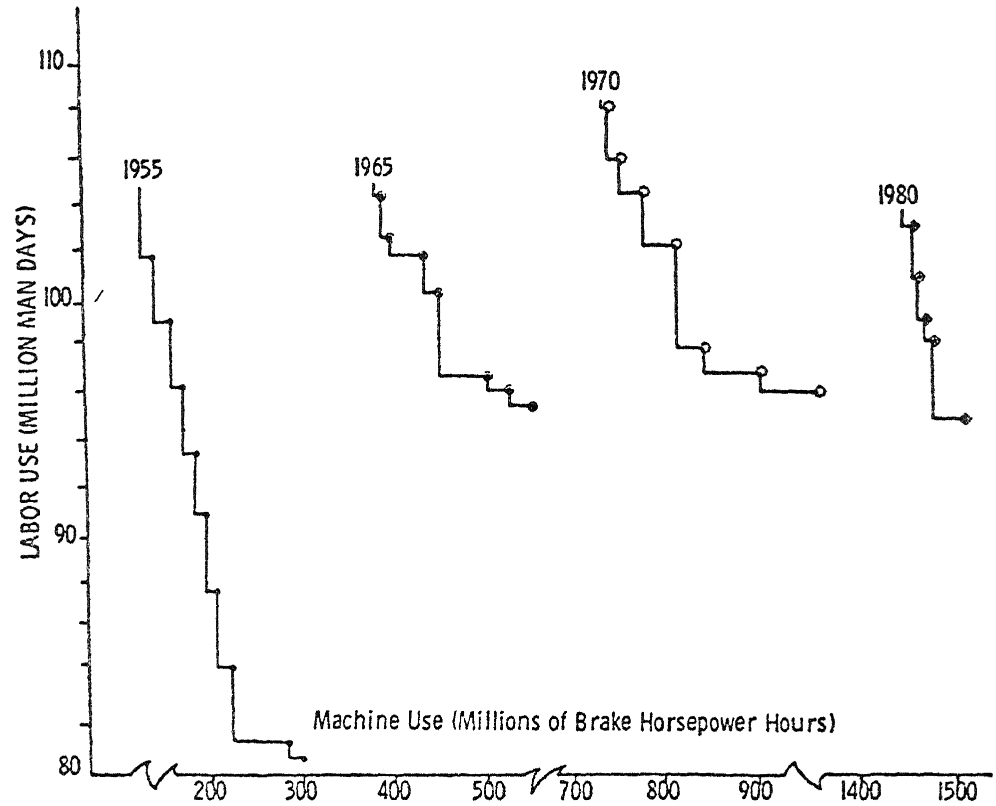
[15] These are projections only for direct employment in crop production. Some believe that the indirect effects of the green revolution will far exceed the direct effects. Shaw (1971). This remains to be seen.

FIGURE 5: MACHINE POWER -- LABOR SUBSTITUTION



display the substitution possibilities between the flow of machine services measured in brake horsepower (BHP) hours and labor use in man days.

The results indicate that the elasticity of substitution of labor for mechanical power sources is low for 1955, 1965 and 1970 (lying in the range 3/5 to 3/7 for the range of the data), but is relatively high for 1980. Thus in 1980 a 5 percent decrease in machine use is projected to increase annual labor use by approximately 9 percent in the range of the data analyzed, while in 1955 and 1970 a 5 percent decrease in machine use results in only a 3 percent increase in labor use and in 1965 only a 2.5 percent increase in labor use. This no doubt is mainly due to the fact that by 1980 the absorptive capacity of the sector for new power sources and capital investments is exhausted as capital saturation occurs and available mechanical technologies are fully adopted.

From the point of view of on-farm employment, however, the results indicate that even by 1980 the minimum labor demand is unlikely to fall below 95 million man days or exceed 108 million man days, for beyond these ranges only large increases in machine use are likely to bring any reduction in labor use, while further increases in labor use are unlikely to reduce the demand for machine services. The range of short-run substitution possibilities is therefore fairly small given the current profitability and availability of capital goods.

6. Substitution Between Labour Intensive and Capital Intensive Power

A further exploration of the effects of short run rigidities in capital labour substitution was obtained by parametrically varying the investment constraints for tractors and related implements in a way that would account for increases in the supply of machines and/or increases in the willingness of farmers to adjust in the short run to profitable investment opportunities. Part of the results of this comparative static exercise are shown in Figure 6 which gives the ranges of substitution possibilities in each year between land-labor intensive bullock power and capital intensive tractor power.

Over time the substitution possibilities have become more elastic, though the range over which it can occur is quite limited in any given year -- as indicated by the dotted lines on the graph.

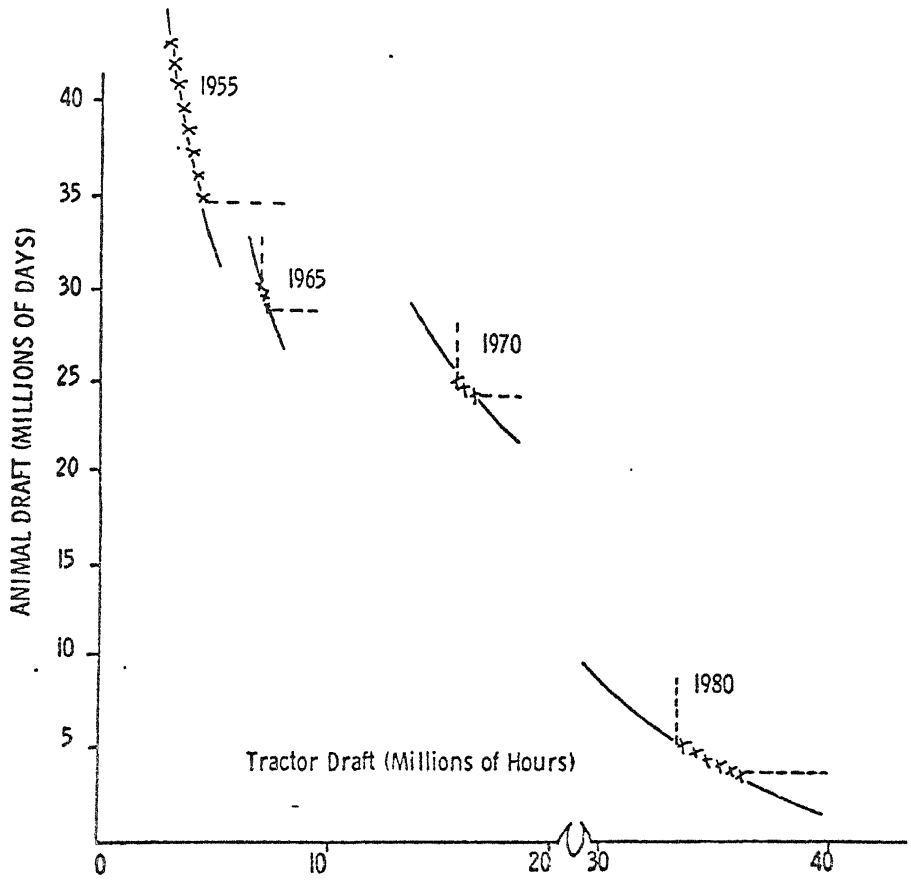
The largest range of actual substitution possibilities existed in 1955 where a substantial drop in the use of animal draft power is registered for small increases in the use of new power sources. By 1980 the shape has reversed itself. Substantial increases in the use of new power sources is required in order to reduce animal draft use by small amounts.

We recall that the Punjab economy has been in transition. Not all tasks have been mechanized, and at a given time no alternatives exist to the use of animal draft for certain tasks. In this hybrid environment some tasks can be mechanized, but others can be performed only by traditional technologies. Thus short-run substitution possibilities are substantially limited. In the absence of these short-run rigidities we would expect the substitution curves to lie along the solid lines shown.

The nature of the complex development process becomes clear from our parametric results. First, large increases in the prices of non-farm capital goods (an increase in the capital-labour price ratio) are required to reduce their aggregate derived demand substantially.

Unless we assume very large factor price distortions in the period analyzed, these distortions if corrected would not have changed the

FIGURE 6: SHORT-RUN SUBSTITUTION POSSIBILITIES BETWEEN ANIMAL AND TRACTOR POWER DRAFT



relatively capital intensive nature of development. Second, the inelasticity of the demand for debt and marginal efficiency schedules suggests a high rate of return to capital use. Only expanded supplies of institutional short term credit in the region prevented the short-term rates of interest from rising substantially. Third, mechanization and the displacement of animal draft has come about only partly due to the problem of seasonal shortages of labour and animal power. It is significantly related to the costs of using animal power sources.

The sequence of events can be summarized as follows. The adoption of the "green revolution" package allows not only a significant expansion of the production boundaries, but changes both the input and output mix. The output mix changes in favour of those outputs for which new varieties are available for adoption. These generally require the use of cash intensive commercial inputs (seeds, fertilizers) and water which shifts the demand for working capital outwards. In addition there is a shift in the seasonal demand for farm power and labour inputs, creating bottlenecks and accounting for some increase in mechanization. The input mix is changed significantly in favor of both commercial and capital inputs. An initial increase in the demand for seasonal labour raises wage rates especially during peak demand periods. Further, the adoption of high yield varieties raises the productivity of land, especially irrigated land. This in its turn raises the opportunity cost of using draft animals, as fodder competes for the now highly productive irrigated land. Thus the demand for non-farm capital inputs shifts further out. In the process labour displacing technologies reduce the demand for labour more than increased output and labour intensive practices associated with the green revolution increase it.

V. CONCLUSIONS

It is tempting to draw broad general conclusions from our analysis, but this would be inappropriate for two reasons. First, though the model incorporates many details in order to track the development processes, its very complexity prevents any easy straight forward procedure for testing its goodness of fit.[16] This is made more difficult by the unavailability of regional data to test the variables estimated by the model and by the usual inaccuracies of data used to estimate the model. Second, the Punjab, as is often emphasized presents a "special case", so that conclusions do not lend themselves to easy generalizations. Therefore we wish to advise some caution with regard to our conclusions.

Nevertheless, given these qualifications three conclusions emerge from our analysis. First, when we take a dynamic, long-run view we find that labour absorbtive capacity generated by the green revolution is quickly dissipated by large increases in labour displacing technology. The positive impact on employment may be very short lived when accompanied by rapid mechanization. Second, in an agricultural sector where land (especially land with assured irrigation) is a scarce factor, and draft animals the main source of farm power, the very adoption of yield intensive technologies may lead to the concurrent adoption of labour displacing technologies. Thus mechanization may be viewed in some circumstances as the outcome rather than an unnecessary companion of the green revolution. Third, the green revolution yields such high rates of return to both variable and quasi-fixed capital inputs, that a

[16] We have discussed the problems of testing models of this nature and provided some non-parametric criteria for testing the models ability to track development in Day and Singh (1972).

mere correction of distortions in factor prices are unlikely to prevent, though they could slow down, the process of capital-intensive development. In general, where irrigated land is scarce, and the use of draft animals predominant, the larger the shifts in the production function brought about by the green revolution, the greater will have to be the cost of capital goods to prevent the substitution of animal by mechanical power and its consequent displacement of labour.

Some important policy implications follow. To begin with, policy makers cannot look to the green revolution and the agricultural sector as a panacea. It is unlikely to solve the growing unemployment in the L.D.C.'s. This coupled with capital intensive development in other sectors of the economy suggests that the unemployment will be the most crucial development problem in the decade of the seventies. Further, where conditions similar to the Punjab exist, we should not expect small changes in factor prices to correct for inappropriate factor use. If capital intensive development is to be prevented, the cost of capital goods will have to be raised substantially, far beyond the two-fold range suggested by those who have emphasized these distortions. Third, when large changes in factor prices choke some of the labour displacing technologies, some mechanization may still continue due to the seasonal peak load and timeliness problems in agriculture. Unless these aspects of the problem are solved without mechanization, then in spite of increased employment, long run output will most likely be curtailed.

Though these results seem to dispel some of the sanguine hopes generated by the green revolution, they also present some opportunities. The cost of capital goods can and possibly should be increased substantially. By shifting the burden on those using capital-intensive technologies the expected gains from their adoption can be captured. Of special importance in this regard is the possibility of raising the interest rates on institutional credit significantly from their current low levels. This policy instrument has a triple edge. It provides a means for retarding the use of credits to finance labour displacing technologies and brings their private and social opportunity costs closer; it provides an effective way to shift some of the costs of socially developed new technologies onto those that use them; most important it allows part of the newly acquired gains to be channeled into rural saving institutions that can then raise the interest on time deposits substantially. If interest rates are raised after the onset of modernization, they can perform these functions without seriously retarding the growth of output that the green revolution makes possible.

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