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9. ABSTRACT

The main objective of this study was a quantitative assessment of various issues using farm-level primary cross-section data; specifically the goals were: 1) to decompose total difference in per acre output between farms employing new technology and those employing old, into two broad forces, technological change and change in the volume of (complementary) inputs; 2) to determine employment elasticities with respect to certain key economic variables; 3) to decompose total difference in per acre employment with the introduction of Mexican wheat into relevant forces -- technical change, output change, change in input prices and input quantities; and 4) to determine the direction and magnitude of changes in functional income distribution. For empirical implementation of these objectives, interrelated economic models based on the neo-classical theory of production and distribution were used. Conclusions are outlined as follows: 1) The measured contribution of technology to output growth demonstrates the importance of technical change to growth; 2) The 25% contribution of increased inputs to total change in output indicates a structural transformation in the form of increased dependence of agriculture on off-farm inputs; 3) Employment elasticities with respect to money wage rate, rental value of land, price of fertilizer, and output are estimated to be the same under old and new technology; 4) The forces affecting employment are technological progress, variations in output, and relative factor prices. Of these, perhaps output is the variable most susceptible to control at various policy levels; 5) Employment elasticity with respect to normalized wage rate, land, and fertilizer between old and new production technology may be concluded to be not significantly different; 6) The use of output price is suggested as an instrument variable for creation of employment; 7) The effect of new technology on income distribution is debated and discussed.

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EFFECTS OF TECHNOLOGICAL CHANGE ON OUTPUT, EMPLOYMENT AND FUNCTIONAL INCOME DISTRIBUTION IN INDIAN AGRICULTURE: A CASE STUDY OF THE PUNJAB WHEAT ECONOMY

A THESIS
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL OF THE
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BY
SIDDANAIK BISALIAH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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To my father and the memory
of my mother

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* These Worksheets are in Appendix II.

"There is law and relative regularity everywhere else - why not in production and distribution"

Paul H. Douglas

"Until the laws of thermodynamics are repealed, I shall continue to relate outputs to inputs - i.e. to believe in production functions"

Paul A. Samuelson

EFFECTS OF TECHNOLOGICAL CHANGE* ON OUTPUT, EMPLOYMENT AND FUNCTIONAL INCOME DISTRIBUTION IN INDIAN AGRICULTURE: A CASE STUDY OF THE PUNJAB WHEAT ECONOMY

CHAPTER I

INTRODUCTION

Problem

National goals underlying the economic and agricultural development of India since 1951, the year when the First Five Year Plan was inaugurated, could be classified into two broad categories. First, the aggregate income, output, and employment objectives include plans for certain rates of growth of the macro development indicators such as gross national product (GNP), per capita income and employment. Second, an equitable distribution of development gains is a value premise intended to guide the formulation and implementation of development plans. To quote the Third Five Year Plan document (in Fourth Five Year Plan, p. 21) "the economic activity must be so organized that the tests of production and growth and those of equitable distribution are equally met." For all India,[1/] the index of agricultural production (1951=100) increased to 139.2 in 1966, and agricultural productivity index increased to 113.3; the corresponding figures

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Schmookler (1966) defines technological change to denote the act of producing new knowledge, and technical change to include incorporation of this new knowledge in the production process of firms. In almost all studies no such distinction is followed. In the present study the concepts of technological change and technical change are used synonymously.

1/ Source: Bulletin of Food Statistics (1972, p. 157)

for wheat were 152.2 and 118.2 respectively.[2/] For Punjab the index of agricultural production (1961-62 = 100) increased to 115.18; for wheat the corresponding figure was 116.57; percentage increase[3/] (1961-62 = 100) in yield per hectare of wheat was 28.11 in 1966-67. The figures quoted above indicate in broad terms small gains in production and productivity dimensions of agricultural development. What has happened to the equitable distribution objective? A study by Dandekar and Rath (1971a, P. 25) summarizes the situation in the following words:

> "It is clear that the small gains of development during the past decade have been very unevenly distributed and the gulf between the rich and the poor has widened."

Details on income and consumption inequalities, and increasing numbers of people below the "poverty line," not merely in India as a whole but also in Punjab, have been extensively documented.[4/] Healey (1972, pp. 765-770, 776-779) has rightly identified unemployment and income distribution as two basic areas in which development efforts of less developed countries have exhibited considerable failure.

Let us examine some recent statistics on production and productivity gains of agricultural development in India as

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2/ Source: Statistical Abstract of Punjab (1974, p. 99)

3/ Source: Socio-Economic Review of Punjab: 1970-71 (1972, p.25)

4/ Some of these details will be examined in subsequent chapters of this study.

a whole and Punjab state. For all India, the index of agricultural production (1951 = 100) increased from 139.2 in 1966 to 190.6 in 1971, and agricultural productivity index increased from 113.3 in 1966 to 146.9 in 1971.[5/] The corresponding figures for wheat increased to 340.5 and 185.6 respectively. For Punjab, the index of agricultural production (1961-62 = 100) increased from 115.18 in 1965-66 to 222.13 in 1972-73; the corresponding figures for wheat are from 116.57 to 326.62. Percentage increase (1961-62 = 100) in yield per hectare of wheat was 28.11 in 1966-67, and 89.02 in 1970-71.[6/] Further, in Ferozepur district of Punjab state, during the production year 1967-68 sample arithmetic mean output per acre on a "Mexican wheat" farm was 13.0 quintals, whereas on a "local wheat" farm the corresponding figure was 8.5 quintals.

The recent figures quoted above on production and productivity dimensions of agricultural development indicate in broad terms substantial (compared to previous periods) growth in output as well as efficiency in this growth. The growth in output as well as growth in efficiency has been more in wheat than in agricultural output as a whole, and the record has been superior in Punjab state to that of India as a whole. This period of growth in wheat farming sector was a period during which Mexican wheat variety was introduced. This growth in wheat farming sector has given rise to many interesting debatable issues relating

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5/ Source: Bulletin of Food Statistics (1972, p. 157)

6/ Source: Socio-Economic Review of Punjab: 1970-71 (1972, p.25)

to both growth and equity. Most development economists no longer agree that growth in aggregate output should be overriding objective, and that measures to redistribute income in favor of the poor are to be postponed. Unemployment is no longer considered as a symptom of underdevelopment which necessarily disappears as GNP increases. The cliche of the 1960's was that the size of GNP in relation to total population was so lo that distribution would mean distribution of poverty; economic growth was therefore the overriding objective in poor countries. The cliche of the 1970's is that in addition to growth in average income economic well-being of the poor majority should be kept in view; therefore equity is the overriding objective. Economic growth with equity has become the stated objective of most developing economies. It is beyond the scope of this study to examine whether both cliches could be right, and the objective of growth-with-equity is feasible. However, interest has certainly shifted from the narrower considerations of economic growth to the broader issues of economic development such as unemployment, poverty and income distribution. It is in this context that an evaluation of economic impacts of new production technology[7/] in the wheat farming sector assumes importance. Various issues are raised with the substantial growth in output of wheat farming sector. What is the source of this "new found" growth in output? How much of the growth in

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7/ In this study new production technology is defined to include Mexican wheat and accompanying production practices; old production technology is to include local wheat and accompanying production practices.

output is due to increased efficiency in production, and how much of it is due to increase in quantity of inputs? What are the effects of this new production technology on employment and income distribution? Using the results from Punjab state, the present study is an attempt to answer some aspects of these questions.

Objectives of the Study

The following may be stated as the specific objectives of the study:

(1) Decompose the total change in wheat output between farms employing old production technology and farms employing new production technology into three forces:

a. neutral technical change;

b. non-neutral technical change; and

c. change in input levels.

(2) Determine employment elasticities with respect to certain key variables - output, input prices, and quantities of inputs.

(3) Decompose total change in employment between farms employing old production technology and farms employing new production technology into the following forces:[8/]

a. neutral technical change;

b. non-neutral technical change;

8/ Details on the combination of these five forces in decomposition process depends on the choice of economic models for deriving labor demand functions. More on this in Chapter IV.

c. change in output;

d. change in input prices; and

e. change in quantities of certain key inputs.

(4) Determine the direction and magnitude of change in functional income distribution.

The above stated objectives will be examined with results from the Punjab wheat economy.

Market Structure and Economic Organization Governing the Punjab Wheat Economy

It will be evident in subsequent chapters of this study that economic models with underlying competitive premises are used for the purpose of analysis. So a brief description of economic characteristics of the Punjab wheat economy is not out of place. Two issues seem to be important in this context. What is the market (input-output) structure confronting wheat farm-firms? Second what is the basic prevailing economic organization in wheat farming?

Regarding the first question, farmers are price takers in both the product and factor markets. In the case of product markets government announces price of wheat much before the harvesting season. Planting decisions can be made by farmers expecting that at least last year's price will prevail. Fertilizer prices are set by the government and are maintained at a uniform level all across the region during a production season. Supplies at fixed prices are made available at the village level by the state marketing federation through village cooperatives.

The level of wages of both annual and daily hired labor are determined fairly in a competitive village labor market. This market sometimes extends over several small contiguous villages. The annual rental of lands rented is also fairly competitively determined in village land market. The assumption that markets for labor and land are competitive does not mean that there are no price variations among farms; these variations are assumed to be the reflections of differential rent.

However, certain kinds of imperfection[9/] are not ruled out in capital markets. Credit market imperfections may show up in the form of difficulties confronting small farmers in gaining access to the market. In some cases certain types of capital costs are indirectly subsidized for larger farmers. Supply of electricity for irrigation purposes is a case in point. Electricity charges are at a fixed rate of approximately Rs 8.50 per month per horse power of the motor used and are thus independent of the electricity used. Subsidies on the purchase of agricultural machinery such as tractors and irrigation pump sets are also extended. Since we don't have any way of measuring the magnitude of imperfections in capital market, the competitive capital market is a maintained hypothesis in this study.

Our next concern is with the prevailing economic

9/ See Rao (1972a pp. 393, 395) and Sidhu (1972, p. 6) for details.

organization, that is the type of business organization, in the wheat economy. The privately managed farm is the economically relevant unit of analysis. Farming in Punjab state is dominantly of the peasant proprietor type. Billings and Singh (1971, P. 99) report that 52 percent of the cultivators farm entirely owned land, 34 percent rent some land to augment their owned land, and 14 percent are exclusively tenants. So nearly all wheat is produced by privately managed farms. Average operational farm size is about 12 acres with about 60 percent farms larger than 7.5 acres and 12 percent smaller than 2.5 acres.

Organization of the Study

Apart from the introductory chapter, the study is organized into five chapters:

Chapter II is concerned with a description of data sources, sampling methodology and some economic characteristics of the region of our study. Discussion on measurement and definition of variables also forms part of this chapter.

In chapter III, decomposition of total change in output between farms employing old production technology and farms employing new production technology is our main concern. First an economic model and its operational counterparts are developed for determining structural break in wheat production relations, identifying causes for structural break, determining the nature of technical change, and for decomposing total change in output into constituent forces. Second, empirical analysis of results on the above aspects is presented in chapter III.

Chapter IV deals with the determination of employment elasticities and decomposition of total change in employment into constituent forces. First, economic models for deriving employment elasticities and decomposing total change in employment are developed. Empirical analysis of employment elasticities and decomposition follow.

An evaluation of the effects of technical change on functional income distribution is presented in chapter V. First income distribution models are briefly reviewed. Second, an economic model for evaluation of effects of technical change on functional income distribution is formulated. Third, empirical results are discussed with an emphasis on comparability of estimated factor shares with actual factor shares, direction and magnitude of change in factor shares, and direction and magnitude of absolute change in actual factor shares. Fourth, implications of change in functional income distribution to personal income distribution are indicated.

Finally, chapter VI summarizes the main findings and draws policy implications with respect to sources of output growth, sources of employment growth and relative importance of key economic variables ingenerating employment. Policy implications of change in functional income distribution to fiscal and land redistribution measures will also be examined.

CHAPTER II

SOURCES OF DATA, AND MEASUREMENT AND DEFINITION OF VARIABLES

This chapter is intended to cover four important aspects:

(1) A description of the nature and sources of data used in this study, emphasizing sampling methodology used in collecting the data,[1/] and possible limitations of empirical basis;

(2) A determination of the sample structure in the context of our study;

(3) A bird's-eye view of economic anatomy of the regions covered in the study; and

(4) A description of measurement and definition of variables.

Sources of Data and Sampling Methodology

The type of investigation outlined for this study requires farm level primary data. There are three different samples which provide cross-section data for four years 1967-68 to 1970-71. We describe each of these sources with an emphasis on sampling methodology used in collecting the data.

1. Ferozepur Sample:

This sample from the southwestern district of

1/ The data base for this study is the same as the one used by Sidhu (1972). So whenever we refer to Sidhu's Study, we refer to the results obtained by him from this data set.

Ferozepur (Punjab) provides input-output data on 131 local wheat farms and 105 Mexican wheat farms for the year 1967-68 and data for 136 Mexican wheat farms for the year 1968-69. The agency which collected these data is the Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India.

The methodology utilized in collecting these data can be characterized as "Multistage Stratified Random Sampling." With the selection of the District, three steps were followed in selecting farms:

First, based on soil-crop complex, the district was demarcated into three relatively homogeneous zones.

Second, a total of 15 villages was selected in the district, such that the number of villages in each zone was proportional to the cultivated area in that zone, and the villages in each zone were selected at random with the probability of each village made proportional to its cultivated area.

Third, for the selection of cultivators, a consolidated list of all farms in the selected 15 villages was prepared in ascending order of their cultivated area, and divided into 5 classes, with each class having equal total cultivated area. Two farms were selected from each class in each village, thus

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2/ Input-output data on other crops raised on these farms during the other growing seasons of the year were also collected. But the present study utilizes data on wheat enterprise only.

giving 10 farms in each village and 150 farms in the district. Of these 150 farms the numbers of "usable"[3/] samples were 131 local wheat farms and 105 Mexican wheat farms for the year 1967-68, and 136 Mexican wheat farms for the year 1968-69.

Data were recorded by trained investigators through daily visits to the sampled farms. This procedure is characterized as the "Cost Accounting Method."

2. Tractor Cultivation Sample:

This sample, made available by the Economic Adviser to the Government of Punjab, covers the crop year 1969-70. It is larger than the Ferozepur Sample in terms of both geographic coverage and number of farms. This sample spreads over the whole of Punjab state, covering 304 farms in 19 villages with 16 farms in each village. Six sample farms from 16 sample farms in each village owned and operated tractors. Of these, 304 farms the number of "usable" samples is 286 Mexican wheat farms.

The "Multistage Stratified Sampling" and "Cost Accounting Methods" were used in collecting these data.

3. Regionally Stratified Sample:[4/]

This sample comes from 128 Mexican wheat farms of Punjab

3/ By "usable" we mean that all items of input-output data were recorded in the case of these selected sample farms for the study.

4/ Data collection of this sample was designed and supervised by Sidhu (1972).

state - 46 from zone (ii), 31 from zone (iii), and 51 from zone (iv).[5/] In consultation with the Soils Department at Punjab Agricultural University, Ludhiana, a representative site was picked for each zone. In zone (iv), two representative sites were selected owing to its larger size relative to other zones. At each site, lists of farms were prepared, large enough so that a randomly selected 10 percent of the farms would give the desired number of farms at each site to be studied.

The Data Sheets or "proformas" and approach used were similar to "Cost Accounting Method," but farm visits were not as frequent.

Limitations of the Data

In spite of the relatively high quality of data, we need to discuss some possible limitations associated with the data. Our analytical and empirical framework involves some abstractions and generalizations. A brief mention of limitations of data is intended to place our analytical and empirical models in proper perspective, and thereby our results as well.

First, the information is concentrated on input-output or technical relations in wheat farming and other aspects of production receive much less emphasis. For example, we have rather non-discriminating, unidimensional, purely quantitative information (in money terms) on irrigation. Effective irrigation

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5/ For a detailed discussion on zone classification see Sidhu (1972, Appendix I)

depends upon the quality of irrigation - the source, regularity, controllability as well as the quantum of water supply. The quality of irrigation is crucial in the case of new irrigation based production technology in wheat farming. Whether a farm is supplied by well irrigation or canal irrigation crucially affects the quality and dependability of water supply. Similarly in the case of tenancy there are no details on terms and conditions of lease arrangements. Tenurial arrangements assume very many diverse forms in the matter of conditions of work, permanenance of tenure, sharing of inputs etc.

Second, there are difficulties in measuring agricultural inputs and output which are much more general and not confined to this study. We found no specific difficulties in getting a measure of wheat output in the context of our study. But we do recognize some specific difficulties associated with human labor and other specific inputs. Farm workers are broadly divided into permanent workers and casual labor. Among the former are included family workers (male, female and children) and permanent farm servants. Labor which can be hired out and labor which may be used on family farms are not independent of the economic status (or sometimes even of the social status of the household). For example, among very small farming households women and children not only work on their own farms but offer themselves for work outside; whereas among the class of more affluent farmers female labor is often withdrawn altogether from crop production. In some peasant households, women and

children may be employed on family farms, but they are not entrants into the labor market even though their working o family farm would influence the functioning of labor market.

The distribution of work between adult males and females and children appears to follow a largely traditional allocation of tasks. Female labor is employed mostly as casual labor for certain typical operations such as weeding. Child labor is employed mostly in cattle grazing, crop watching etc. Al these details are intended to bring out the point that we ar abstracting from all these complex forces while comparing agricultural wage rates with the marginal productivity of labor. Wage rate is but one variable in the scheme of things which goes to determine labor utilization on farms.[6/] Are family and hired labor exclusively separable categories so that the family labor is a datum for a cultivatinghousehold? Or are these substitutes so that the prevailing wage rate for hired labor measures the opportunity cost of family labor? We don't have answersto these questions, but we would want these questions to be kept in view while looking at the results of this study.

In addition to problems associated with human labor input, valuation of assets - especially those created on the farm-poses a difficult problem. The question of evaluating their replacement value or depreciation is especially tricky when capital assets are neither standardized nor regularly

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6/ For more details on this particular aspect see Bharadwaj (1974, pp. 25-30).

maintained. Data on the technological and financial aspects of agriculture are prone to be less accurate and to allow for much wider margins of reporting and non-reporting errors

Third, added to these difficulties is the fluctuating performance of agriculture which is sensitive to climatic variations. This will be distinctly evident when we present empirical results.

The preceding discussion has brought out some possible limitations associated with the data. Some of the limitations are more general and not peculiar to this study. We have laid emphasis on some aspects of labor market behavior with a view to bring out the complexities from which we are abstracting in developing our analytical and operational framework.

Sample Structure for the Present Study

So far we have described the data sources and the methodology used in collecting these data. In this section our concern is to present a sample structure which we believe to be relevant for the purpose of our study. Using the data available from the sources discussed in the preceding section, we form three sample structures as presented in Table II.1.

Table II.1 Sample Structure: A Brief Summary

Sample	Geographic Coverage	Production Year	Wheat Variety	Number of Observations
I	Ferozepur District	1967-68	Local	131
		1967-68	Mexican	105
II	Ferozepur District	1967-68	Local	131
		1967-68	Mexican	105
		1968-69	Mexican	136
III	Ferozepur District	1967-68	Local	131
		1967-68	Mexican	105
		1968-69	Mexican	136
	Punjab State	1969-70	Mexican	286
		1970-71	Mexican	128

As shown in Table II.1, Sample I includes 131 local wheat farms and 105 Mexican wheat farms of Ferozepur district for the year 1967-68. This provides us a "homogeneous" data set in terms of both geographic area and year. So a decomposition of total output and employment change into respective forces between local wheat farms and Mexican wheat farms, and an evaluation functional income distribution effects are not far from valid.

Sample II includes 131 local wheat farms of Ferozepur district for the year 1967-68, and 241 Mexican wheat farms of the same district for the years 1967-68 and 1968-69. This data set is still "homogeneous" in terms of geographic coverage, but not "homogeneous" in terms of year. However, if we eliminate year effect by introducing a year dummy into our estimating equation, we will still have a relatively "homogeneous" data set

for examining the objectives of our study.

Sample III includes 131 local wheat farms of Ferozepur district for the year 1967-68, and 655 Mexican wheat farms for the years 1967-68 through 1970-71. This sample is not "homogeneous" in terms of either geographic coverage or years. We will take out yearly effects by introducing yearly dummy variables into our estimating equation; but our estimates of parameters will still be left with regional biases. We will be examining the objectives of our study with results from Ferozepur for local wheat, and results from Punjab state [7/] for Mexican wheat. So we are less certain in our analysis with Sample III than with Sample I and Sample II.

Some Economic Characteristics of the Punjab Region

We hope that a presentation of some economic characteristics of Punjab region would provide a required background for placing the results on sources of output growth, employment growth and changes in functional income distribution in proper perspective. These economic characteristics are presented under three heads:

(1) A few general aspects of Punjab state such as area and population.

(2) An analysis of agricultural growth and growth potentials in agriculture.

7/ There is need for qualifying the statement that for Mexican wheat we are considering the state of Punjab as one unit. Of the 655 samples of Mexican wheat farms, 241 farms were from the district of Ferozepur.

(3) A description of employment structure.

Wherever possible, these economic characteristics of Punjab are compared with the corresponding characteristics of India as a whole.

1. Area and population:

Punjab is situated in the northwest corner of the Indian union. It came into existence on November 1, 1966 as a result of the reorganization of the erstwhile state of Punjab. The state covers an area of 50,376 kilometers which is about 1.6 percent of the total area of the Indian union.

The Punjab state, covering only about 1.6 percent of the total area of the country, accommodates 2.5 percent of the population (1971 census). The density of population per square kilometers in Punjab in 1971 works out at 267 persons as against 178 persons at all India level in the same year. However, the density of population in Ferozepur district is 186 per kilometers, the lowest in the state. The total population of the state during the decade 1961-1971 increased by 21 percent. The proportion of urban in the total population increased from 22.97 percent in 1961 to 23.80 percent in 1971. This means that the state has a strong agricultural base with over 76 percent of its people living in the villages and dependent on agriculture for livelihood.

The state of Punjab is on the average one of the more affluent in India. The per capital income of the state is Rs 472 in 1970-71 at 1960-61 prices compared to Rs 374 in 1960-61.

2. Agricultural Growth and Growth Potentials:

According to a study by the Economic and Statistical Adviser, Ministry of Food and Agriculture, Government of India (1966) in the period 1952-53 to 1964-65 the growth of crop output in Punjab (the old state) was the highest in India with an average annual rate of 5.56 percent (linearly) compared to 3.42 percent for the country as a whole. This growth rate was composed of a growth in agricultural productivity per acre per year of 2.86 percent, while the all-India rate was 1.91 percent. Thus much before the recent introduction of high-yielding varieties, Punjab had a high rate of growth of both total output and productivity.[8/]

Let us examine some indices of agricultural growth with an emphasis on wheat in Punjab.

Table II.2: Some Indices of Agricultural Growth in Punjab

Item	1965-66	1967-68	1969-70	1970-71	1972-73
(1) Index of agricultural production: all commodities (1961-62 = 100)	115.15	--	--	208.97	222.13
(2) Index of wheat production (1961-62 = 100)	116.57	--	--	313.05	326.62
(3) Yield per hectare of wheat (kilograms)	1,236	1,863	2,245	2,238	2,233

Sources: 1. Statistical Abstract of Punjab (1974, pp. 98,99) for items (1) and (2).
2. Socio-Economic Review of Punjab (1972, p. 25) and Statistical Abstract of Punjab (1974, p. 74) for item (3)

8/ Krishna (1964) provides an excellent account of agricultural growth in Punjab even before the introduction of high yielding varieties.

Considerable gains in agricultural production in Punjab especially in wheat and gains in yield as evidenced in Table II.2 have placed Punjab as one of the most important agricultural growth centers in India. These gains in wheat have been substantial with the introduction of new production technology. Among the foodgrains wheat is the most important cereal crop in the state as it covers 58.6 percent of the total cropped area under food grains in 1970-71. Relative share of Punjab in the Indian wheat area was 12.6 percent for 1969-70 to 1971-72 average, whereas its share in total production was 22.1 percent for the same period.[9/] This is because yield per hectare of wheat was 2,232 kilograms in Punjab for the year 1972-73, whereas the corresponding all-India figure was 1,254 kilograms. It may be inferred from above statistics that growth performance of Punjab wheat economy in terms of production index and yield indices has been very good. These performance indices moved upward rapidly with the introduction of new production technology into the wheat farming sector.

So far we have examined the considerable progress made in Punjab agriculture, especially in wheat farming with the introduction of new production technology. In Table II.3 we present some growth potentials - cultivated area, irrigation, agricultural machinery, use of chemical fertilizer and pesticides that have been built into the Punjab farm economy.

9/ Source: Indian Agriculture in Brief (1973, pp. 94, 96)

Table II.3 Some Indices of Growth Potentials for Punjab Agricultur

Item of Growth Potential	Indices	
(1) Total cropped area (Thousand hectares)	4,732	(1960-61)
	5,931	(1972-73)
(2) Total wheat area cropped (Thousand hectares)	1,400	(1960-61)
	2,404	(1972-73)
(3) Cultivable area per agricultural worker (Hectares)	1.75	(1971)
(4) Percentage wheat area under high-yielding varieties	3.5	(1966-67)
	57.9	(1968-69)
	69.1	(1970-71)
(5) Percentage irrigated area to total area under crops:		
all crops	74.2	(1969-70)
cereals	80.2	(1969-70)
wheat	83.2	(1969-70)
(6) Agricultural machinery and implements:		
ploughs	1,085,650	(1961)
	1,255,095	(1972)
sugarcane crushers	75,257	(1961)
	71,702	(1972)
tractors	4,935	(1961)
	39,798	(1972)
bullock carts	283,575	(1961)
	295,016	(1972)
oil engines with pumping sets	6,983	(1961)
	229,906	(1972)
electric pumps for tube wells	6,565	(1961)
	71,062	(1972)
(7) Consumption of fertilizer (Thousand metric tons)	26	(1960-61)
	876	(1969-70)
	1,694	(1971-72)
(8) Area under plant protection (Thousand hectares)	2,609	(1966-67)
	4,047	(1971-72)

Table II.3 continued

Sources: 1. Statistical Abstract of Punjab (1974, pp. 55, 58, 153) items (1), (2), and (6).

2. Socio-Economic Review of Punjab (1972, pp. 17, 19, 20) for items (6), (7), and (8).

3. Indian Agriculture in Brief (1973, pp. 39, 37) for item (5).

4. Statistical Hand Book of Punjab (1972, p. 14) for item (3).

As evidenced in Table II.3, growth in the productive capacity of the Punjab farm economy is in terms of what Schultz (1964) calls "modern inputs." Three items are worth mentioning. First, there was a tremendous growth in irrigation infrastructure as a result of which for all crops the percentage of irrigated area to total area was 74.2 percent in Punjab as against 22.7 percent for all India during 1969-70. This explains partly the rapid adoption of new production technology in Punjab state. Second, growth in application and fertilizer has been considerable. For example, during the year 1972-73, quantity of fertilizer used per hectare was 58.72 kilograms in Punjab whereas the corresponding figure for all India was 16.46 kilograms.[10/] Third, there was a many fold increase in the use of tractors. The implications of rapid increase in the number of tractors in Punjab to employment will be evident in Chapter IV.

3. Employment structure:

Shift in working force from primary industries to

10/ See "Fertilizer Statistics 1972-73" (1973, p. I-178, I-179).

secondary and tertiary industries is one of the traditional indicators of economic growth. Let us examine the trends in India as well as Punjab in particular. According to 1971 census, the percentage of workers to total population is about 32.92 for all-India and 28.87 for Punjab. Table II.4 shows the sectoral distribution of working force.

Table II.4 Percentage Distribution of Working Force, All-India and Punjab 11/

	1961		1971	
Class of workers (1)	India (2)	Punjab (3)	India (4)	Punjab (5)
Cultivators	43.3	46.24	52.8	42.75
Agricultural laborers	26.3	9.65	16.7	20.03
Other workers	30.4	44.11	30.5	37.22
Total workers	100.0	100.0	100.0	100.0

Source: (1) Indian Agriculture in Brief (1973, p. 6) for columns (2) and (4).

(2) Socio-Economic Review of Punjab (1972, p. 9) for columns (3) and (5).

It is evident from Table II.4 that about 62.7 percent of workers are cultivators and agricultural laborers in Punjab. They have to earn a living for themselves and for their dependents

11/ The definition of a worker has undergone a change in 1971 census. In 1961 census persons economically active even for an hour a day were treated as workers but in 1971 they were treated as such only if their activity occupied them daily for a period sufficient to make it gainful.

by working on farms. This brings out the importance of growth in output and employment in the farming sector.

Measurement and Definition of Variables

This section deals with the measurement and definition of variables used in this study:

Y = physical output of wheat measured in quintals per farm including by-products.[12/] The by-products are converted into quintals of wheat by dividing the total value of by-products by wheat price.

L = the land input measured in acres.

N = the labor input per wheat farm measured in hours. It includes both family and hired labor. Child and female labor is converted into man-equivalents by treating two children (or women) equal to one man. This type of conversion is based on the assumption that each type of labor is paid its marginal value product.

F = the current value of fertilizer and farm produced manures measured in rupees per farm.

K = a measure of the flow of capital services going into wheat production per farm. It includes depreciation charges, operating expenses of physical capital, value of irrigation expenses, bullock labor expenses, value of seed and interest expenses all measured in rupees.

12/ The major by-product is wheat straw, which in chaffed form is used as cattle feed. Sometimes sarson (an oilseed crop) is also grown mixed with wheat.

Depreciation charges are calculated by straight line method.

WN = the total wage bill measured in rupees for wheat production per farm. It includes payments to hired labor on casual basis, to labor hired on annual contract basis, and the imputed value of family labor service. Family labor services are valued as equivalent to those of the annual contract labor for each farm. For farms which do not employ labor on annual contracts, the average rate of those farms in the sample which do employ contract labor was applied for evaluating the services of family labor.

P_n = the hourly wage rate of labor measured in rupees. It is obtained simply by dividing the total wage bill (WN) by the total labor input (N).

P_l = the average rental price of land per acre per farm. It is obtained by dividing the total rental value of land per farm by the size of wheat land (L) per farm. The total rental value of land per farm consists of the actual rent paid for rent-in land in cash or share of the produce and the imputed rental value of owned land. For imputing rental values of owned lands, the actual rental rates of the fields in close proximity considered as equivalent in land fertility are applied. For lands producing

two crops during the year half of the annual rent is treated as the share of the wheat crop.

P_f = price of nitrogen per kilogram. We recall that fertilizer variable (F) is defined to include the current value of chemical fertilizer and farm produced manures. Regarding chemical fertilizers, we don't have data on quantities of N, P and K, but only expenditure in value terms. If we had quantity data on N, P and K, we could convert these into plant nutrients and divide the total nutrients by total expenditure to get prices of a unit of plant nutrient. In the absence of quantity data, we propose to use price of nitrogen as a proxy for price of fertilizer. The choice may be justified in view of the fact that nitrogen (N) is the single most important form of fertilizer used in Punjab.[13/] Further, of all the different forms of nitrogeneous fertilizer, urea is the most important one in view of it forming a large proportion to total quantity of nitrogeneous fertilizer used in Punjab.[14/] So price of urea per kilogram is a measure of fertilizer price used in this study.

13/ See "Socio-Economic Review of Punjab 1970-71" (1972, p.19) for details

14/ See "Fertilizer Statistics: 1972-73" (1973) for details

P_k = hourly rental price of bullock capital. We recall that the capital variable (K) is defined to include depreciation charges, interest expenses, operating expenses of physical capital, value of irrigation expenses, value of bullock capital services and value of seed, all measured in rupees. With the data available, we can develop rental price only of bullock capital by dividing total expenditure by total number of hours employed and use it as a proxy for price of capital. This is what we propose. This procedure ignores variation in rental prices of other capital services. However with the data available, using rental price of bullock capital as a proxy for price of capital is the only choice left. Further, it may be stated that expenses on bullock capital are a major component of capital expenditures.

P = the price of wheat per quintal measured in Rupees.

π = the profit from wheat production is defined as total revenue less total variable costs, that is, the total wage bill.

CHAPTER III

DECOMPOSING TOTAL CHANGE IN OUTPUT

One of the specific objectives of this study is to decompose total difference in output between farms employing old wheat production technology and farms employing new wheat production technology into three forces:

(1) Neutral technical change

(2) Non-neutral technical change; and

(3) Change in volume of inputs.

Before developing economic and empirical models for this purpose, a review of some studies on the sources of growth is in order. The formal analysis of economic growth started as an analysis of accumulation of factors of production, in particular of capital. Simple Harrod-Domar models[1/] regarded increase in the capital-labor ratio as the only source of increase in per capita income. Therefore, increases in investment in physical capital (through increases in the savings rate) were considered the single most important policy goal for countries trying to achieve economic growth.

However, studies of growth in the U.S. and elsewhere found that measured output growth can be attributed only in part to measured input growth. Empirical studies attempted to isolate the separate influence of input growth (movement along

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1/ For details see Hahn and Matthews (1964).

a production function) and technical change (shift of the production function). The upsurge in the attention given to technical change can be dated in 1956 with the appearance of an article by Abramovitz (1956). He found that between the decade 1869-78 to 1944-53 in the U.S. economy, almost the entire increase in net product per capita was associated with the rise in something - subsequently called the 'residual' - other than the inputs of the physical capital stock and the services of labor. After the appearance of this article, evidence on the importance of the residual accumulated. The conclusions of various studies vary. Solow (1957) reported that during 1909-1949 in the U.S. economy, gross output per man hour doubled, with 87.5 percent of the increase attributed to technical change and remaining 12.5 percent to increased use of capital. This study seems to have suggested drawing attention away from capital formation as a source of growth to technical change as the only important factor. However, Solow (1960) went some way toward giving weight back to capita.[2/] He showed that since technical advance occurs when the capital used embodies the new technology, capital formation is important to make use of new methods.[3/] Griliches (1964), Jorgenson and

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2/ For details see Resek (1963).

3/ This point is relevant for our study in view of more expenditure per acre that has to be incurred on complementary inputs such as irrigation, fertilizer, pesticides, and other current inputs when a farmer plants Mexican wheat.

Griliches (1967), and Denison (1969) have made efforts to allocate technical change to various elements of efficiency or quality changes of traditional factors - increase in education, quality changes of capital equipment and land, changes in the utilization rate of capital and economies of scale. Jorgensen and Griliches (1967) reported that almost all 1945-65 growth in the U.S. was due to input growth. In their view, there is little or no technical progress when the production function is specified correctly. This conclusion is just the reverse of the conclusion drawn from Abramovitz (1956) and Solow (1957). Using Griliches (1964), and the Jorgenson and Griliches (1967) approach, Akino and Hayami (1974) reports that overall, about half of the long-term rate of growth in agricultural output in Japan has been accounted for by changes in the four conventional inputs - land, labor, fertilizer, and capital; one quarter by an increase in the level of education; and another quarter by an increase in the public expenditure for agricultural research and extension.

Our interest in reviewing briefly the research on the sources of growth is to bring out the relative importance of technical change and change in volume of inputs in generating growth in output. The ultimate source of growth in output is always some sort of investment, although not the traditional investment of the Harrod-Domar model. Schultz (1964, p. 131) argues that "there is at best little opportunity for growth from traditional agriculture because farmers have exhausted the profitable production possibilities of the state of the arts

at their disposal." In fact Bhattacharya (1972, pp. 51, 52) using the Cobb-Douglas production function, showed that technological progress did not contribute significantly to the growth of the Indian agricultural sector between the period 1948-49 and 1960-61; whereas technological progress was a significant factor in explaining the movements in the level of non-agricultural output in India.[4/] This result is in conformity with the Schultz (1964, p.145) argument that less developed countries will not be able to obtain growth by investing more in capital goods of the traditional form. Instead they will have to create new institutions capable of providing improved inputs into production such as a better educated labor force, better intermediate inputs (e.g. seeds) and new capital equipment adapted to the local conditions. It is his "High-pay-off Input Model"[5/] that has provided a theoretical foundation for the "Green Revolution" in less developed countries, both through the transfer of specific agricultural techniques and a general body of scientific knowledge.

The efficiency gains of new production technology in rice and wheat production have been well documented. Swenson (1973, p. 52 for example) reports that in the survey villages of

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4/ This is not to argue that technological progress has been of the right type in the non-agricultural sector. In fact Bhattacharya (1972) argues that the basic problem of economic development in a country like India has been the absence of continuous technological progress in the agricultural sector, and the nature of tecnological progress (not in line with the factor proportions of the country) in the non-agricultural sector.

5/ See Hayami and Ruttan (1971) for an exposition on the "High-pay-off Input Model" of agricultural development.

Thanjavur district, Tamil Nadu state (India), there was a 22 percent increase in paddy production between 1965-66 and 1960-71. Of the total change in production, changes in yields accounted for 18.9 percent, and the rest is accounted for by changes in the double-cropped area. Sidhu (1972, 1974a) has determined empirically the nature and magnitude of technical change in the wheat farming sector of Punjab. He reported that technical efficiency in wheat production increased by almost one-fourth. Here a new source of growth is introduced into the wheat economy. However, this study does not provide a complete account of the differences in output between farms employing new and old production technology, because technical change in the sense of efficiency gain is just one source of output growth; the other source is the change in inputs. The present study is an attempt to decompose the total change in output into output growth attributable to technical change - neutral and non-netural and to change in inputs. We have to develop an economic model and its operational counterparts for the purpose.

Economic Model

In this section our main interest is to decide on an economic model that will enable us to decompose the total change in output. Since one of the basic generators of output change is postulated to be technical change, we want an economic framework that enables us to measure its contribution. There are broadly

three ways of measuring technical change; partial productivity measures such as output per man hour, per acre; total productivity measures such as output per unit of total input; and aggregate production function.[6/] Productivity indices are deduced either from an explicitly defined production function or from a distribution theory where the production function is implicit. The level of technical change can be conceptualized in terms of an aggregate production function whose parameters reflect current available technical production possibilities. Technical change can then be viewed as a change in one or more of the parameters of the aggregate production function resulting from the addition of new production techniques to the existing stock. Even though Tinbergen in 1942 (in Kennedy and Thirlwall, 1972, p. 17) was the first explicitly to estimate technical progress as a separate item in the aggregate production function, Solow's study (1957) is by far the most sophisticated of the earliest attempts to estimate the rate of technical change through the use of aggregate production functions. Even though Tinbergen restricted the measure to neutral technical change, Brown and Popkin (1962) have generalized the method so that non-neutral as well as neutral technical progress can be measured.

6/ For details on these measures see Ruttan (1964). Lave (1966), Brown (1968), Nadiri (1970), Kennedy and Thirlwall (1972) and Peterson and Hayami (1973).

So far we have decided on aggregate production function as our basic economic framework.[7/] However, we have to decide on the functional form Cobb-Douglas, Constant Elasticity of Substitution (CES), or Translog Cost function[8/] (as well as the Translog production function)[9/] - which we are going to use. The popularity of the Cobb-Douglas production function lies chiefly in its ease in manipulation and interpretation of results. But one of its restrictive properties is that it implies a unitary elasticity of substitution between any pair of inputs. There is considerable empirical evidence supporting the assumption of unitary elasticity of substitution and thereby the use of Cobb-Douglas form. Hayami (1970), and Hayami-Ruttan (1971) in their test using intercountry cross section data found their results consistent with unitary elasticity of substitution. Lau and Yotopoulos (1972, p. 14) report that they fitted Indian data to a CES production function directly with non-linear methods, and found the elasticity of substitution not to be significantly different from one. But Bhardhan (in Srivastava and Heady, 1973) recently estimated the elasticity of substitution between land and labor by means of "Kmenta approximation"

7/ See Pasinetti (1959) for a critical look at the use of aggregate production function for measuring technical change.

8/ For details on Translog Cost Function see Binswanger (1973, 1974a, 1974b).

9/ See Christensen, Jorgenson and Lau (1973) for details on Translog production function.

(1967) and found the elasticity of substitution between land and labor inputs to be significantly different from unity. However, Sidhu (1972, Appendix II) estimated the CES production function and obtained the result that elasticity of substitution was not different from unity. So we choose to work with the assumption that the Cobb-Douglas function would represent the data fairly. The attraction of Cobb-Douglas derives not only from its simplicity, but also from the desirable neo-classical properties it possesses.[10/] It satisfies all the three neo-classical criteria: positive marginal products, diminishing marginal products over the relevant range, and non-specification of the degree of economies of scale.

Following the preceding discussion, we specify our production function in the Cobb-Douglas form as follows:

$$Y = A\, L^{\beta_l}\, N^{\beta_n}\, F^{\beta_f}\, K^{\beta_k}\, e^{u} \qquad (1)$$

where: A = constant term, a scale parameter

u = random disturbance term independently distributed with zero mean and finite variance[11/]

Definitions of Y, L, N, F, and K are as defined in Chapter II. The coefficients denoted by β's represent individually

10/ See Brown (1968) for details

11/ See Zellner, et.al. (1966) for details on the need for including a stochastic term when estimating production functions.

the percentage changes in output, the four coefficients taken together measure the total percentage change in output for a given percentage change in inputs. In short, $\beta_l+\beta_n+\beta_f+\beta_k$ is the degree of homogeneity of the Cobb-Douglas production function.

In production function (1), technical change finds expression in variations in A and the β's. Variations in A would indicate neutral technical change. The Cobb-Douglas production function would give evidence of non-neutrality if the slope coefficients (β's) shift. Details on the implications of neutral and non-neutral technical change will be provided in a subsequent section of this chapter.

We want to use production function (1) for determining:

(1) the contribution of technical change - both neutral and non-neutral -- to difference in output between farms employing old production technology and farms employing new production technology;[11a/]

11a/ A major point on this attempt to break technical change up into neutral and non-neutral components needs to be made explicit. In the context of decomposing total differences in output and employment between old and new production technology, the neutral component of technical change is defined to be the shift in term (A) of production function (1), and the non-neutral component is defined to be the shifts in slope parameters (β's) in production function (1). If we add both components, we get an approximate measure of technological contribution to differences in output and employment.

(2) the contribution of technical change to employment; and

(3) the effects of technical change on functional income distribution.

In this chapter, our concern is with the first relationship. The other two will be discussed in Chapter IV and Chapter V respectively. Regarding the first relationship, for any production function, the total change in output is produced by changes in the factors of production and in the parameters that define the function. The impact of technical change on output is felt in two stages. Initially, more output is made possible from the existing resource base under the new production technology. This is the efficiency component, reflected in a shift in the production function. Second, an adjustment component of technical change is evident in movement along new production function. This movement along new production function follows from the efforts of firms to adjust to disequilibrium caused by new level of efficiency. Our interest is to capture the effects of both stages.

The decomposition analysis is undertaken with per acre production function estimates in that scale effects are eliminated. We assume that per acre production relations for our "representative firm" are approximated by the following Cobb-Douglas production function in logarithmic form:

$$\ln Y^1 = \ln A^1 + \beta^1_n \ln N^1 + \beta^1_f \ln F^1 + \beta^1_k \ln K^1 \qquad (2)$$

where:

Y^1 = output of wheat in quintals per acre.

N^1 = number of hours of human labor employed per acre;

F^1 = value of fertilizer expenditure in rupees per acre;

K^1 = value of other capital services per acre; and A^1 is the scale parameter in per acre production function estimates. The underlying production function (2) is homogeneous of degree one, that is constant returns to scale.

Differentiating (2) totally

$$\frac{dY^1}{Y^1} = \frac{dA^1}{A^1} + \beta^1_n \frac{dN^1}{N^1} + \beta^1_f \frac{dF^1}{F^1} + \beta^1_k \frac{dK^1}{K^1} + \ln N^1 d\beta^1_n$$

$$+ \ln F_1 d\beta^1_f + \ln K^1 d\beta^1_k \qquad (3)$$

Replacing derivatives by discrete approximations and rearranging terms:

$$\frac{\Delta Y^1}{Y^1} = \frac{\Delta A^1}{A^1} + \ln N^1 \Delta\beta^1_n + \ln F^1 \Delta\beta^1_f + \ln K^1 \Delta\beta^1_k$$

$$+ \beta^1_n \frac{\Delta N^1}{N^1} + \beta^1_f \frac{\Delta F^1}{F^1} + \beta^1_k \frac{\Delta K^1}{K^1} \qquad (4)$$

Equation (4) considers the technological parameters - A^1, β^1_n, β^1_f, β^1_k - as variables. These technological parameters are themselves the functions of biochemical technology such as new seeds, fertilizer, pesticides, irrigation, and mechanical

technology such as tractors, weeders and threshing machines. Equation (4) gives us insights on how much change in labor, fertilizer, and other capital services is required to attain a given level of output change per unit of land. We hope to bring out the importance of technical change, and of change in the level of inputs for producing a given level of output. In brief, this is an attempt to determine the sources of output growth per unit of land.[12/]

Let us see how we can use equation (4) to decompose the total difference in output per acre between farms employing new production technology and farms employing old production technology:

The expression $\frac{\Delta Y^1}{Y^1}$ represents the percentage change in output with the introduction of new production technology. If Y^1 is the per acre geometric mean output under old production technology, we define ΔY^1 as:

$$\Delta Y^1 = Y^1_{New} - Y^1_{Old}$$

The expression $\frac{\Delta A^1}{A^1}$ on the right hand side of equation (4) measures the percentage change in output due to neutral technical change. If A^1 is the constant term in the Cobb-Douglas production function governed by old production technology, we define ΔA^1 as:

12/ See Martin (1972) for more details on this line of reasoning.

$$\Delta A^1 = A^1_{New} - A^1_{Old}$$

To measure the percentage change in output due to non-neutral technical change, we evaluate the following expression in equation (4):

$$\ln N^1 \, \Delta\beta^1_n + \ln F^1 \, \Delta\beta^1_f + \ln K^1 \, \Delta\beta^1_k \qquad (5)$$

If β^1_n is the output elasticity with respect to labor, $\Delta\beta^1_n$ is defined as

$$\Delta\beta^1_n = \beta^1_{n\,New} - \beta^1_{n\,Old}, \text{ and}$$

$\Delta\beta^1_f$ and β^1_k in the same way.

An evaluation of following expression in (4) would provide us an approximate measure of percentage change in output due to changes in the level of input use per acre:

$$\beta^1_n \frac{\Delta N^1}{N^1} + \beta^1_f \frac{\Delta F^1}{F^1} + \beta^1_k \frac{\Delta K^1}{K^1} \qquad (6)$$

If N^1 is the geometric mean number of hours of labor employed per acre by farms, ΔN^1 is defined as $(N^1)_{New} - (N^1)_{Old}$, and ΔF^1 and ΔK^1 defined in the same way. So equation (4) provides us with the basic expressions required for decomposing into growth sources the total change in per acre output with the introduction of new production technology.

Technical Change: Neutral vs Non-Neutral

Technical change is one of the major forces leading to changes in output, employment and functional income distribution. Change in technological parameters with the introduction of Mexican wheat is postulated to affect:

(1) the sources of output growth by shifting either the scale parameter (A), or slope parameters (β's) or both, and by changing the level of resource use;

(2) the parameters governing the labor demand function; and

(3) functional income distribution through variations in the ratios of output elasticity of inputs.

So the nature and magnitude of technical change is of crucial importance for our study. In this section we are concerned with a review of theory underlying the nature of technical change and with drawing some implications from our study. We illustrate the nature of technical change, first, in a two-factor framework and then extend it to a four-factor framework which is our concern in this study.

1. Two-factor Case: To illustrate the traditional two-factor case in the context of our study, we write a wheat production function in Cobb-Douglas tradition as:

$$Y = A N^{\beta_n} K_1^{\beta_{k1}} \qquad (7)$$

where Y and N are as defined in Chapter II.

K_1 = value of all capital services that go into wheat production. So K includes rental value of land, value of fertilizer (F), and the value of all other capital services (K).

A = scale parameter; and β_n and β_{kl} are output elasticities with respect to labor and capital respectively.

If technical change governing the production relations in Mexican wheat is Hicks-neutral[13/] the following results would be evident:

(1) Neutral technical change finds expression in variation in scale parameter (A) of production function (7); $(A)_{MW} > (A)_{LW}$

(2) Variation in A does not affect the marginal rate of substitution (MRS) at a constant capital - labor ratio. Neutrality is a homothetic inward shift of the unit isoquant, that is, the parallel shift in isoquant toward the origin. The following relationship follows from the unaltered MRS,

$$\left(\frac{F_n}{F_{kl}}\right)_{MW} = \left(\frac{F_n}{F_{kl}}\right)_{LW},$$

where F_n and F_{kl} stand for the marginal products of labor and capital respectively. The ratios of marginal products remain unaltered. Alternatively Hicks-neutrality may be stated as

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13/ Detailed exposition of the concept can be found in Hicks (1936), Hicks (1964), Brown (1968), Neher (1971), Nadiri (1970), Ferguson (1971), Bronfenbrenner (1971), and Johnson (1973)

$$B = \pi_n - \pi_{kl} = 0.$$

where π_n = proportional change in the marginal product of labor;

π_{kl} = proportional change in the marginal product of capital.

Bias (B) is zero if marginal products of both labor and capital change in the same proportion.

(3) Another important implication of neutral technical change i

$$\left(\frac{\beta_n}{\beta_{kl}}\right)_{MW} = \left(\frac{\beta_n}{\beta_{kl}}\right)_{LW}$$

that is, the ratio of output elasticity will remain unaltered.[14/]

If technical change is of Hicks-non-neutral type, following results would be obtained in a two-factor case:

(1) Marginal products of factors change other than equiproportionally, that is,

$$\left(\frac{F_n}{F_{kl}}\right)_{MW} \gtrless \left(\frac{F_n}{F_{kl}}\right)_{LW}$$

If $\left(\frac{F_n}{F_{kl}}\right)_{MW} < \left(\frac{F_n}{F_{kl}}\right)_{LW}$ holds, marginal product of labor (F_n) rises relative to the marginal product of capital (F_{kl}) implying that

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14/ The implication of unaltered ratio of output elasticities to functional income distribution will be discussed in Chapter V.

technical change is labor-biased or labor-using, and therefore capital-saving. It implies that $B = \pi_n - \pi_{kl} > 0$

Converse results would follow if $\left(\frac{F_n}{F_{kl}}\right)_{MW} > \left(\frac{F_n}{F_{kl}}\right)_{LW}$

Technical change would be judged very capital-biased (very labor-saving) if the value of the F_n not only declined relative to F_{kl}, but also declined absolutely, i.e. $(F_n)_{MW} < (F_n)_{LW}$.

(2) Non-neutral variations in Cobb-Douglas function will be found in variations in the ratio of output elasticities as follows,

$$\left(\frac{\beta_n}{\beta_{kl}}\right)_{MW} \gtrless \left(\frac{\beta_n}{\beta_{kl}}\right)_{LW}$$

The direction of bias is indicated by the direction of change in the ratios of the elasticity coefficients of output.[15/] If β_{kl} rises relative to $\dot{\beta}_n$ a capital-using (labor saving) technical change has occurred, and vice versa.

2. Four Factor Case: We recall that the Cobb-Douglas production function (1) specified for our purpose is a four factor case-land (L), labor (N), fertilizer (F), and other capital services (K). We rewrite production function (1) below:

15/ Implications of change in the ratio of output elasticities to functional income distribution will be examined in Chapter V.

$$Y = A\,L^{\beta_l}\,N^{\beta_n}\,F^{\beta_f}\,K^{\beta_k} \qquad (1)$$

The same analysis applied to two-factor case could be extended to our four-factor case. But there are more possibilities for the outcome. An extension of two-factor Hicks definition of technical bias leads to n-1 measures of technical bias for each factor. Binswanger (1973, 1974b) uses the Hicksian classification scheme in a slightly amended version which leads to a definition of biases in terms of factor shares, i.e., share of a factor in total costs. Technical change is labor-saving, labor-neutral or labor-using according to whether the labor share in total cost decreases, stays constant, or increases at constant factor prices. This definition generalizes easily to the many-factor case and leads to a single measure of bias for each factor. The direction of factor i bias is measured as:

$$B_i = \frac{d\alpha_i^*}{dt}\,\frac{1}{\alpha_i} \gtreqless 0 \qquad \text{Hicks}\begin{cases} i\text{ - using} \\ i\text{ - neutral} \\ i\text{ - saving} \end{cases} \quad \ldots\ldots (8)$$

where α_i is the share of factor i in total costs, and the notation $d\alpha_i^*$ indicates that relative factor prices are held constant for this share change; B_i is a measure of proportionate rate of change in factor share; dt denotes time derivative.

Ferguson (1971) argues that technical change can also be classified on the basis of changes in the output elasticities.

We modify the measure used by Binswanger (1973, 1974 b) as follows:

$$B_i = \frac{d\beta_i^*}{dT} \quad \frac{1}{\beta_i} \gtreqless 0 \qquad \text{Hicks} \begin{cases} i \text{ - using} \\ i \text{ - neutral} \\ i \text{ - saving} \end{cases} \quad \ldots\ldots (9)$$

where β_i is the output elasticity of factor i, the notation $d\beta_i^*$ indicates that relative factor-ratios are held constant, and dT indicates change in production technology as represented by Mexican wheat production; B_i is a measure of proportionate rate of change in output elasticity of factor i. For example, a measure of technical bias for labor, in discrete form, may be stated as follows:

$$B_n = \frac{(\beta_n)_{MW} - (\beta_n)_{LW}}{(\beta_n)_{LW}} \gtreqless 0 \qquad \text{Hicks} \begin{cases} \text{labor-using} \\ \text{labor-neutral} \\ \text{labor-saving} \end{cases} \quad \ldots (10)$$

As stated earlier, the measure represented by expression (10) would provide one single measure of the bias for each factor.

Some Comments on the Estimation of Cobb-Douglas production function

The test performed by Sidhu (1972) supports the contention that the Cobb-Douglas function would fairly represent the data we are using. However, it is well to keep in mind some of the problems (some common to estimation of any form of production function) associated with estimating the Cobb-Douglas

function. We discuss these problems under four important headings:

(1) Least-squares bias.

(2) Multicollinearity

(3) Specification error

(4) Factor share effects[16/]

1. Least-Squares Bias:

One criticism of estimating any form of production function concerns the use of straightforward single equation least-squares regression equation. The variables which appear in the function are all endogeneous variables and hence they are subject to simultaneous determination. Observed data are the result of profit maximizing considerations of the firm and thus output and input levels are simultaneously determined. The production function is only one of a system of simultaneous equations and single equation estimates are in general biased and inconsistent.[17/]

Hoch (1958, pp. 568, 569) argued that if a disturbance in the production equation affects only the output and is not transmitted to the other variables in the system, then there is no simultaneous equation bias, and the single equation estimates

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16/ The implication placed on factor shares by the use of the Cobb-Douglas functional form are discussed in Chapter V.

17/ See Walters (1963) for details on this issue.

are consistent. Simultaneous equation bias arises when disturbance in the production relation affects the observed values of all variables, and, as a result, single equation estimates are not consistent. However, later Hoch (1962, p. 38) tended to accept the argument that, in the case of agriculture, the disturbance probably includes the effects of weather variability, and it can be argued that these effects do not affect independent variables. Further Mundlak and Hoch (1965, p. 817) advanced the view that in estimating parameters for the Cobb-Douglas production function, assuming competition and profit maximization, the estimator to be employed depends on the specification of the behavior of the disturbance term in the production function. If this disturbance is not transmitted to inputs, that is, inputs are independent of this disturbance, then the least-square estimator is consistent. This is the case in those situations where there is a time lag between the application of inputs and realization of output. Following the same line of reasoning Griliches (1963) argued that in agriculture, where the error term is largely a weather phenomenon and production takes a substantial amount of time, one may be able to assume that the correlation between the largely weather-affected error variable and the largely predetermined input variables is zero or very small. However this argument may be less tenable for harvest-associated inputs such as labor. In general, the simultaneous-equation bias will be small if the production function is well specified (has a small residual error).

We believe the production environment for the present study is not basically different from the specification requirements of the studies discussed above. The production function for our study is well specified, and we assume that there is no identification problem of high magnitude. We wind up the discussion on this issue by quoting Griliches (1963, p. 422). "It is important, however, to raise the problem of simultaneity, not so much because of the possibility of bias in the estimates of coefficients, but because of the possibility that no sensible estimates could be had by any technique."

2. Multicollinearity:

The second objection against the Cobb-Douglas function is that it suffers from inter-correlation among the different factors of production. Such multicollinearity is defined as the general problem which arises when some or all of the explanatory variables in a relation are highly correlated with one another. Then it becomes difficult to disentangle the separate influence of each independent variable and obtain a reasonably precise estimate of their relative effects. In cross-section samples we would expect large farms to employ more labor, more capital and larger amounts of other capital services, and small farms to use less labor, less fertilizer and less of other capital services. Klein (1962, p.101) suggests that inter-correlation or multicollinearity is not

necessarily a problem unless it is high relative to the over-all degree of multiple correlation among all variables simultaneously. Production functions with over-all correlations much in excess of 0.95 can be well-estimated with intercorrelations between labor and capital as high as 0.8 to 0.9.

3. Specification Errors:

Griliches (1957) has explored the impact of some common empirical "compromises" on the estimates of the Cobb-Douglas production function. In production function studies, some variables (management, for example) cannot be included in the analysis. Returns to scale are underestimated if the excluded input varies less than proportionately with the included inputs, and vice versa. The omission of managerial inputs from the production function biases the estimate of the elasticity of input with respect to capital inputs upwards and the estimate of return to scale downwards. If quality differences in our measure of land and labor are disregarded, it would lead to an upward bias in our estimate of the elasticity of output with respect to land and labor. We discussed some problems associated with the measurement of labor input, irrigation, and other physical assets in Chapter II. There is no way that we can determine how serious it is to disregard the quality aspects.

Empirical Models and Analysis of Results

So far we have formulated an economic model for the purpose of decomposing total changes in output. As a step toward the decomposition process, we develop empirical models to determine the nature and magnitude of technical change. Sidhu (1972) reports that technical change introduced into Punjab wheat economy is approximately neutral. In this regard, the present study differs from Sidhu's study in two respects.

First, we will investigate the nature of technical change with respect to all three samples outlined in Chapter II; whereas Sidhu's conclusion is based on Sample I.

Second, in arriving at his conclusion on the nature of technical change Sidhu used per farm results. We intend to arrive at our conclusion by testing results from per farm and per acre production function estimates. Performing tests with per acre estimates is designed to take out the scale effect.

Empirical models are formulated to answer the following questions. First, is there a structural break in production relations governed by new production technology compared to the production relations governed by old production technology? Second, if there is a structural break, is the structural break caused by a difference in intercept (A) of production functions, or difference in slope parameters (β's), or both? Third, are the slope coefficients for old production technology equal to

the slope coefficients for new production technology? Empirical Models I, II, and III are designed to answer the three questions.

1. Empirical Model I: Stability Test for Identifying Structural Break

This section is concerned with setting up an empirical model for investigating the question of whether the parameters of the production function governed by new production technology are different from the parameters generated by old production technology.[18/] The question is investigated with respect to all three samples. We set out our estimation equations for the purpose as follows:

$$\ln Y_1 = \ln A_1 + \beta_1 \ln L + \beta_2 \ln N + \beta_3 \ln F + \beta_4 \ln K + \mu_1 \quad (11)$$

$$\ln Y_2 = \ln A_2 + \phi_1 \ln L + \phi_2 \ln N + \phi_3 \ln F + \phi_4 \ln K + \mu_2 \quad (12)$$

$$\ln Y_p = \ln A_p + \gamma_1 \ln L + \gamma_2 \ln N + \gamma_3 \ln F + \gamma_4 \ln K + \mu_p \quad (13)$$

For Sample I, equation (11) is the ordinary least-squares regression linear in natural logarithms for production function (LW), equation (12) for production function (MW), and equation (13) is for the pooled data. For Sample II, equation (11) is the same, but equation (12) has two years of Mexican wheat data with a "year dummy" of value one for 1967/68 and zero for 1968/69; Equation (13) is the estimating equation for pooled data.

18/ See Chow (1960) and Fisher (1970) for details on this test.

In the case of Sample III, equation (11) is the same, but equation (12) has four years of Mexican wheat data with "year dummy variables" of value one for 1967/68 and zero for 1968/69, 1969/70 and 1970/71; equation (13) is the estimating equation for pooled data. Following is the null hypothesis for the purpose of this test.

$$Ho: A_1 = A_2,\ \beta_1 = \phi_1,\ \beta_2 = \phi_2,\ \beta_3 = \phi_3,\ \beta_4 = \phi_4$$

Results for the test are presented in Table III.1

Table III.1 Testing the Hypothesis on Structural Break in Production Relations, Per Farm Analysis

Sample (1)	Number of Observations (2)	Residual Sum of Squares (3)	Degrees of Freedom (4)	Calculated F (5)	Theoretical F $\alpha = 0.05$ (6)
I.					
1967/68 (LW)	131	14.3755	126		
1967/68 (MW)	105	15.8456	100	3.23	2.21
Pooled	236	32.3817	231		
II.					
1967/68 (LW)	131	14.3755	126		
1967/68 and 1968/69 (MW)	241	37.9892	235	5.44	2.10
Pooled	372	57.0970	367		
III.					
1967/68 (LW)	131	14.3755	126		
1967/68 and 1970/71 (MW)	655	78.2437	647	6.53	1.94
Pooled	786	98.8750	781		

As is evident in Table III.1, we reject the null hypothesis that the parameters of production functions governed by two production technologies are the same, since observed F-ratios exceed critical F-ratios at $\alpha = 0.05$ in the case of all three samples. So the two population structures are different in the case of three samples implying a structural break in production relations.

2. Empirical Model II: A Test for Identifying Causes of Structural Break

What we have shown in Table III.1 is that there was a structural break in production relations. But we don't know yet whether the structural break was caused either by shifts in intercept, or by shifts in slope parameters, or both. Empirical Model II has the objective of approaching this problem.

For Sample 1 following is the extimating equation:

$$\ln Y_p = \ln A + \beta_l \ln L + \beta_n \ln N + \beta_f \ln F + \beta_k \ln K + \gamma_i D_{1i} + \delta_i X_i D_{2i} + \varepsilon_i \qquad (14)$$

Equation (14) is the ordinary least square regression linear in natural logarithms for pooled data. D_{1i} is the "intercept dummy" of value one for Mexican wheat and zero for local wheat. D_{2i} is the "slope dummy variable" with a value of one for independent variables (X_i) - L, N, F, K - in the case of Mexican wheat and zero for independent variables in local wheat.

Following is the estimating equation for Sample II:

$$\ln Y_p = \ln A + \beta_l \ln L + \beta_n \ln N + \beta_f \ln F + \beta_k \ln K + \gamma_i D_{1i} + \delta_i X_i D_{2i} + \alpha_i D_{3i} + \varepsilon_i \quad (15)$$

Equation (15) is the ordinary least-square regression linear in natural logarithms for pooled data. D_{1i} is the "intercept dummy" of value one for Mexican wheat and zero for local wheat. D_{2i} is the "slope dummy variable" with a value of one for independent variables (X_i) - L, N, F, K - for Mexican wheat and zero for independent variables in local wheat. D_{3i} is the "year dummy variable" with a value of one for 1968/69(MW) and zero for 1967/69(MW). There are two important observations to be made on this estimating equation set up for Sample II. First, the estimates for Mexican wheat are average estimates for the years 1967/68 and 1968/69. Second, the way in which we have introduced "year dummy variable" assumes that the difference between 1967/68 (MW) and 1968/69 (MW) is only in the intercept, with slope parameters remaining the same.

For Sample III, the estimating equation is essentially the same as equation (15). But, the estimates for Mexican wheat are averages for 1967/68, 1968/69, 1969/70, and 1970/71; D_{3i} is the "year dummy variable" with a value of one for 1968/69 (MW), 1969/70 (MW) and 1970/71 (MW), and a value of zero for 1967/68 (MW) and the "year dummy variable" assumes that the difference between 1967/68 (MW) and 1968/69 (MW), 1969/70 (MW) and 1970/71 (MW) arise only in intercept, with slope parameters remaining the same. Results of estimates for all three samples are presented in Tables III.2, III.3 and III.4.

It is shown in Table III.2 that for Sample I, "intercept dummy variable" and "slope dummy variable" for Capital (K) seem to indicate that the structural break is caused basically by shifts in intercept (A) and the output elasticity of capital (β_k). The "intercept dummy variable" is significant at $\alpha = 0.15$, and the "slope dummy variable" for capital (K) is significant at $\alpha = 0.05$.

Table III.2 Identification of Causes for Structural Break, Per Farm Analysis, Sample I.

Variables 1/	OLS Coefficients	Stan. Error	Computed T
A (Constant)	0.533	0.529	1.009
L	0.646	0.088	7.110
N	0.209	0.088	2.385
F	0.092	0.018	5.098
K	0.060	0.102	0.586
DVA 2/	-0.834	0.732	-1.139
DVL 3/	-0.092	0.122	-0.757
DVN 3/	-0.115	0.122	-0.939
DVF 3/	-0.026	0.051	0.509
DVK 3/	0.262	0.145	1.814

$\bar{R}^2 = 0.92$

1/ Dependent variable is the output of wheat in physical units

2/ DVA is the "intercept dummy variable" with a value of one for Mexican wheat and zero for local wheat.

3/ DVL, DVN, DVF and DVK are "slope dummy variables" for Land (L), Labor (N), Fertilizer (F), and Capital (K) with a value of one for Mexican wheat and zero for local wheat.

Table III.3 Identification of Causes for Structural Break, Per Farm Analysis, Sample II.

Variables 1/	OLS Coefficients	Stan. Error	Computed T
A (Constant)	0.533	0.550	0.969
L	0.624	0.091	6.826
N	0.209	0.091	2.290
F	0.092	0.019	4.895
K	0.060	0.106	0.561
DVA 2/	-0.460	0.692	-0.665
DVL 3/	-0.052	0.116	-0.453
DVN 3/	-0.080	0.117	-0.689
DVF 3/	0.012	0.032	0.362
DVK 3/	0.175	0.133	1.317
DY 68-69 4/	-0.298	0.055	-5.440

$\bar{R}^2$ = 0.91

1/ Dependent variable is the output of wheat in physical units

2/ DVA is the "intercept dummy variable" with a value of one for 1967/68 (MW) and 1968/69 (MW), and zero for local wheat

3/ DVL, DVN, DVF and DVK are "slope dummy variables" for Land (L), Labor (N), Fertilizer (F), and Capital (K), with a value of one for 1967/68 (MW) and 1968/69 (MW), and zero for local wheat.

4/ DY is the "year dummy variable" with a value of one for 1968/69 (MW) and zero for 1967/68 (MW).

Table III.4 Identification of Causes for Structural Break, Per Farm Analysis, Sample III.

Variables 1/	OLS Coefficients	Stan. Error	Computed T
A (Constant)	0.533	0.529	1.066
L	0.624	0.088	7.511
N	0.209	0.088	2.519
F	0.092	0.018	5.386
K	0.060	0.102	0.617
DVA 2/	-0.132	0.560	-0.235
DVL 3/	0.005	0.093	0.057
DVN 3/	-0.014	0.092	-0.146
DVF 3/	-0.025	0.022	-1.134
DVK 3/	0.078	0.104	0.750
DY 4/ 68-69	-0.302	0.048	-6.337
DY 4/ 69-70	-0.287	0.044	-6.503
DY 4/ 70-71	-0.175	0.048	-3.636

$\bar{R}^2 = 0.91$

1/ Dependent variable is the output of wheat in physical units.

2/ DVA is the "intercept dummy variable" with a value of one for 1967/68 (MW), 1968/69 (MW), 1969/70 (MW) and 1970/71 (MW), and zero for Local Wheat.

3/ DVL, DVN, DVF and DVK are "slope dummy variables" for Land (L), Labor (N), Fertilizer (F), and Capital (K) with a value of one for 1967/68 (MW), 1968/69 (MW), 1969/70 (MW), 1970/71 (MW), and zero for local wheat.

4/ DY is the "year dummy variable" with a value of one for 1968/69 (MW), 1969/70 (MW), 1970/71 (MW), and zero for 1967/68 (MW).

concerning the identification of causes for structural break in production relations in Sample II, two results from Table III.3 may be cited as important. First, "intercept dummy variable" and "slope dummy variables" for Land (L), Labor (N), and Fertilizer (F), are not significar at any reasonable level of significance. The "slope dummy variable" for Capital (K) is significant at $\alpha = 0.01$. This seems to imply that capital variable (K) has played a significant role in causing the structural break. Second the "year dummy variable" is significant at $\alpha = 0.005$, but has a negative value implying a downward parallel shift in productior function for Mexican wheat. We will examine some details on this later in this chapter.

When we examine results on identification of causes for structural break in production relations in the case of Sample III, as given in Table III.4, we recall from Chapter II that the population is no longer homogeneous in terms of both geographical and temporal aspects. So results on sample III need to be examined in this perspective. Two results from Table III.4 seem to be important. First, neither the "intercept dummy variable" nor the "slope dummy variables" for Land (L), Labor (N), and Capital (K) are significant at any reasonable level. The "slope dummy variable" for fertilizer (F) is

significant at $\alpha = 0.15$.[19/] So we cannot pinpoint any independent variable as the cause of the structural break in production relations. Second, "year dummy variables" are all significant at $\alpha = 0.005$, but each has a negative value, implying a downward parallel shift in production function for Mexican wheat. Some details on this will be discussed in a subsequent section in this chapter.

3. Empirical Model III: Testing Equality of Slope Coefficients in Production Functions.

Empirical Model I provided for all three samples, the finding of a structural break in production relations. The results from Empirical Model II suggest that the scale parameter (A) and the slope parameter for capital (K) were significant factors in the structural break in Sample I; in Sample II, capital (K) was a relatively significant element in the structural break; in the case of Sample III, no single independent variable can be pointed out as an important factor in the structural break. Empirical Model III is designed to answer our third question, are the slope coefficients for the production function generated by new production technology the same as for the production

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19/ But the negative value for fertilizer "slope dummy variable" is not believable, because it implies that output elasticity with respect to fertilizer is lower under Mexican wheat than under local wheat. We recall that output elasticity for Mexican wheat is an average estimate of four years data. We don't have clear evidence on whether the adverse weather conditions, as reported by Sidhu (1972), during the years 1968/69 - 1970/71 would account for this result.

function generated by old production technology? Our estimating equation for Sample I may be stated as follows:

$$\ln Y_1 = \ln A_1 + \beta_1 \ln L + \beta_2 \ln N + \beta_3 \ln F + \beta_4 \ln K + \mu_1 \quad (16)$$

$$\ln Y_2 = \ln A_2 + \phi_1 \ln L + \phi_2 \ln N + \phi_3 \ln F + \phi_4 \ln K + \mu_2 \quad (17)$$

$$\ln Y_p = \ln A_p + \gamma_1 \ln L + \gamma_2 \ln N + \gamma_3 \ln F + \gamma_4 \ln K + \gamma_5 Di + \mu_p \quad (18)$$

For Sample I, equation (16) is the ordinary least squares regression linear in natural logarithms for the local wheat production function, equation (17) for the Mexican wheat production function, and equation (18) is based on the pooled data with a "variety dummy variable" (Di), of value one for Mexican wheat and zero for local wheat.

For Sample II, the following are our estimating equations:

$$\ln Y_1 = \ln A_1 + \beta_1 \ln L + \beta_2 \ln N + \beta_3 \ln F + \beta_4 \ln K + \mu_1 \quad (19)$$

$$\ln Y_2 = \ln A_1 + \phi_1 \ln L + \phi_2 \ln N + \phi_3 \ln F + \phi_4 \ln K + \phi_5 D_i + \mu_2 \quad (20)$$

$$\ln Y_p = \ln A_p + \gamma_1 \ln L + \gamma_2 \ln N + \gamma_3 \ln F + \gamma_4 \ln K + \gamma_5 D_{1i} + \gamma_6 D_{2i} + \mu_p \quad (21)$$

Equation (19) is the same as in Sample I; Equation (20) is for estimating production function for Mexican wheat with a "year dummy variable" (D_i) of value one for 1968/69 Mexican wheat and zero for 1967/68 Mexican wheat. Equation (21) is for pooled data with a "variety dummy variable" (D_{1i}) of value

one for 1967/68 and 1968/69 Mexican wheat and zero for 1967/68 local wheat, and a "year dummy variable" (D_{2i})of value one for 1968/69 Mexican wheat and zero for 1967/68 Mexican wheat.

Following are the estimating equations for Sample III:

$$\ln Y_1 = \ln A_1 + \beta_1 \ln L + \beta_2 \ln N + \beta_3 \ln F + \beta_4 \ln K + \mu_1 \quad (22)$$

$$\ln Y_2 = \ln A_1 + \phi_1 \ln L + \phi_2 \ln N + \phi_3 \ln F + \phi_4 \ln K + \phi_5 D_{1i} + \phi_6 D_{2i} + \phi_7 D_{3i} + \mu_2 \quad (23)$$

$$\ln Y_p = \ln A_p + \gamma_1 \ln L + \gamma_2 \ln N + \gamma_3 \ln F + \gamma_4 \ln K + \gamma_5 D_{1i} + \gamma_6 D_{2i} + \gamma_7 D_{3i} + \gamma_8 D_{4i} + \mu_p \quad (24)$$

Equation (22) is the same as in Samples I and II; Equation (23) is for estimating production function for Mexican wheat with "year dummy variables" (D_{1i}, D_{2i}, D_{3i}) of value one for 1968/69 Mexican wheat, 1969/70 Mexican wheat and 1970/71 Mexican wheat respectively, and zero for 1967/68 Mexican wheat; Equation (24) is for pooled data with a "variety dummy variable" (D_{1i}) of value one for Mexican wheat and zero for local wheat, and "year dummy variables" (D_{2i}, D_{3i}, D_{4i}) of value one for 1968/69 Mexican wheat, 1969/70 Mexican wheat and 1970/71 Mexican wheat, and zero for 1967/68 Mexican wheat.

Results of testing the equality of slope coefficients for all three samples are presented in Table III.5. For Sample I a per farm analysis of covariance gave an F-ratio of 1.36 with 4 and 226 degrees of freedom; this observed F-ratio of 1.36 is less than critical F-ratio of 2.37 at $\alpha = 0.05$. For

Sample II, the observed F-ratio of 0.72 with 4 and 361 degrees of freedom is less than critical F-ratio of 2.37 at $\alpha = 0.05$. In the case of Sample III, the observed F-ratio of 0.57 with 4 and 773 degrees of freedom is again less than critical F-ratio of 2.37 at $\alpha = 0.05$. Sidhu (1972, 1974a), using analysis of covariance test on Sample I, reported that technical change for Mexican wheat production was approximately neutral. Our result agrees with this conclusion. Extension of the test to Sample II and Sample III also supports the conclusion that technical change is neutral. However, we recall the population compositions for Samples II and III are different from Sample I. The conclusion that follows from these tests is that output elasticities for the different inputs are the same in separate regressions for local wheat and Mexican wheat, if we allow the intercept terms (As) in two regressions to differ.

Analysis of covariance for investigating the equality of slope coefficients is also extended to per acre estimates (Table III.6), taking out the scale effect. From Table III.6, computed F-ratios are less than critical F-ratios in the case of all three samples, implying that we cannot reject the hypothesis of equality of respective slope coefficients for new-technology production functions and old-technology production functions. So this result also supports the conclusion that technical change is approximately neutral.

Table III.5 Testing the Hypothesis on Equality of Slope Coefficients in Production Functions, Per Farm Analysis.

Sample (1)	Number of Observations (2)	Residual Sum of Squares (3)	Degrees of Freedom (4)	Calculated F (5)	Theoretical F 0.05 (6)
I.					
1967/68 (LW)	131	14.3755	126		
1967/68 (MW)	105	15.8456	100	1.36	2.37
Pooled	236	30.9496	230		
II.					
1967/68 (LW)	131	14.3755	126		
1967/68 - 1968/69 (MW)	241	37.9892	235	0.72	2.37
Pooled	372	52.7847	365		
III.					
1967/68 (LW)	131	14.3755	126		
1967/68 - 1970/71 (MW)	655	78.2437	647	0.57	2.37
Pooled	786	92.8940	777		

Table III.6 Testing the Hypothesis on Equality of Slope Coefficients in Production Functions, Per Acre Analysis

Sample (1)	Number of Observations (2)	Residual Sum of Squares (3)	Degrees of Freedom (4)	Calculated F (5)	Theoretical F 0.05 (6)
I.					
1967/68 (LW)	131	14.3940	127		
1967/68 (MW)	105	16.7235	101	0.80	2.37
Pooled	236	31.4467	231		
II.					
1967/68 (LW)	131	14.3940	127		
1967/68 1968/69 (MW)	241	38.4976	236	0.53	2.37
Pooled	372	53.1252	366		
III.					
1967/68 (LW)	131	14.3940	127		
1967/68 - 1970/71 (MW)	655	78.7575	648	0.43	2.37
Pooled	786	93.3068	778		

Summary of Results on the Nature of Technical Change

In broad terms, the results of the empirical analysis of the nature of technical change may be summarized as follows: First, a structural break in production relations with the introduction of new production technology was established for all three samples. Second, as for the causes for the structural break, the conclusion is mixed. In Sample I, the shift in the coefficient of the capital variable (K) and the shift in intercept (A) seem to have contributed more. A shift in the coefficient of the capital variable (K) seems to have played a role in the structural break in Sample II. For Sample III, no single independent variable can be identified as a significant factor in the structural break.[20/] Third, results from analysis of covariance--both per farm and per acre results--suggest the conclusion that technical change is approximately neutral.

In addition to these statistical results which suggest that technical change is approximately neutral, let us use the concept of technical bias defined in terms of proportionate change in the output elasticities. We generalize expression (10) as follows:

20/ Since data from Sample III are not homogeneous in terms of geographic region and years, analysis of decomposition of output change, employment change, and the evaluation of functional income distribution effects will be undertaken with the results from Samples I and II.

$$B_i = \frac{(\beta_i)_{MW} - (\beta_i)_{LW}}{(\beta_i)_{LW}} \gtreqless 0 \quad \text{Hicks} \begin{cases} i \text{ - using} \\ i \text{ - neutral} \\ i \text{ - saving} \end{cases} \tag{25}$$

where β_i is a measure of technical bias for factor i in terms of proportionate change in elasticity of output of factor i. Results on the nature of bias in the case of both per farm analysis and per acre analysis are shown in Table III.7 and Table III.8 respectively.

We draw three important results from Table III.7 and III.8 for interpretation. First, in Sample I, which is more homogeneous in terms of geographic area and year technical change introduced into the Punjab wheat farming sector is fertilizer-using and capital-using, and land and labor-saving. This conclusion is supported by results in Table III.2 as well. However, since the "slope dummy variables" for land, fertilizer, and labor are not statistically significant, bias in technical change is Hicks-neutral. This is to say that slope coefficients for land, labor and fertilizer for old and new production technology are almost the same as shown in Table III.2. However, "slope dummy variable" for Capital (K) is significant at $\alpha = 0.05$. This tends to support the conclusion that technical change is capital-using.

Second, in Sample II, which is less homogeneous in terms of years, the nature of bias is the same as in Sample I. Bias in technical change is Hicks-neutral with respect to land, labor and fertilizer as supported by results from Table III.3.

Table III.7 Nature of Technical Bias, Per Farm Analysis

Sample	Factor of Production	$B_i = \frac{(\beta_i)_{MW} - (\beta_i)_{LW}}{(\beta_i)_{LW}}$	Nature of Bias
(1)	(2)	(3)	(4)
Sample I:			
	Land	-0.148	L-saving
1967/68 (LW)	Labor	-0.550	N-saving
versus	Fertilizer	+0.283	F-using
1967/68 (MW)	Capital	+4.367	K-using
Sample II:			
	Land	-0.083	L-saving
1967/68 (LW)	Labor	-0.383	N-saving
versus	Fertilizer	+0.130	F-using
1967/68-1968/69 (MW)	Capital	+2.900	K-using

Note: parametric values for computing Column (3) are drawn from Table III.9.

Table III.8 Nature of Technical Bias, per Acre Analysis

Sample	Factor of Production	$B_i = \frac{(\beta_i)_{MW} - (\beta_i)_{LW}}{(\beta_i)_{LW}}$	Nature of Bias
(1)	(2)	(3)	(4)
Sample I:			
	Land	-0.093	L-saving
1967/68 (LW)	Labor	-0.699	N-saving
versus	Fertilizer	+0.011	F-using
1967/68 (MW)			
	Capital	+3.104	K-using
Sample II:			
	Land	-0.062	L-saving
1967/68 (LW)	Labor	-0.523	N-saving
versus	Fertilizer	+0.154	F-using
1967/68-1968/69			
(MW)	Capital	+2.060	K-using

Note: parametric values for computing column (3) are drawn from Table III.10.

But bias in technical change is capital-using, and it is significant at $\alpha = 0.01$.

So it may be possible to conclude that technical change in the Punjab wheat farming sector is approximately neutral, but some degree of non-neutrality is evident in Samples I and II. In our study, we may not want to proceed with the unquestioned assumption that technical change is neutral. We may prefer to incorporate the effects of difference in intercepts and slope parameters into our decomposition process. When we decompose total change in output and employment, the effect of shift in intercept will be reflected in constant term (A), and the effects of non-neutral technical change will show up as differences in slope parameters.

Analysis of Results on Decomposition of Total Change in Output

Following our preceding discussion, we decided to incorporate the appropriate effects of shifts in intercept (neutral technical change) and shifts in slope parameters (non-neutral technical change) into our decomposition process. Since production function estimates are needed in addition to input levels, results of production function estimates - per farm and per acre are shown in Tables III.9 and III.10 respectively. These estimates seem reasonable in the sense that the output elasticity for each input has the postulated sign and a low standard error.

In broad terms the following results were obtained from Tables III.9 and III.10.

First, in Samples I and II, per farm as well as per acre results indicate the increasing relative importance of fertilizer and other capital services in increasing output under new production technology compared to old production technology, whereas labor that was significant under old production technology seems to have lost in relative importance under new production technology. One of the basic components of new production technology is found to be the higher level of output per unit of fertilizer than under old production technology. This follows from the fact that the new wheat varieties respond to heavier fertilizer applications without lodging and thus have a higher "yield ceiling" than the local wheat. Local wheat is said to have long tender straw and to be susceptible to lodging under heavy fertilizer applications. This characteristic works as a limiting factor beyond a low "yield ceiling" and constitutes a major barrier to increased wheat production.

The fact that the purchased inputs like fertilizer and other capital services have become more important in generating output has a major implication for the growth promoting interaction between agriculture and industry that has been a major characteristic of economic growth in developed countries.[21/] An increase in agricultural productivity

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21/ A more detailed examination of this issue can be found in Johnston and Nielsen (1966) and Johnston (1970)

Table III.9 Per Farm Production Function Estimates

Sample	Variables 1/	Elasticity of Output	Standard Error	Returns to Scale	$\bar{R}^2$
I. 1967/68 (LW) 2/	A (Constant)	1.704	0.488		
	L	0.623	0.081		
	N	0.209	0.081	0.983	0.85
	F	0.092	0.017		
	K	0.060	0.094		
II. 1967/68 (MW) 3/	A (Constant)	0.741	0.551		
	L	0.531	0.092		
	N	0.096	0.093		
	F	0.118	0.052	1.065	0.94
	K	0.322	0.112		
III. 1967/68-1968/69 4/ (MW)	A (Constant)	1.070	0.442		
	L	0.571	0.075		
	N	0.129	0.077		
	F	0.104	0.027	1.038	0.92
	K	0.234	0.084		
	$DY_{68\ 69}$	-0.298	0.058		

1/ Regressions linear in natural logarithms are estimated by least-squares. Dependent variable is output of wheat in physical units.

2/ For 1967/68, local wheat, t-values for all independent variables except capital are significant at $\alpha = 0.005$. In the case of capital, t-value is not significant at any normally accepted level.

3/ For 1967/68 Mexican wheat, t-values for all independent variables except labor are significant at $\alpha = 0.005$; for labor t-value is approximately significant at $\alpha = 0.15$.

4/ Estimates for 1967/68 Mexican wheat and 1968/69 Mexican wheat are averages for two years. For all independent variables except labor, t-values are significant at $\alpha = 0.005$; for labor t-value is significant at $\alpha = 0.05$; "year dummy variable" is significant at $\alpha = 0.005$, but negative.

Table III.10 Per Acre Production Function Estimates.

Sample	Variables	Elasticity of Output 1/	$\bar{R}^2$ 5/
1967/68 (LW) 2/	A (Constant)	1.530	
	L	0.626	
	N/L	0.216	0.27
	F/L	0.091	
	K/L	0.067	
1967/68 (MW) 3/	A (Constant)	1.320	
	L	0.568	
	N/L	0.065	0.16
	F/L	0.092	
	K/L	0.275	
1967/68-1968/69 4/ (MW)	A (Constant)	1.490	
	L	0.587	
	N/L	0.103	0.24
	F/L	0.105	
	K/L	0.205	
	DY 68 69	-0.259	

1/ Regressions linear in natural logarithms are estimated by least-squares, restricting estimates to constant returns to scale. Elasticity of output for land is obtained by the homogeneity (of degree one) constraint as follows:

$$Y/L = \left(\frac{N}{L}\right)^{\beta_n} \left(\frac{F}{L}\right)^{\beta_f} \left(\frac{K}{L}\right)^{\beta_k}$$

so $Y = AL^{1-\beta_n-\beta_f-\beta_k} N^{\beta_n} F^{\beta_f} K^{\beta_k}$

Output elasticity for land is: $\beta_l = 1-\beta_n-\beta_f-\beta_k$

2/ For 1967/68 local wheat, t-values for labor and fertilizer are significant at $\alpha = 0.005$, but for capital it is not significant at any reasonable value.

3/ For 1967/68, Mexican wheat, t-value for fertilizer is significant at about $\alpha = 0.005$, for capital at $\alpha = 0.01$. For labor, t-value is not significant at any reasonable level.

4/ For 1967/68-1968/69, Mexican wheat, t-values for fertilizer and capital are significant at $\alpha = 0.005$, for labor at $\alpha = 0.10$. "Year dummy" variable is significant at $\alpha = 0.005$ but negative

5/ Low $\bar{R}^2$ follows from the overwhelming importance of land as a generator of output in relation to other inputs, and elimination of land as an explanatory variable from the estimating equation.

and growth in demand for purchased inputs supplied by industry are forces that provide impetus for general economic growth. In one of the studies of this type of interaction between agricultural and industrial development, Falcon (1967) noted that rapid expansion of private tube wells in west Pakistan gave a strong stimulus to the growth of local machine shops.

Second, the "year dummy variable" in Sample II is negative. The negative value implies a decline in the efficiency parameter of Mexican wheat production function in 1968/69 compared to that of 1967/68. The way in which we set up the "year dummy variable" also implies that a decline in the efficiency parameter does not involve the slope parameters.[22/]

22/ Sidhu (1972) found negative values for "year dummy variables" for the years 1968/69, 1969/70, and 1970/71. He argued that this downward shift in the efficiency parameter could have happened after 1967/68, due to adverse weather conditions in those years compared to 1967/68, defective seed quality, addition of marginal land to Mexican wheat production, and possible technological regression in the production of Mexican wheat. However, it does not seem to be possible to assess the relative importance of these possible factors in the downward shift in the efficiency parameter.

Decomposition Analysis

Using the production function estimates in Table III.10, we undertake to decompose the difference in per acre output into neutral technical change [that is, shift in parameter A' of production function (2)], non-neutral technical change [that is, shift in parameters β',s of production function (2)], and change in levels of labor, fertilizer and capital services used. We rewrite our basic decomposition equation (4) as follows:

$$\frac{\Delta Y^1}{Y^1} = \left[\frac{\Delta A^1}{A^I}\right] + \left[\ln N^1 \, \Delta\beta_n^1 + \ln F^1 \, \Delta\beta_f^1 + \ln K^1 \, \Delta\beta_k^1\right]$$
$$+ \left[\beta_n^1 \frac{\Delta N^1}{N^I} + \beta_f^1 \frac{\Delta F^1}{F^I} + \beta_k^1 \frac{\Delta K^1}{K^I}\right] \qquad (4)$$

Decomposition analysis with equation (4) did not yield satisfactory results in the sense that the estimated change was substantially different from the actual change. We propose an alternative decomposition formula which includes all the basics needed for decomposing total change in output into constituent forces.

Per acre Cobb-Douglas production function (2) for local wheat with error term is:

$$\ln Y_1 = \ln A_1 + \beta_n \ln N_1 + \beta_f \ln F_1 + \beta_k \ln K_1 + U_1 \qquad (26)$$

Per acre Cobb-Douglas production function (2) for Mexican wheat is:

$$\ln Y_2 = \ln A_2 + \gamma_n \ln N_2 + \gamma_f \ln F_2 + \gamma_k \ln K_2 + U_2 \qquad (27)$$

Taking differences between (27) and (26), and adding some terms and subtracting the same terms:

$$\ln Y_2 - \ln Y_1 = (\ln A_2 - \ln A_1) + (\gamma_n \ln N_2 - \beta_n \ln N_1 + \gamma_n \ln N_1 - \gamma_n \ln N_1) + (\gamma_f \ln F_2 - \beta_f \ln F_1 + \gamma_f \ln F_1 - \gamma_f \ln F_1) + (\gamma_k \ln K_2 - \beta_k \ln K_1 + \gamma_k \ln K_1 - \gamma_k \ln K_1) + (U_2 - U_1) \qquad (28)$$

Rearranging terms in (28)

$$\ln Y_2 - \ln Y_1 = [\ln A_2 - \ln A_1] + [(\gamma_n - \beta_n) \ln N_1 + (\gamma_f - \beta_f) \ln F_1 + (\gamma_k - \beta_k) \ln K_1] + [\gamma_n (\ln N_2 - \ln N_1) + \gamma_f (\ln F_2 - \ln F_1) + \gamma_k(\ln K_2 - \ln K_1)] + [U_2 - U_1] \qquad (29)$$

Equation (29) can also be written as:

$$\ln\left[\frac{Y_2}{Y_1}\right] = \ln\left[\frac{A_2}{A_1}\right] + \left[(\gamma_n - \beta_n) \ln N_1 + (\gamma_f - \beta_f) \ln F_1 + (\gamma_k - \beta_k) \ln K_1\right] + \left[\gamma_n \ln(\frac{N_2}{N_1}) + \gamma_f \ln(\frac{F_2}{F_1}) + \gamma_k \ln(\frac{K_2}{K_1})\right] + \left[U_2 - U_1\right] \qquad (30)$$

Equation (30) permits us to decompose the total difference in output into the constituent forces in which we are interested. This decomposition equation involves decomposing the natural logarithm of the ratio of "new" output to "old". It is approximately a measure of percentage change

in output with the introduction of new technology.[24/] The first bracketed expression on the right hand side, natural logarithm of the ratio of constant terms, is a measure of percentage change in output due to neutral technical change, that is, change due to a shift in term (ln A); the second bracketed expression, the sum of the arithmetic changes in output elasticities each weighted by the logarithm of the volume of that input used, is a measure of change in output due to non-neutral technical change, that is, shifts in slope parameters of the production function; the third bracketed expression is the sum of the logarithms of the ratio, for each input, of "new" to "old" input, each weighted by the output elasticity of that input; this expression is a measure of change in output due to changes in labor, fertilizer and capital used given the output elasticities of these inputs under new production technology. Obviously, the fourth bracketed expression is a measure of differences in error terms. Results of the decomposition analysis with equation (30) are shown in Table III.11.

The following observations on sources of growth in output per acre in the Punjab wheat Economy may be made on

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24/ $\ln\left[\frac{Y_2}{Y_1}\right] = \ln(1 + X) \approx X \qquad \text{for } |X| < 1$

where X is a percentage change in output; it is <u>approximately</u> a percentage change because the higher order terms in a Taylor Expansion are discarded.

the results shown in Table III.11

Table III.11: Decomposition Analysis of Total Difference in per Acre Output between New and Old Production Technology

Item	Percentage attributable	
	Sample I	Sample II
(1)	(2)	(3)
Total difference in output[1/]	40.2	22.3
Sources of Change:		
1. Neutral technical change[2/]	-15.1	-2.6
2. Non-neutral technical change[2/]	30.0	16.8
3. Change in inputs:[1/]		
a) Labor	2.1	2.9
b) Fetilizer	15.1	15.7
c) Capital	8.3	5.7
Total: due to input change	25.5	24.3
Total Change: due to all sources	40	38.3

Notes: 1. Sample geometric mean levels of output and inputs per acre are shown for Samples I and II in Appendix I, Table I.A.

2. Parametric values for computation are drawn from Table III.10

First, regarding Sample I which is homogeneous in terms of both the geographic region and the year, per acre production on a Mexican wheat farm was about 40 percent higher than on a local wheat farm. What are the sources of this increased productivity of land? How much of this increased output is due to neutral technical change (in the sense of shift in parameter A of production function (1)), how much of it to non-neutral technical change (in the sense of shift in slope parameters of production function (1)), and how much of it is due to change in input levels? Contribution of the shift in parameter A, that is neutral technical change, is shown as negative. This implies that yield is lower for new seed varieties when low levels of purchased inputs are applied and is only above the old varieties when these inputs have reached a high enough level. To quote Zarembka (1972, pp. 165, 166) on this issue, "... the technical characteristics of new seeds, particularly the most high yielding one, are often that their yields are higher than traditional yields only when accompanied by higher utilization of other variable inputs." This perhaps provides an explanation of why the intercept for Mexican wheat production function is lower (Tables III.9 and III.10) than for local wheat, giving rise to negative contribution of neutral technical change. We think that this perhaps needs more empirical verification with data from experimental plots of research stations.

This contribution of non-neutral technical change to increased output is shown as 30 percent. If we add both neutral and non-neutral components, we get approximately a measure of contribution of technology to output growth. That contribution turns out to be about 15 percent. This implies that with the same level of per acre input of labor, fertilizer and capital used on a local wheat farm, 15 percent more output could be obtained per acre on a Mexican wheat farm. Here is a new growth source whose presence has characterised the growth process of developed economies, but its absence in less developed countries has been partly responsible for low growth rates.

As shown in Table III.11, increased use of labor, fertilizer and capital per acre under new production technology has contributed about 25.5 percent of the increased growth in output. The contribution of fertilizer (15 percent) is the highest, the contribution of capital being about 8 percent and of labor being about 2 percent. The major contribution of fertilizer is consistent with the idea that the "Green Revolution" is basically a "Seed-Fertilizer Revolution," based on biochemical technology.

Second, regarding Sample II, which is less homogeneous in terms of production years, per acre production on a Mexican wheat farm was about 22 percent higher than on a local wheat farm. As against this observed 22 percent difference in output,

the expected (that is, by adding the sources of growth in output) growth in output was about 38 percent. If we examine Appendix Table I.A, the geometric mean per acre levels of labor, fertilizer and capital were almost the same for 1967/68 - 1968/69 (MW) as 1967/68 (MW), whereas there was a considerable difference in output.[25/] As we stated earlier in footnote 22, adverse weather conditions in 1968/69 would perhaps account for some of the difference in per acre output and thereby the actual deviation from the estimate. This seems to be the case because the percentage contribution made by technical change was about 14 percent, and the contribution made by change in inputs was about 23 percent in the case of Sample II. This is in close agreement with the result from Sample I. So perhaps the main reason why the actual (22 percent) deviated from the estimated (38 percent) was adverse weather conditions.

25/ It is shown in Appendix Table I.A that the geometric mean level of output per acre was 12.32 quintals for the year 1967/68 (MW), whereas it was 10.30 quintals for the year 1967/68 - 1968/69 (MW).

SUMMARY

From the statistical analyses of Samples I and II, which will be used in the subsequent analyses of this study, the following substantive conclusions seem to follow:

(1) The stability test (Table III.1) suggests that the parameters of the production function generated by the new production technology are different from those generated by the old production technology. This implies a structural change in wheat production relations;

(2) The tests (Tables III.2 and III.3) on the causes of structural break seem to indicate that the capital variable is mainly responsible for the structural change, because the "slope dummy variable" for capital is statistically significant at a reasonable level of α;

(3) The analysis of covariance (Table III.5) indicates that the slope coefficients for two production functions are the same; output elasticities with respect to various inputs are the same in separate regressions for local wheat and Mexican wheat, if we allow the intercept term (A) in the two regressions to differ.

However, an analysis of technical bias in terms of the proportionate change in the output elasticities (Tables III.7 and III.8) suggests that the new technology is land and labor saving, and fertilizer and capital using. But as shown in Tables III.2 and III.3, "slope dummy variables" for the output

elasticities of land, labor and fertilizer are not statistically significant. So we attach less importance to this conclusion on technical bias with respect to these three inputs. That the new technology is capital-using seems to be supported by the significant "slope dummy variable" for the output elasticity of capital.

On the nature of technical change introduced into the Punjab wheat economy, the preceding analysis seems to suggest that, in broad terms, it is approximately neutral. However, as we suggested earlier that we may not proceed with the unquestioned assumption that technical change is neutral. We would prefer to incorporate the effects of shifts in intercept (A) and slope coefficients (β_is) of production function (1) into decomposition analysis of total change in output and employment.

(4) Our decomposition analysis (Table III.11) with Sample I suggests that of the 40 percent increase in per acre output, technical change-neutral and non-neutral - contributed about 15 percent, and increased use of complementary inputs - fertilizer (15 percent), capital (8 percent) and labor (2 percent) contributed about 25 percent.

In the case of Sample II, there does not seem to be any substantial change in the sources of output growth; but adverse weather conditions in 1968/69 seem to have caused the estimated (38 percent) change in output to deviate from the actual (22 percent).

CHAPTER IV

EMPLOYMENT ELASTICITIES, AND DECOMPOSING TOTAL CHANGE IN EMPLOYMENT

Ever since the Committee on Distribution of Income and Levels of Living, set up by the Government of India, reported (1964, 1969) on the glaring inequalities of income and consumption, much empirical evidence has been accumulated on the distribution of income and consumption, and on the percentage of the people below the "poverty line."[1/] The percentage of people below the poverty line has increased over a period of time not only in India as a whole, but also in Punjab, a state where substantial economic growth has been recorded.[2/] There is no easy answer to the question of what is to be done to alleviate poverty. Johnson (1973) examines two important sources of poverty; first, there is an excessive number of people dependent on the earning capacity of the family unit for their sustenance; second, there is an inadequate income to support the normal-sized family. This inadequate income may be due to inadequate employment opportunities, and/or inadequacy of the factors of production the family can supply to command a non-poverty level of income. Johnson also argues that poverty will not cure

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1/ For details on these issues see Bardhan and Srinivasan (1971), Dandekar and Rath (1971a, 1971b), Bardhan (1970a, 1970b, 1973 1974), Ojha and Bhatt (1971), Ojha (1970), Minhas (1970), Santana (1970), Abel (1971) and Rajaraman (1974). See McNamara (1972) and Adelman and Morris (1973) on experiences of developing economies.

2/ More details on this aspect are provided in Chapter V.

itself through economic progress; deliberate attempts wi. have to be made by governments concerned to alleviate it. This is as true of India as any other country.

It seems that a "package" approaches to the problem is necessary; the "package" may include redistribution of income from the rich to the poor through fiscal mechanisms, increased public investment for increasing the human capital of the poor (e.g. education, training in job skills), public works redistribution of property especially land (the source or income), and creating more employment opportunities. It is beyond the scope of this study to indicate how much could be done under each of these programs. However, a few general remarks are in order. Experience in redistribution through fiscal mechanism has not been at all effective in view of opposition of landed property groups of increasing the tax burden on them. The human capital approach could be only a supplement to any other possible measure in view of its long gestation period. The redistribution of land approach is an immediate possibility if there is a political will; but how much could be done through this approach is still uncertain. In fact Dandekar and Rath (1971b) argue that it is futile to try to resolve the problem of rural poverty, in an overpopulated land, by redistribution of land which is in short supply. Provision of income through the creation of employment opportunities is a major approach widely believed to be the feasible one. Employment is the process by

which a laboring family is linked to the economic life of society. For such a family, employment mediates income and offers the opportunity for participation in the development process. Provision of employment offers a means of using ones own working skills, a means of earning income, and a means of crossing above the "poverty line." There are some questions to be examined in placing the employment issue in proper perspective. What is the nature and magnitude of unemployment in rural India? What has been the experience in absorbing labor in the industrial sector? What are the employment dimensions of new production technology in the wheat farming sector? These questions are briefly examined below.

The Committee of Experts on Unemployment Estimates, 1970 (in Sethuraman (1972)), tells us that in rural areas there is very little open or outright unemployment, but there would be considerable seasonal unemployment and/or underemployment. Describing the situation in an overpopulated country like India Georgescu - Roegen (1960, p. 31) argues that in overpopulated countries it is hard to find someone unemployed. With an excess of labor, everyone fights to establish a solid claim to a share of the national product. This leads to a social pattern which may be labelled "splitting-the-job." Various attempts have been made to estimate unemployment and under-employment in India. Estimates of surplus in terms of the number unemployed range widely from 3 to 50 million including an amalgam of unemployment, underemployment, low productivity,

and indolence. Even the estimates made by the National Sample Survey and suggested by the Dandekar-Rath study (1971b) suffers from various limitations.[3/] Krishna (1973) in a recent study reports that, including the wholly unemployed and severely underemployed available for additional work, the number of workers unemployed in rural India comes to about 19.3 million for the year 1971, and 2.2 million in the urban areas for the same period. However these estimates do not include those whose premium on leisure is high and for whom social status even with semi-starvation is more important than gainful employment. Comparable figures are not available for Punjab, eventhough studies by the National Council of Applied Economic Research (1962), and Uppal (1973) suggest that underemployment and unemployment may not have been as serious a problem in the rural Punjab of 1950's as elsewhere in India.

We have discussed briefly the nature and magnitude of unemployment in rural India. The next question is, what has been the experience in absorbing labor to industrial sector? The contribution of the industrial sector to employment growth over the last decade has been disappointing in many countries.[4/] Sethuraman (1970) reports that between 1950 and 1964 employment

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3/ For a critical evaluation of these estimates, see Sethuraman (1972).

4/ Details can be found in Turnham and Ingelies (1971), Todaro (1971a, 1971b, 1973), Werner and Herve (1966), and Morawetz (1974). See Hazari and Krishnamurthy (1970) for Indian experience.

in the Indian large-scale manufacturing secton increased at an annual rate of 6 percent while the real value added by this sector rose at an annual rate of over 10 percent. During the same period capital stock in constant prices rose at an annual rate of about 17 percent per year. Thus the growth of employment lagged behind the growth of value added and capital stock.[5/] Morawetz (1974) also reports that in 1970, manufacturing labor force as a percentage of total labor was 9.5, whereas gross value added in manufacturing as a percentage of value added in commodity production in 1969 was 20.5. In recent years, a voluminous literature has emerged attempting to explain the poor performance of industrial sector in generating employment, and to suggest ways in which it might be improved. Most of it is directed to three fundamental and interrelated questions. Is there necessarily a conflict between increasing employment and increasing output?[6/] Which goods should be produced (the output composition problem)? How should they be produced (the choice of technique problem)? It is beyond the scope of present study to examine these interesting issues.

In addition to a labor force explosion due to high rate of population growth, and poor performance of industrial sector

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5/ See Sethuraman (1970) for reasons why the capital-labor ratio rose rapidly in India.

6/ For excellent discussions of this issue see Marsden (1969 and Stewart and Streeten (1971).

in generating employment, various reasons have been advanced as to why reliance on agricultural sector for employment generation is inevitable.[7/] Two major reasons need to be stated. One is the sectoral arithmetic. Of the projected increase of more than 60 million in the labor force of India during the 1970's, it is estimated that 43 million may require employment in the rural sector. In Punjab, rural population as percentage of total population was 76.3 according to 1971 census. All these additional people have to find their means of livelihood mainly in rural areas. The other major reason is the technical change in agriculture with the introduction of high yielding varieties. The new cereal varieties are said to have the power of being the catalysts of employment creation. One may examine different dimensions of employment opportunities offered by recent technical change in agriculture. Technical change may increase the labor input used per growing season may generate additional employment by facilitating multiple cropping, and may contribute to employment by creating a dynamic environment for farm diversifications.[8/] In addition to these on-farm employment opportunities, it may generate employment through backward and forward linkages in output and input markets.[8a/] Some

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7/ Discussions on these reasons are outlined in Shaw (1971), and Nurul (1973).

8/ See Donovan (1974) for some details on effects of multiple cropping and farm diversification on employment.

observers believe, for example, Shaw (1971), that the amount of employment created indirectly will exceed the direct employment effects of the new technology. Krishna (undated) has proposed a model for measuring indirect employment effects by using the basic input-output model.

The present study is concerned with one dimension of the direct employment effects of technical change, that is the employment effects per growing season of wheat in Punjab. The study does not measure by farm operations the employment effects of technical change[9/] - seedbed preparation, irrigation and harvest. Rather the study is concerned with a measure of total effect. It is the fundamental premise of this study that there must be greater provision of employment opportunities within the agricultural sector, and creation of employment opportunities is one of the main ways through which the government can give expression to its "equity objective." The "pull" of high urban wages pointed out in the Todaro studies (1969, 1971a, 1971b) are very important in causing migration to urban areas, but the "push" factors may be made less operative by creating employment in farming sector.

8a/ The effects of green revolution in Pakistani Punjab on small scale industries supplying diesel engines, pumps, and other farm implements are reported by Child and Kaneda (1975).

9/ Such studies are reported by Billings (1970), Billings and Singh (1971), and Jhunjhunwala (1973).

Reliable measures of relevant quantities are required for the formulation of employment policy. The purpose of this study is to quantify the various forces affecting employment, and to learn how much we must change variables which we can control in order to effectuate the change required in employment. There are two important directions in which the government can have impact on generation of employment. First, it can influence the creation of employment by influencing the price of some inputs such as fertilizer, irrigation water, and price of farm machinery. Second, the government can also influence the creation of employment through its physical planning, that is, planning of the production and distribution of off-farm inputs. Further, a decomposition of employment into their constituent causal forces is also required to provide an empirical perspective on the relative importance of technological and economic forces in generating employment. Estimation of employment elasticities with respect to certain key variables, and decomposing the total difference in employment between farms employing old production technology and farms employing new production technology into constituent forces is the direct concern of this chapter. We need economic models and their operational counterparts. These we develop in the sections below.

Economic Models

In this section our main concern is to formulate economic models that would enable us to estimate employment elasticities for certain key variables, and to decompose the total change in employment into constituent forces. There are three principal theoretical constructs available for this purpose:

(1) Constrained Cost-Minimization Model;

(2) The Unit-Output-Price (UOP) Profit Function Model, and

(3) The Unrestricted Profit-Maximization Model

Because the unrestricted profit-maximization model yields solutions only for returns to scale less than unity,[10/] we chose to work with the first two models. A review of these two models, with an emphasis on their strengths and weaknesses in the context of our study, is in order.

1. Labor Demand Function Derived from Constrained Cost Minimization Model:

The Cobb-Douglas production function (1) from chapter III is rewritten as:

$$Y = A L^{\beta_l} N^{\beta_n} F^{\beta_f} K^{\beta_k} \qquad (1)$$

The cost equation is

$$C = P_l L + P_n N + P_f F + P_k K \qquad (2)$$

where C denotes total cost incurred by the firm, and P_l, P_n, P_f and P_k are prices of land service, labor, fertilizer and other

10/ For a detailed exposition of this point, see Henderson and Quandt (1971).

capital services respectively. Variables L, N, F and K are defined as in Chapter II. Following Nerlove (1965), minimization of cost equation (2) subject to production function (1) would yield us the following labor demand function.

$$N = \beta Y^{\frac{1}{\gamma}} P_l^{\frac{\beta_l}{\gamma}} P_n^{\frac{\beta_n}{\gamma} - 1} P_f^{\frac{\beta_f}{\gamma}} P_k^{\frac{\beta_k}{\gamma}} \qquad (3)$$

where

$$\beta = \beta_n \left(A \, \beta_l^{\beta_l} \beta_n^{\beta_n} \beta_f^{\beta_f} \beta_k^{\beta_k}\right)^{-\frac{1}{\gamma}} \qquad (4)$$

and $\gamma = \beta_l + \beta_n + \beta_f + \beta_k$ = returns to scale; presumably $\beta_l, \beta_n, \beta_f, \beta_k \geq 0, < 1$.

In labor demand function (3), both output and factor prices are exogeneous. Heady and Dillon (1961), Brown (1968), Bronfenbrenner (1971), and Samuelson (1974) have examined various versions of this model. There is one aspect of the model that needs to be stated explicitly. That is, in deriving the labor demand function (3), we have constrained the firm to a given level of output. This has implication for the sign of the exponents in the labor demand function (3). It is obvious why we have a negative exponent for wage rate (P_n). But in the case of other exponents the sign is positive. This implies that an increase or decrease in input prices would gi rise to an increase or decrease in the quantity of labor employed. For example, an increase in the price of Capital (K)

would lead to a decrease in the quantity of it employed. Since we have constrained the firm to a given isoquant, the firm would be producing this given level of output by employing more labor. We propose to employ labor demand function (3) to determine employment elasticities with respect to output and input prices. Per farm production function estimates allowing for returns to scale differing from unity will be used for evaluating employment elasticities.

If we assume constant returns to scale, $\gamma = 1$, equation (3) and expression (4) may be stated as:

$$N = \beta Y P_l^{\beta_l} P_n^{\beta_n - 1} P_f^{\beta_f} P_k^{\beta_k} \qquad (5)$$

$$\beta = \beta_n (A \beta_l^{\beta_l} \beta_n^{\beta_n} \beta_f^{\beta_f} \beta_k^{\beta_k})^{-1} \qquad (6)$$

Labor demand function (5) is employed for determining employment elasticities with respect to output, and input prices. Per acre production function estimates imposing the constraint of homogeneity of degree one in returns to scale will be used for evaluating employment elasticities. So labor demand function (3) is used for evaluating per farm employment elasticities and labor demand function (5) for evaluating per acre employment elasticities.

In addition to determining employment elasticities, the other main concern in this chapter is to decompose the total difference in employment between farms employing old production technology and farms employing new production technology into

constituent forces. In the constrained cost minimization framework, we propose to decompose the total difference in employment into:

a) change in output;

b) neutral technical change;

c) non-neutral technical change; and

d) change in factor prices.

Decomposition will be done with respect to per acre labor demand function (5), since it seems more meaningful to talk in terms of per acre change in employment.

Taking the natural logarithm of labor demand function (5):

$$\ln N = \ln \beta + \ln Y + \beta_1 \ln P_1 + (\beta_n - 1) \ln P_n + \beta_f \ln P_f + \beta_k \ln P_k \qquad (7)$$

Differentiating (7) totally:

$$\frac{dN}{N} = \frac{d\beta}{\beta} + \frac{dY}{Y} + \beta_1 \frac{dP_1}{P_1} + \ln P_1 \, d\beta_1 + (\beta_n - 1) \frac{dP_n}{P_n} + \ln P_n \, d\beta_n + \beta_f \frac{dP_f}{P_f} + \ln P_f \, d\beta_f + \beta_k \frac{dP_k}{P_k} + \ln P_k \, d\beta_k \qquad (8)$$

Taking the natural logarithm of the expression (6) and taking total differential:

$$\ln \beta = \ln \beta_n - \ln A - \beta_1 \ln \beta_1 - \beta_n \ln \beta_n - \beta_f \ln \beta_f - \beta_k \ln \beta_k \qquad (9)$$

$$\frac{d\beta}{\beta} = \frac{d\beta_n}{\beta_n} - \frac{dA}{A} - \frac{\beta_1}{\beta_1} d\beta_1 - \ln \beta_1 \, d\beta_1 - \frac{\beta_n}{\beta_n} d\beta_n - \ln \beta_n \, d\beta_n$$

$$- \frac{\beta_f}{\beta_f} d\beta_f - \ln \beta_f \, d\beta_f - \frac{\beta_k}{\beta_k} d\beta_k - \ln \beta_k \, d\beta_k \qquad 10)$$

Rearranging terms in (10):

$$\frac{d\beta}{\beta} = d\beta_n \left\{ \frac{1}{\beta_n} - 1 - \ln \beta_n \right\} - \frac{dA}{A} - d\beta_1 \left\{ 1 + \ln \beta_1 \right\}$$

$$- d\beta_f \left\{ 1 + \ln \beta_f \right\} - d\beta_k \left\{ 1 + \ln \beta_k \right\} \qquad (11)$$

Substituting (11) into (8) and rearranging terms:

$$\frac{dN}{N} = \left\{ \frac{1}{\beta_n} - 1 - \ln\beta_n \right\} d\beta_n - \frac{dA}{A} - \left\{ 1 + \ln\beta_1 \right\} d\beta_1 - \left\{ 1 + \ln\beta_f \right\} d\beta_f$$

$$- \left\{ 1 + \ln \beta_k \right\} d\beta_k + \frac{dY}{Y} + \beta_1 \frac{dP_1}{P_1} + \ln P_1 \, d\beta_1 + \left(\beta_n - 1 \right) \frac{dP_n}{P_n}$$

$$+ \ln P_n \, d\beta_n + \beta_f \frac{dP_f}{P_f} + \ln P_f \, d\beta_f + \beta_k \frac{dP_k}{P_k} + \ln P_k \, d\beta_k$$

..(12)

$$\frac{dN}{N} = \frac{dY}{Y} - \frac{dA}{A} + \beta_1 \frac{dP_1}{P_1} + \left(\beta_n - 1 \right) \frac{dP_n}{P_n} + \beta_f \frac{dP_f}{P_f} + \beta_k \frac{dP_k}{P_k}$$

$$\left\{ \frac{1}{\beta_n} - 1 - \ln \beta_n + \ln P_n \right\} d\beta_n - \left\{ 1 + \ln \beta_1 - \ln P_1 \right\} d\beta_1$$

$$\left\{ 1 + \ln \beta_f - \ln P_f \right\} d\beta_f - \left\{ 1 + \ln \beta_k - \ln P_k \right\} d\beta_k$$

...(12a)

$$\frac{dN}{N} = \left[\frac{dY}{Y}\right] - \left[\frac{dA}{A}\right] - \left[\left(1 + \ln\frac{\beta_n}{P_n} - \frac{1}{\beta_n}\right)d\beta_n + \left(1 + \ln\frac{\beta_1}{P_1}\right)d\beta_1 + \left(1 + \ln\frac{\beta_f}{P_f}\right)d\beta_f + \left(1 + \ln\frac{\beta_k}{P_k}\right)d\beta_k\right] + \left[\beta_1\frac{dP_1}{P_1} + (\beta_n - 1)\frac{dP_n}{P_n} + \beta_f\frac{dP_f}{P_f} + \beta_k\frac{dP_k}{P_k}\right] \quad (13)$$

The expression $\frac{dN}{N}$ denotes percentage difference in employment per acre between a farm employing old production technology, and one employing new technology.

The first bracketed expression on the right hand side is a measure of percentage change in employment due to a given percentage change in output; the second bracketed expression is a measure of percentage change in employment due to neutral technical change; the percentage change in employment due to non-neutral technical change is approximately measured by the third bracketed expression; it is a measure of percentage change in employment due to shift in slope parameter given the levels of input prices; and the fourth bracketed expression is a measure of percentage change in employment due to change in input prices given the slope coefficients (β's) of new production technology.

Equation (13) provides the following insights on the sources of change in employment:

First if all prices change in the same proportion, then the fourth bracketed expression vanishes. If μ is the

proportion, then $(\beta_l + \beta_n - 1 + \beta_f + \beta_k)\mu = 0.\mu = 0$. This implies that there will be no change in employment if all prices change in the same proportion implying constancy of relative prices. Change in employment will have to come from changes in output and technical change - neutral and non-neutral.

Second, if output elasticities for all inputs are identical under both old production technology and new production technology, then $d\beta_l = d\beta_n = d\beta_f = d\beta_k = 0$, the third bracketed expression vanishes. If one or more of the $d\beta_i$'s $\neq 0$ (suppose $d\beta_k > 0$), then the contribution of the third bracketed expression would be to make $\frac{dN}{N}$ (if $d\beta_k > 0$) greater than it would be if all the $d\beta_i$'s $= 0$. If input prices were relatively stable, $d\beta_l = d\beta_n = d\beta_f = 0$, $d\beta_k > 0$, then

$$\frac{dN}{N} = \frac{dY}{Y} - \frac{dA}{A} - (1 + \ln \frac{\beta_k}{P_k})\, d\beta_k$$

where $1 + \ln \frac{\beta_k}{P_k} < 0$;[11/] then the contribution of $d\beta_k$ to employment will be positive. If $d\beta_n < 0$, then $(1 + \ln \frac{\beta_n}{P_n} - \frac{1}{\beta_n})d\beta_n$ would be a negative number and would tend to be offsetting

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11/ If the expression $\frac{\beta_k}{P_k}$ became a fairly small fraction as it would if β_k was small and P_k large, then $\ln \frac{\beta_k}{P_k}$ would be a fairly large negative number. This is true for other $\ln \frac{\beta_i}{P_i}$ in the third bracketed expression as there is symmetry in all the coefficients except that for the coefficient of $d\beta_n$.

to $(1 + \ln \frac{P_k}{P_L})d\beta_k$ with $d\beta_k > 0$. Net employment effect depends on the relative magnitude of $d\beta_n$ (<0) and $d\beta_k$ (>0).

Third, if $\frac{dY}{Y} = 0$, then the situation would be that of the changes that would take place on the same isoquant; employment effects depend on relative input prices and technical change.

Fourth, suppose $\frac{dP_l}{P_l} = \frac{dP_n}{P_n} = \frac{dP_f}{P_f} = \frac{dP_k}{P_k}$, 12/ and $\ln \frac{\beta_n}{P_n} = \ln \frac{\beta_l}{P_l} = \ln \frac{\beta_f}{P_f} = \ln \frac{\beta_k}{P_k} = \theta < -2$; then

$$\frac{dN}{N} = \frac{dY}{Y} - \frac{dA}{A} - (\theta - 1)\,(d\beta_n + d\beta_l + d\beta_f + d\beta_k) + \frac{d\beta_n}{\beta}$$

$d\beta_n + d\beta_l + d\beta_f + d\beta_k = 0$. 13/ so

$$\frac{dN}{N} = \frac{dY}{Y} - \frac{dA}{A} + \frac{d\beta_n}{\beta_n}$$

If $d\beta_n < 0$, as we would expect under capital-intensive technical change, then employment effects would depend on $\frac{dY}{Y}$ 14/ and the magnitude of $\frac{dA}{A}$ and $\frac{d\beta_n}{\beta_n}$, both negative.

12/ This is very unlikely because of differences in supply elasticities of inputs in response to changes in quantity demanded.

13/ Since we are working with the assumption of constant returns to scale, $\beta_n + \beta_l + \beta_f + \beta_k = 1$. Differentiating the above expression totally $d\beta_n + d\beta_l + d\beta_f + d\beta_k = 0$.

14/ Change in output could be induced on the demand side by changes in output price, population, or per capita income.

For the purpose of decomposition derivatives in equation (13) are converted to discrete values as below:[15/]

$$\frac{\Delta N}{N} = \left[\frac{\Delta Y}{Y}\right] - \left[\frac{\Delta A}{A}\right] - \left[\left(1 + \ln \frac{\beta_n}{P_n} - \frac{1}{\beta_n}\right)\Delta\beta_n + \left(1 + \ln \frac{\beta_l}{P_l}\right)\Delta\beta_l + \left(1 + \ln \frac{\beta_f}{P_f}\right)\Delta\beta_f + \left(1 + \ln \frac{\beta_k}{P_k}\right)\Delta\beta_k\right] + \left[\beta_l \frac{\Delta P_l}{P_l} + (\beta_n - 1)\frac{\Delta P_n}{P_n} + \beta_f \frac{\Delta P_f}{P_f} + \beta_k \frac{\Delta P_k}{P_k}\right] \quad (14)$$

In summary, labor demand function (3) is used for evaluating per farm employment elasticities with per farm production function estimates; labor demand function (5) for evaluating per acre employment elasticities with per acre production function estimates; and equation (14) is employed to decompose total difference in employment.

2. Labor Demand Function Derived From the UOP Profit Function Model:

The constrained cost minimization model permits us to derive labor demand as a function of output and input prices, to estimate employment elasticities with respect to these variables and to decompose the difference in employment between old and new technology into respective forces. Given the production technology, the basic policy variables in this

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15/ For example, if N denotes the geometric mean number of hours of employment per acre, $\Delta N = (N)MW - (N)LW$. So are ΔY, ΔA, $\Delta\beta_i$'s and ΔP_i's defined.

framework are output, and input prices. We recall that physical planning - planning the supply of farm inputs such as irrigation services,[16/] fertilizer, farm machinery and implements - is a part of agricultural development planning in India. An estimate of employment elasticities with respect to these key inputs would provide an empirical basis for government's employment policy as well. The recently developed UOP profit function model (Lau and Yotopoulos, 1971, 1972, 1973) enables us to derive estimates of employment elasticities with respect to these key inputs. A brief outline of the UOP profit function model, including a critical evaluation of its "desirable" and "undesirable" properties in the context of our study, is in order.

a) The UOP Profit Function MOdel in a General Framework:

Consider a firm with a following production function with the usual neo-classical properties,

$$Y = G\ (N;\ L,\ F,\ K) \qquad (15)$$

Definitions of Y, N, L , F and K are the same as in Chapter II except that labor (N) is treated as a variable input, and land (L), fertilizer (F) and capital (K) are treated as fixed inputs in optimization process. The production function is assumed to

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16/ Provision of irrigation either through public projects or by advancing credit for developing private irrigation would increase the effective supply of land to the extent that irrigation facilities multiple cropping.

be concave in N, continuous and increasing in N, L, F and K twice differentiable in N and once differentiable in L, F and K.

The profit (defined as current revenues less current total labor costs) can be written as follows: 17/

$$\lambda = P \cdot G(N; L, F, K) - WN \qquad (16)$$

where:

λ = profit; P = unit price of output; W = unit price of labor; other variables are as defined before.

The marginal productivity conditions for a profit-maximizing firm are:

$$\frac{\partial \lambda}{\partial N} = P \frac{\partial G(N; L, F, K)}{\partial N} = W \qquad (17)$$

By defining $W' = \frac{W}{P}$ as the normalized (with respect to output price) wage rate, equation (17) is written as

$$\frac{\partial G}{\partial N} = W' \qquad (18)$$

By a similar deflation by the price of output, equation (16) can be written as:

$$\lambda^* = \frac{\lambda}{P} = G(N; L, F, K) - W'N \qquad (19)$$

where λ^* = "unit-output price" profit (or UOP profit)

17/ Since fixed costs do not affect the optimal combination of the variable input, namely labor (N), these are ignored. How reasonable it is to assume fertilizer expenditure (F) and items of other capital expenditure (K) as fixed will be discussed later in this chapter.

Marginal productivity conditions in equation (18) can be solved for the optimal quantity of variable input, N*, as a function of the normalized wage rate (W') and of the quantities of fixed inputs, namely, L, F and K.

$$N^* = g\ (W'; L, F, K) \qquad (20)$$

Substitute (20) into (16) to the profit function[18/] as:

$$\pi = P\ \ G\ (N^*; L, F, K)\ \ - W'\ N^*$$

This profit function gives the maximized value of the profit for each set of values (P, W, L, F, K)

Since $N^* = g\ (W'; L, F, K)$ by (20), we can rewrite (21) as:

$$\Pi = \frac{\lambda}{P} = G^*\ (W'; L, F, K) \qquad (22)$$

The preceding discussion is intended to relate the production function, profit function and the labor demand function. The general framework is translated into the Cobb-Douglas framework below.

b) Labor Demand Function Derived from the Cobb-Douglas UOP Profit Function

Consider a firm with the following Cobb-Douglas production (1) [from chapter III] with the usual neo-classical properties as discussed earlier:

18/ The profit function (21) is called the partial profit function, because L, F and K are fixed.

$$Y = A N^{\beta_n} L^{\beta_l} F^{\beta_f} K^{\beta_k} \qquad \beta_n < 1 \qquad (23)$$

The variables are defined as in chapter II. It seems appropriate to comment on the definition of capital variables F and K. Lau and Yotopolous (1971, 1972) and Yotopolous and Lau (1973) considered just one capital variable. The capital variable in their study is defined to include interest charges paid or imputed on the quantity of fixed capital per farm. In Sidhu's study (1972, 1974b), the capital variable includes all expenditures(or imputations)on capital services such as fertilizer, irrigation, seeds, bullock labor, depreciation, and interest charges. In the specification of our model we have divided Sidhu's composite capital input into fertilizer (F) and other capital services (K). The rationale for this division is that an estimate of employment elasticity with respect to fertilizer would provide insights on the importance of a major nonfarm input in generating employment, and would provide an important instrumental variable for any government with an employment objective. Following Lau and Yotopolous (1972), we write our Cobb-Douglas UOP profit function as follows:[19/]

$$\Pi = A^* W^{\lambda_1} L^{\lambda_2} F^{\lambda_3} K^{\lambda_4} \qquad (24)$$

19/ For details on derivations see Lau and Yotopolous (1971. 1972)

where

$$A^* = (A)^{(1-\beta_n)^{-1}} (1-\beta_n)^{\beta_n(1-\beta_n)^{-1}} \beta_n^{\beta_n(1-\beta_n)^{-1}} \tag{25}$$

$$\lambda_1 = -\beta_n (1-\beta_n)^{-1} < 0 \tag{26}$$

$$\lambda_2 = \beta_l(1-\beta_n)^{-1} > 0 \tag{27}$$

$$\lambda_3 = \beta_f(1-\beta_n)^{-1} > 0 \tag{28}$$

$$\lambda_4 = \beta_k(1-\beta_n)^{-1} > 0 \tag{29}$$

$W^1 = \underline{W}$ = normalized wage rate

Definitions of Π, L, F, and K are the same as in Chapter II; β_i's in A^* and λ_i's denote output elasticities in production function (23).

It is evident from the way in which parameters of UOP profit function (24) are defined that the production function (23) and the UOP profit function (24) are closely related This follows from the proposition that every concave production function has a dual which is a convex profit function, and vice versa.[20/] We have UOP profit in (24) as a function of normalized wage rate, and quantities of land (L), fertilizer (F), and other capital services (K). On the basis of a priori theoretical considerations we know that the UOP profit function is decreasing and convex in the normalized wage rate, and increasing in quantities of L, F, and K. It follows also that

20/ See Lau and Yotopolous (1972) for details on this proposition.

the UOP profit function is increasing in the price of the output.

Following are the assumptions underlying the UOP profit function (24):

(1) Firms are profit-maximizing;

(2) Firms are price-takers both in the output and labor markets;

(3) Labor is the only variable input; land (L) fertilizer (F), and other capital (K) services are fixed inputs.

The crucial feature of the UOP profit function model is that it assumes firms behave according to certain decision rules, which includes profit maximization, given the price regime for output and labor and given the quantities of L, F and K. For the purpose of our study, the existence of these systematic decision rules is a maintained hypothesis.

Following Lau and Yotopolous (1972), the labor demand function in the UOP profit function framework is

$$\frac{W^1 N}{\Pi} = (-\lambda_1) \tag{30}$$

Taking the natural logarithm of (30) and rearranging terms:

$$\ln N = \ln(-\lambda_1) - \ln W^1 + \ln \Pi \tag{31}$$

Taking the natural logarithm of (24):

$$\ln \Pi = \ln A^* + \lambda_1 \ln W^1 + \lambda_2 \ln L + \lambda_3 \ln F + \lambda_4 \ln K \tag{32}$$

Substituting (32) into (31) and rearranging terms:

$$\ln N = \ln(-\lambda_1) + \ln A^* + (\lambda_1 - 1)\ln W^1 + \lambda_2 \ln L + \lambda_3 \ln F + \lambda_4 \ln K \qquad (33)$$

In equation (33), we have a labor demand function in terms of normalized wage rate, and quantities of land (L), fertilizer (F) and capital (K). Equation (33) is used to estimates employment elasticities with respect to the variables mentioned above. We estimate production function (23), and evaluate parameters for our labor-demand function (33) by using the duality property underlying the Cobb-Douglas production and profit functions discussed earlier.

In addition to determining employment elasticities, decomposition of total difference in employment between farms employing old production technology and farms employing new production technology is our other main concern. For this purpose, we differentiate (33) totally:

$$\frac{dN}{N} = \frac{d\lambda_1}{\lambda_1} + \frac{dA^*}{A^*} + (\lambda_1 - 1)\frac{dW^1}{W^1} + \lambda_2 \frac{dL}{L} + \lambda_3 \frac{dF}{F} + \lambda_4 \frac{dK}{K}$$
$$+ \ln W^1 (d\lambda_1) + \ln L(d\lambda_2) + \ln F(d\lambda_3) + \ln K(d\lambda_4) \qquad (34)$$

We recall that λ_1 and A^* are defined as follows:

$$\lambda_1 = -\frac{\beta_n}{1-\beta_n} \text{ or } -\lambda_1 = \frac{\beta_n}{1-\beta_n} \qquad (26)$$

$$A^* = A^{(1-\beta_n)^{-1}} (1-\beta_n)^{\beta_n(1-\beta_n)^{-1}} \beta_n \qquad (25)$$

Taking the natural logarithm of (26) and differentiating it totally:

$$\ln(-\lambda_1) = \ln \beta_n - \ln(1-\beta_n) \tag{35}$$

$$\frac{d\lambda_1}{\lambda_1} = \frac{d\beta_n}{\beta_n} + \frac{d\beta_n}{1-\beta_n} \tag{36}$$

$$\frac{d\lambda_1}{\lambda_1} = \frac{d\beta_n}{\beta_n(1-\beta_n)} \tag{36a}$$

Taking the natural logarithm of (25) and differentiating it totally:

$$\ln A^* = \frac{1}{1-\beta_n} \ln A + \ln(1-\beta_n) + \frac{\beta_n}{1-\beta_n} \ln \beta_n . \tag{37}$$

$$\frac{dA^*}{A^*} = \frac{(1-\beta_n)\frac{dA}{A} + \ln A \, d\beta_n}{(1-\beta_n)^2} - \frac{d\beta_n}{1-\beta_n} + \frac{\beta_n}{1-\beta_n} \frac{d\beta_n}{\beta_n}$$

$$+ \ln \beta_n \left[\frac{(1-\beta_n)\, d\beta_n + \beta_n \, d\beta_n}{(1-\beta_n)^2} \right] \tag{38}$$

$$\frac{dA^*}{A^*} = \frac{dA}{(1-\beta_n)A} + \ln A \left[\frac{d\beta_n}{(1-\beta_n)^2} \right] + \ln \beta_n \left[\frac{d\beta_n}{(1-\beta_n)^2} \right] \tag{38a}$$

$$\frac{dA^*}{A^*} = \frac{dA}{(1-\beta_n)A} + \left[\frac{\ln A + \ln \beta_n}{(1-\beta_n)^2} \right] d\beta_n \tag{38b}$$

Substituting (36a) and (38b) into (34):

$$\frac{dN}{N} = \frac{d\beta_n}{\beta_n(1-\beta_n)} + \frac{dA}{(1-\beta_n)A} + \left\{\frac{\ln A + \ln \beta_n}{(1-\beta_n)^2}\right\} d\beta_n + (\lambda_1 - 1)\frac{dW^1}{W^1}$$

$$+ \lambda_2 \frac{dL}{L} + \lambda_3 \frac{dF}{F} + \lambda_4 \frac{dK}{K} + \ln W^1 (d\lambda_1)$$

$$+ \ln L (d\lambda_2) + \ln F (d\lambda_3) + \ln K (d\lambda_4) \qquad (39)$$

Rearranging (39):

$$\frac{dN}{N} = \left[\frac{dA}{(1-\beta_n)A}\right] + \left[\frac{d\beta_n}{\beta_n(1-\beta_n)} + \left\{\frac{\ln A + \ln \beta_n}{(1-\beta_n)^2}\right\} d\beta_n + \ln W^1 (d\lambda_1)\right.$$

$$\left. + \ln L(d\lambda_2) + \ln F(d\lambda_3) + \ln K(d\lambda_4)\right]$$

$$+ \left[(\lambda_1 - 1)\frac{dW^1}{W^1}\right] + \left[\lambda_2 \frac{dL}{L} + \lambda_3 \frac{dF}{F} + \lambda_4 \frac{dK}{K}\right] \qquad (39a)$$

Since our interest is to undertake decomposition analysis with per acre estimates, equation (39a) can be simplified further as follows:[21/]

21/ Since we specify our decomposition analysis with respect to per acre estimates, terms $\ln L(d\lambda_2)$ in the second bracketed expression of (39a) and $\lambda_2 \frac{dL}{L}$ in the fourth bracketed expression vanish.

$$\frac{dN}{N} = \left[\frac{dA}{(1-\beta_n)A}\right] + \left[\frac{d\beta_n}{\beta_n(1-\beta_n)} + \left\{\frac{\ln A + \ln \beta_n}{(1-\beta_n)^2}\right\} d\beta_n\right.$$

$$\left. + \ln W^1 (d\lambda_1) + \ln F (d\lambda_3) + \ln K (d\lambda_4)\right] + \left[(\lambda_1 - 1)\frac{dW^1}{W^1}\right]$$

$$+ \left[\lambda_3 \frac{dF}{F} + \lambda_4 \frac{dK}{K}\right] \qquad (40)$$

To get the terms $d\lambda_1$, $d\lambda_3$ and $d\lambda_4$ in (40) we take the total differential of expressions (26), (28) and (29) respectively as follows:

$$d\lambda_1 = \frac{-(1-\beta_n)d\beta_n - \beta_n\, d\beta_n}{(1-\beta_n)^2} = \frac{-d\beta_n}{(1-\beta_n)^2} \qquad (41)$$

$$d\lambda_3 = \frac{d\beta_f - \beta_n d\beta_f + \beta_f d\beta_n}{(1-\beta_n)^2} = \frac{(1-\beta_n)d\beta_f + \beta_f d\beta_n}{(1-\beta\ \ )^2} \qquad (42)$$

$$d\lambda_4 = \frac{d\beta_k - \beta_n d\beta_k + \beta_k d\beta_n}{(1-\beta_n)^2} = \frac{(1-\beta_n)d\beta_k + \beta_k d\beta_n}{(1-\beta_n)^2} \qquad (43)$$

Substituting (26), (28), (29), (41), (42), and (43) into (40):

$$\frac{dN}{N} = \left[\frac{dA}{(1-\beta_n)A}\right] + \left[\frac{d\beta_n}{\beta_n(1-\beta_n)} + \left\{\frac{\ln A + \ln \beta_n}{(1-\beta_n)^2}\right\} d\beta_n\right.$$

$$+ \ln W^1 \left\{\frac{-d\beta_n}{(1-\beta_n)^2}\right\} + \ln F \left\{\frac{(1-\beta_n)d\beta_f + \beta_f d\beta_n}{(1-\beta_n)^2}\right\}$$

$$\left. + \ln K \left\{\frac{(1-\beta_n)d\beta_k + \beta_k d\beta_n}{(1-\beta_n)^2}\right\}\right] + \left[\left(\frac{-\beta_n}{(1-\beta_n)} - 1\right)\frac{dW^1}{W^1}\right]$$

$$\left[\frac{\beta_f}{(1-\beta_n)} \cdot \frac{dF}{F} + \frac{\beta_k}{(1-\beta_n)} \cdot \frac{dK}{K} \right] \qquad (44)$$

Equation (44) permits us to decompose the per acre total difference in employment $\frac{dN}{N}$ into four forces: 22/

(a) neutral technical change (the first bracketed expression on the right hand side);

(b) non-neutral technical change (the second bracketed expression);

(c) difference in normalized wage rate (the third bracketed expression); and

(d) difference in quantities of fertilizer (F) and capital (K) per acre between Mexican wheat farms and local wheat farms (the fourth bracketed expression).

For decomposition analysis, derivatives in equation (44) are expressed in discrete form as follows:

22/ We have divided the technological effects on employment into two components, namely, neutral [working through shift in intercept term (A) of production function (23)]; and non-neutral [working through shifts in slope parameters of production function (23)]. If we add both components that will be approximately a measure of technological effects on employment.

$$\frac{\Delta N}{N} = \left[\frac{\Delta A}{(1-\beta_n)A}\right] + \left[\frac{\Delta\beta_n}{\beta_n(1-\beta_n)} + \left\{\frac{\ln A + \ln \beta_n}{(1-\beta_n)^2}\right\}\Delta\beta_n\right.$$

$$+ \ln W^1 \left\{\frac{-\Delta\beta_n}{(1-\beta_n)^2}\right\} + \ln F \left\{\frac{(1-\beta_n)\Delta\beta_F + \beta_f\,\Delta\beta_n}{(1-\beta_n)^2}\right\}$$

$$\left. + \ln K \left\{\frac{(1-\beta_n)\Delta\beta_k + \beta_k\,\Delta\beta_n}{(1-\beta_n)^2}\right\}\right] + \left[\left(\frac{-\beta_n}{(1-\beta_n)} - 1\right)\frac{\Delta W^1}{W^1}\right]$$

$$+ \left[\frac{\beta_f}{(1-\beta_n)}\,\frac{\Delta F}{F} + \frac{\beta_k}{(1-\beta_n)}\,\frac{\Delta K}{K}\right] \qquad 45$$

In summary, labor demand function (33) is employed for deriving employment elasticities with respect to normalized wagerate (W^1), and quantities of land (L), fertilizer (F) and capital (K). Equation (45) is used for decomposition analysis.

Before undertaking an empirical analysis of results, it would seem appropriate to evaluate some of the "desirable" and "undesirable" properties of the UOP profit function model in the context of our study. Two desirable properties are discussed first.

First, since the UOP profit function framework would enable us to derive labor demand as a function of normalized wage rate (W^1), quantities of land (L), fertilizer (F), and other capital (K), employment elasticities with respect to key farm inputs in addition to wage rate would provide a new empirical basis for influencing employment creation through policy measures.

Second, decomposition of total difference in employment between farms employing old production technology and farms employing new production technology into constituent forces would add an important dimension to our understanding of relative importance of these variables in generating employment.

On the adverse side, we do recognize some degree of arbitrariness in specifying fertiliser (F) and capital (K) as fixed inputs in the profit function (24). We recall that the definition of capital variable as a fixed input in Lau and Yotopolous (1971, 1972), and in Yotopolous and Lau (1973) includes interest charges paid or imputed on the quantity of fixed capital per farm; whereas in Sidhu's study (1972, 1974b), capital variable as a fixed input includes all expenditure or imputation on capital services such as fertilizer, irrigation, seeds, bullock, labor, depreciation and interest charges. In the specification of our model, capital is divided into two components, namely, fertilizer (F) and all other capital services (K). Unlike land, it does not seem reasonable to expect farmers to treat these capital expenditure items, especially fertilizer, as fixed inputs. However, we have, in an arbitrary way, treated them as fixed inputs in the optimization process.

Empirical Analysis

Empirical analysis in this section has two major parts, namely, empirical analysis of labor demand functions derived from constrained cost minimization framework; and of the labor demand functions derived from the UOP profit function framework.

Part A

Here we are concerned with the empirical analysis of labor demand functions derived from the constrained cost minimization framework. Empirical analysis in this part is further divided into two sections, namely, empirical analysis of employment elasticities and of empirical decomposition of labor demand.

1. Empirical Analysis of Employment Elasticities:

We recall from the previous section that labor demand function (3) and (5) are used for estimating per farm and per-acre employment elasticities respectively. Parameters of the per farm production function (Table III.9) and of per acre production function (Table III.10) are used for evaluating employment elasticities with labor demand functions (3) and (5). Results on per farm and per acre employment elasticities are shown in Tables IV.1 and IV.2 respectively.

Per farm employment elasticities shown in Table IV.1 are measures of percentage change in employment due to one

Table IV.1: Per Farm Employment Elasticities Derived from Constrained Cost-Minimization Model.

Sample (1)	Variables (2)	Employment Elasticities (3)
1967/68 (LW)	β (constant)	0.339
	Y	1.017
	P_n	-0.787
	P_l	0.634
	P_f	0.094
	P_k	0.061
1967/68 (MW)	β (constant)	0.376
	Y	0.939
	P_n	-0.912
	P_l	0.499
	P_f	0.111
	P_k	0.302
1967/68-1968/69 (MW)	β (constant)	0.368
	Y	0.963
	P_n	-0.876
	P_l	0.550
	P_f	0.100
	P_k	0.225

Table IV.2: Per Acre Employment Elasticities Derived from Constrained Cost-Minimization Model

Sample (1)	Variables (2)	Employment Elasticities (3)
1967/68 (LW)	β (constant)	0.391
	Y/L	1.000
	P_n	-0.784
	P_l	0.626
	P_f	0.091
	P_k	0.067
1967/68 (MW)	β (constant)	0.143
	Y/L	1.000
	P_n	-0.935
	P_l	0.568
	P_f	0.092
	P_k	0.275
1967/68-1968/69 (MW)	β (constant)	0.209
	Y/L	1.000
	P_n	-0.877
	P_l	0.587
	P_f	0.105
	P_k	0.205

percent change in wage rate (P_n), output (Y), prices of land service (P_l), of fertilizer (P_f) and of capital (P_k). Of course appropriate assumptions about ceteris paribus conditions with respect to each of these variables are necessary. These employment elasticities are derived from the respective technological parameters of local and Mexican wheat production functions. We analyze them for both Sample I and II. Our analysis takes two broad forms; first the difference in slope parameter, that is, the parameter associated with wage rate (P_n) between local and Mexican wheat farms is examined; second we discuss the difference in shift parameters, that is, shift parameters associated with output (Y), price of labor service (P_l), price of fertilizer (P_f) and price of capital (P_k). These general remarks are equally applicable to per acre estimates.

The slope parameter (P_n) implies that labor has a negative own price elasticity of demand as predicted by economic theory. Further in the case of both Samples I and II the absolute value of elasticity for Mexican wheat is greater than that of local wheat. For Sample I, in response to one percent increase in wage rate (P_n), holding Y, P_l, P_f and P_k constant, an average local wheat farm reduces employment of labor by 0.79 percent whereas a Mexican wheat farm reduces employment by 0.91 percent. However, this difference in employment elasticities between a Mexican wheat farm and a local wheat farm with respect to wage rate (P_n) must be

concluded to be statistically insignificant because the output elasticity of labor between old and new production technology is not statistically significant as evidenced in Tables III.2 and III.3.

Turning to the shift parameters, demand for labor responds positively to increases in Y, P_l, P_f, and P_k. On an average local wheat farm a one percent increase in output (Y), holding other things constant, led to 1.02 percent increase in employment of labor, whereas on an average Mexican wheat farm it increased by 0.94 percent for the year 1967/68. This slight difference in response follows from the difference in returns to scale as shown in Table III.9. Regarding other shift parameters, employment elasticities with respect to prices of fertilizer (P_f) and land service (P_l) are almost the same under both old and new production technology, because the "slope dummy variables" for output elasticities as shown in Tables III.2 and III.3 are not statistically significant.

Among shift variables, price of capital services (P_k) seems to have emerged as the most important force in influencing employment under new production technology compared to its role under old production technology. In view of higher output elasticity of capital (Tables III.9 and III.10) under new production technology, a given change in price of capital leads to substantial change in quantity of it used. This implies, other things being equal, a substantial change in quantity of labor employed to produce a given level of output. For

example, as shown in Table IV.1, a one percent change in the price of capital, other things being equal, would change employment by 0.30 percent on an average Mexican wheat farm in Sample I, whereas the change is only 0.06 percent on an average local wheat farm. This difference in employment responses to a given change in price of capital (P_k) may be concluded as significant because the "slope dummy variable" for output elasticity with respect to capital is statistically significant as shown in Tables III.2 and III.3.

Estimates of per acre employment elasticities are shown in Table IV.2. Out discussions, in the context of per farm estimates, on slope and shift parameters are approximately relevant here as well.

2. Decomposition Analysis:

Decomposing the total difference in employment is our main concern in this section. Let us again write our final decomposition equation (14) as follows:

$$\frac{\Delta N}{N} = \left[\frac{\Delta Y}{Y}\right] - \left[\frac{\Delta A}{A}\right] - \left[\left(1+\ln\frac{\beta_n}{P_n} - \frac{1}{\beta_n}\right)\Delta\beta_n + \left(1+\ln\frac{\beta_l}{P_l}\right)\Delta\beta_l + \left(1+\ln\frac{\beta_f}{P_f}\right)\Delta\beta_f + \left(1+\ln\frac{\beta_k}{P_k}\right)\Delta\beta_k\right] + \left[\beta_l\frac{\Delta P_l}{P_l} (\beta_n - 1)\frac{\Delta P_n}{P_n} + \beta_f\frac{\Delta P_f}{P_f} + \beta_k\frac{\Delta P_k}{P_k}\right] \quad (14)$$

Results obtained with this equation on decomposition are shown in Table IV.3. In the case of Sample I, that is, 1967/68 (MW) versus 1967/68 (LW), the percentage change in per-acre employment is about 38. The following observations may be made on the sources of this change in employment:

First, the change in output alone is indicated to have generated about 49 percent increase in employment; but technological change alone would have decreased employment by about 40 percent.[22/] This source of decrease in employment follows from technical efficiency leading to a decrease in employment of labor for producing a given amount of output. Differences in input prices - P_n, P_l, P_f and P_k - alone are indicated to have contributed over 4 percent increase in employment. Among input prices, the only difference was in the rental value of land, the rental value of an acre of Mexican wheat land being higher as shown in Appendix Table II.A.

Second, there is a considerable difference between the

22/ In Table IV.3, the contribution of neutral technical change to employment is indicated as positive. This follows from the result (Table III.10) discussed in Chapter III that the value of constant term (A) for Mexican wheat production function is lower than for local wheat production function. If we add both neutral and non-neutral components, what we get is an approximate measure of technological effect on employment.

Table IV.3: Decomposition Analysis of Total Difference in Per Acre Employment Between Old and New Production Technology: The Constrained Cost Minimization Framework[1]

Item	Percentage attributable	
	1967/68 (MW) versus 1967/68 (LW)	1967/68-1968/69 (MW) versus 1967/68 (LW)
Total percentage change in employment[2]	37.9	32.3
Source of change:		
1. Change in output;[2]	49.5	25.0
2. neutral technical change;[3]	13.7	2.6
3. non-neutral technical change;[4]	-53.9	40.8
4. difference in input prices[2]	4.5	14.5
Total change: due to all sources	13.8	1.3

Notes:
1. Details on computation are shown in Appendix II, worksheets 1 and 2.
2. Parametric values for computing this item are from Appendix Table II.A
3. Parametric values for computing this item are from Table III.10
4. Parametric values for computing this item are from Table III.10 and Appendix Table II.A

actual change in employment (37.9 percent) and the estimated change (13.8 percent). Several reasons may have given rise to this situation. It may follow from the limitations associated with the measurement of labor input as we discussed in chapter II, from the crude measures of fertilizer price and capital price used, from the conversion of derivatives into discrete values, and from the marginal productivity conditions underlying the derived labor demand function not being satisfied. One reason that seems to cause the problem needs to be stated explicitly. We know from Table III.10 that the t-value for the output elasticity of labor (β_n) under new production technology is not statistically significant at any reasonable level of α for the year 1967-68. This means a higher standard error for β_n of new production technology. The numerical value of the term $(1+\ln \frac{\beta_n}{P_n} - \frac{1}{\beta_n})\Delta\beta_n$ in equation (14) as shown in Appendix II worksheet 1 is -0.70, indicating a negative employment effect of 70 percent. On the otherhand the numerical value of this term, as shown in Appendix II worksheet 2, for Sample II, that is 1967/68-1968/69 (MW) versus 1967/68 (LW), is -0.50. This 20 percent lower negative employment effect evidently follows from lower $\Delta\beta_n$ as shown in Appendix II worksheet 2, because all other components in the term $(1 + \ln \frac{\beta_n}{\beta_n} - \frac{1}{\beta_n}) \Delta\beta_n$ are the same for both samples. This lower $\Delta\beta_n$, given β_n under old technology, follows from higher β_n

under new production technology of Sample II. In fact, as shown in Table III.10, the t-value for β_n under new production technology of Sample II is significant at least at $\alpha = 0.10$, that is 80 percent level of significance, indicating a lower standard error for β_n. This lower standard error alone reduces negative employment effect by 20 percent. So the major conclusion that follows from this discussion is that it is the higher standard error of β_n under new production technology of 1967/68 that seems to be a major explanation for actual change in employment deviating from the estimated.

In the case of Sample II, 1967/68-1968/69 (MW) versus 1967/68 (LW), there is a wide difference between the actual change in employment (32.3 percent) and the estimated change (1.3 percent). The negative employment effect of technical change is almost the same as in the case of Sample I. The positive employment effect due to input price differences is indicated to have increased to 14.5 percent. But the decrease in positive contribution of output from 49.5 percent in the case of Sample I to 25.0 percent was large enough to offset the increased positive contribution of differences in input prices to employment. If the contribution of output had been 49.5 percent, which it could have if the per acre geometric mean level of output was 12.32 instead of 10.30 (Appendix, Table II.A), the estimated change in employment would have been about 29 percent instead of 1.3 percent. This suggests the obvious

importance of output in generating employment, and illustrates how adverse weather conditions, discussed in chapter III, could affect employment through affecting output.

In the preceding discussion on decomposition, we attempted to incorporate the effects of technical change through shifts in intercept term (A), the neutral component, and shifts in β_i's, the non-neutral component, on employment. Even though the actual change in employment is substantially different from the estimated, our economic model on decomposition has illustrated the basic mechanics through which employment is affected. We now illustrate the working of our model under Hicks-neutral technical change. Our Empirical Model III in chapter III led us to conclude that we could not reject the hypothesis that output elasticities with respect to various inputs were the same in separate regressions for local and Mexican wheat if we allow constant terms (A's) in the two regressions to differ. Economically, this is Hicks-neutral technical change. This was also the major finding of Sidhu's (1972, 1974b) study. With the results[23/] obtained by Sidhu (1972, p.53) under the assumption of Hicks-neutral technical change, we intend to illustrate the working of our decomposition

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23/ Following are the estimated per acre production functions obtained by Sidhu imposing the assumption of equal slope coefficients for Sample I:

$$Y = 2.718\, N^{.139}\, L^{.600}\, F^{.088}\, K^{.173} \quad \text{(Mexican wheat)}$$

$$Y = 2.316\, N^{.139}\, L^{.600}\, F^{.088}\, K^{.173} \quad \text{(Local wheat)}$$

model

With the assumption of Hicks-neutral technical change, the main consequence is $d\beta_n = d\beta_l = d\beta_f = d\beta_k = 0$. So we modify our decomposition equation (14) as follows:

$$\frac{\Delta N}{N} = \left[\frac{\Delta Y}{Y}\right] - \left[\frac{\Delta A}{A}\right] + \left[\beta_l \frac{\Delta P_l}{P_l} + (\beta_n - 1)\frac{\Delta P_n}{P_n} + \beta_f \frac{\Delta P_f}{P_f} + \beta_k \frac{\Delta P_k}{P_k}\right] \quad (46$$

We note that the third bracketed expression in equation (14) vanishes. Equation (46) permits us to decompose total change in employment into three forces, namely, change in output, technical change and difference in input prices. Results on decomposition are shown in Table IV.4.

As shown in Table IV.4, 37.9 percent increase in per acre employment with the introduction of new technology is decomposable broadly into three forces. Change in per acre output alone would increase employment by 49.5 percent. But technical change alone reduces employment by 17.4 percent. This follows from the efficiency gain; that is a given amount of output could be produced with less labor. Differences in input prices alone would generate 4.5 percent more employment under new production technology, the major one being the difference in per acre rental value of land. So positive employment effects of output change and difference in input prices more than

Table IV.4: Decomposition Analysis of Difference in Per Acre Employment Between Old and New Production Technology: The Constrained Cost Minimization Framework, 1967/68[1]

Item	Percentage attributable
Total percentage change in employment[2]	37.9
Sources of change:	
1. change in output[2]	49.5
2. technical change.[3]	-17.4
3. difference in input prices[2]	4.5
Total change: due to all sources	36.6

Notes: 1. Details on computation are shown in Appendix II, worksheet 3.
2. Parametric values for computing this item are from Appendix Table II.A, and footnote 23.
3. Parametric values for computing this item are from footnote 23.

offset the negative employment effect of technical change. The estimated change in employment is close to the actual change.

The discussion in this section has shown the basic forces working in creation of employment. Our model in equation (14) even though it did not yield satisfactory results in the sense of the actual not being close to estimated, seems to have illustrated the relative importance of output, input prices and technical change in creating employment. The modified decomposition model in equation (46), with the assumption of Hicks-neutral technical change, has not merely illustrated the working of our model, but also has yielded satisfactory results.

Part B

In this part, our concern is with the empirical analysis of labor demand functions derived from the UOP profit function model. As under part A, empirical analysis is further divided into analysis of employment elasticities and decomposition analysis.

1. Empirical Analysis of Employment Elasticities:

Estimates of employment elasticities evaluated from the labor demand function (33) are shown in Tables IV.5 and IV.6.

In Table IV.5 per farm employment elasticities are shown for average local and Mexican wheat farms. These elasticities measure percentage change in employment due to one percent change in normalized wage rate (W^1), land (L), fertilizer (F)

Table IV.5: Per Farm Employment Elasticities Derived from UOP Profit Function Model

Sample (1)	Variables (2)	Employment Elasticities[1] (3)
1967/68 (LW)	δ (Constant)[2]	0.271
	W^1	-1.264
	L	0.788
	F	0.116
	K	0.076
1967/68 (MW)	δ (Constant)[2]	0.051
	W^1	-1.104
	L	0.586
	F	0.130
	K	0.355
1967/68-1968/69 (MW)	δ (Constant)[2]	0.103
	W^1	-1.148
	L	0.656
	F	0.119
	K	0.269

Notes: 1. Parametric values for evaluating employment elasticities are drawn from Table III.9

2. $\delta = \ln(-\lambda_1) + \ln A^*$

Table IV.6: Per Acre Employment Elasticities Derived from UOP Profit Function Model

Sample (1)	Variables (2)	Employment Elasticities[1/] (3)
1967/68 (LW)	δ (Constant)[2/]	0.245
	W^1	-1.276
	L	0.798
	F	0.116
	K	0.085
1967/68 (MW)	δ (Constant)[2/]	0.073
	W^1	-1.070
	L	0.607
	F	0.098
	K	0.294
1967/68-1968/69 (MW)	δ (Constant)[2/]	0.124
	W^1	-1.115
	L	0.654
	F	0.117
	K	0.229

Notes: 1. Parametric values for evaluating employment elasticities are drawn from Table III.10

2. $\delta = \ln(-\lambda_1) + \ln A^*$

and capital (K) with appropriate assumptions about ceteris paribus conditions. We recall that these employment elasticities are derived from the respective technological parameters of local wheat and Mexican wheat production functions. Discussion of employment elasticities for both samples assumes two forms; first, we examine the difference in slope parameter, that is, parameter associated with normalized wage rate (W^1) between farms employing old production technology and farms employing new; second we examine differences in shift parameters, that is, parameters associated with land (L), fertilizer (F) and capital (K). All remarks here are applicable to per acre estimates as well.

Regarding slope parameter (W^1), it is apparent that labor has a negative own price elasticity of demand. Moreover, the absolute value of the elasticity is greater than one, indicating a rather elastic response of farms to labor employment with respect to wage rate. As shown in Table IV.5, in the case of Sample I, in response to one percent increase in wage rate, holding quantities of L, F and K constant, an average farm reduces employment of labor by 1.26 percent under old production technology, whereas under new production technology it reduces employment by 1.10 percent. It does not seem possible to attach any importance to this slight difference in employment with respect to normalized wage rate.

However, the implication of high absolute employment elasticity with respect to normalized wage rate (W^1) needs to be

examined further in the context of labor absorption under new production technology. Sidhu (1972, 1974b) estimated the elasticity of output supply with respect to normalized wage rate as -0.271. The relatively inelastic output response with respect to normalized wage rate along with an elastic response of demand for labor with respect to the same variable may imply a substantial reduction in employment of labor if wage rate higher than the market rate are exogeneously enforced by labor group or the government.[24/]

Now we examine the differences in shift parameters associated with land (L), fertilizer (F) and capital (K) of labor demand function (33). It is apparent that labor demand responds positively to increases in the endowments of L, F and K. A given increase in the quantity of L, F and K will shift the marginal product curve of labor upward. As a result the profit-maximizing firm will employ more labor than before at a given wage rate. An examination of employment elasticities would have obvious partial equilibrium implications for the labor absorptive capacity of new production technology; it also provides a better perspective on the changing importance of these key inputs in generating employment. For example, on an

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24/ For a discussion of the impending problem of labor force absorption in the context of the "Green Revolution" and farm mechanization see Johnston and Cownie (1969), Billings (1970), Billings and Singh (1971), Rao (1972a), Srivastava and Heady (1973), and Jhunjhunwala (1973).

average local wheat farm, a one percent increase in L, holding other things constant, leads to the employment of 0.79 percent more labor, whereas an average Mexican wheat farm employed only 0.59 percent more labor during the year 1967/68. To explain this difference in response, we rewrite expression (27) as follows:

$$\lambda_2 = \frac{\beta_1}{(1-\beta_n)} > 0 \qquad (27)$$

It is shown in equation (33) that λ_2 is the employment elasticity with respect to land. We also know from Table III.9 that $(\beta_1)_{LW} > (\beta_1)_{MW}$ and $(\beta_n)_{LW} > (\beta_n)_{MW}$. It follows that

$$\left[\frac{\beta_1}{(1-\beta_n)}\right]_{LW} > \left[\frac{\beta_1}{(1-\beta_n)}\right]_{MW} \quad \text{or } (\lambda_2)_{LW} > (\lambda_2)_{MW}$$

Similarly, a one percent increase in capital (K) holding other things constant, leads to an employment of 0.36 percent more labor in a Mexican wheat farm, whereas an average local wheat farm employs only 0.08 percent more labor during the same period. This changing role of inputs in generating employment is significant, because generation of more employment will have to be brought about through the application of purchased inputs in view of limited supply of land.

In Table IV.6 the per acre employment elasticities are presented. Our earlier discussions of per farm results on slope and shift parameters hold here as well, since employment elasticities with both per farm and per acre results

are almost the same.

2. Decomposition Analysis:

The second aspect of this empirical analysis is the decomposition of total difference in per acre employment. Results obtained with decomposition equation (45) are shown in Table IV.7. In the case of Sample I, that is 1967/68 (MW) versus 1967/68 (LW), the per acre percentage change in employment is about 38. If we examine the sources of change in this employment, the following observations seem to be relevant.

First, the effect of neutral component of technical change on employment is indicated as negative, because as we discussed in chapter III, Table III.10, the constant term (A) in per acre Mexican wheat production function is lower than of local wheat production function; the effect of non-neutral component of technical change on employment is also indicated as negative. So negative employment effect of technological change comes to 74.7 percent. Before examining the possible reasons for this unexpected result, let us discuss the direction of employment change predicted by our decomposition model based on the UOP profit function framework. We recall from our earlier discussion that every concave production function has a dual which is a convex profit function and vice versa. Technical change that shifts production function also shifts profit function. This shift in profit function, other things being equal, shifts demand for labor. This is clearly suggested in

Table IV.7: Decomposition Analysis of Total Difference in Per Acre Employment Between Old and New Production Technology: The UOP Profit Function Framework[1]

Item	Percentage attributable	
	1967/68(MW) versus 1967/68(LW)	1967/68-1968/69 versus 1967/68 (LW)
Total percentage change in employment[2]	37.9	32.3
Sources of change:		
1. neutral technical change;[3]	-17.5	- 3.3
2. non-neutral technical change;[4]	-57.2	-50.2
3. difference in normalized wage rate;[4]	-13.4	-27.9
4. difference in input levels [2]		
fertilizer	40.7	40.3
capital	10.3	7.3
Total change: due to all sources	-37.1	-33.8

Notes:
1. Details on computation are shown in Appendix II, worksheets 4 and 5.
2. Parametric values for computing these items are from Appendix Table II.6.
3. Parametric values for computing this item are from Table III.10
4. Parametric values for computing these items are from Table III.10 and Appendix Table II.B.

labor demand function (31). So the negative employment effect of technical change does not square with the prediction of our model. The main reason for this unexpected result, as we discussed earlier while doing decomposition analysis with the Cost Minimization framework, seems to be a high standard error for β_n (Table III.10) for new production technology. In the decomposition analysis with Cost Minimization framework, the high standard error of β_n affected only $(1+\ln \frac{\beta_n}{P_n} - \frac{1}{\beta_n})\Delta\beta_n$ in equation (14), but in decomposition equation (45), the standard error affects all the terms in the second bracketed expression, that is, the expression for non-neutral component of technical change. This argument can be easily read from Appendix II, worksheet 4. So the unexpected large negative employment effect of technical change may be attributed mainly to high standard error of β_n for new production technology.

Second, the negative employment effect caused by the difference in normalized wage rate ($W^1 = W/P$) between a farm employing new technology and a farm employing old is shown as 13.4 percent. Given the new $\left(-\frac{\beta_n}{1-\beta_n} - 1\right)$, the difference in $\frac{W}{P}$ alone decreases employment by 13.4 percent. This follows from the fact that the hourly normalized wage rate paid by a Mexican wheat farm is slightly higher than the one paid by a local wheat farm as shown in Appendix, Table II.B. This higher

normalized wage rate follows, even though the money wage rate can be assumed the same for both classes of farms as shown in Appendix, Table II.A, from the lower output price per quintal of Mexican wheat than of local wheat.[25/] This result seems to indicate the importance of output price, given the money wage rate, in generating employment. The negative employment effect of magnitude of 13.4 percent could perhaps have been averted if the price of Mexican wheat per quintal was the same as that of local wheat.

Third, the positive employment effect of complementary inputs, namely fertilizer and capital, results from the increased marginal product of labor with the use of more fertilizer and capital under new production technology. This increase in marginal product of labor alone shifts demand for labor to the right. The positive employment effect of increased use of complementary inputs is indicated as 51 percent.

Fourth, there is a substantial difference between the actual (39.7 percent) and estimated (-37.1 percent) change in employment. As we discussed earlier, no other explanation, except the high standard error of β_n of new technology, occurs to us.

25/ Sample mean price per quintal:

	Rupees
Local wheat (1967/68)	79.9
Mexican wheat (1967/68)	75.5
Mexican wheat (1967/68-1968/69)	76.3

In the case of Sample II, that is 1967/68-1968/69 (MW) versus 1967/68 (LW), the negative employment effects of technology are reduced somewhat due to lower standard error of β_n of new technology of 1967/68-1968/69. As we discussed earlier, the t-value for β_n is significant only at 80 percent level. As a result the effect of technology on employment is still negative. The negative employment effect of normalized wage rate has increased substantially from 13.4 percent to 27.9 percent. This results, as shown in Appendix, Tables II.A and II.B and footnote 24, mainly from almost a constant output price per quintal of Mexican wheat but an increased money wage rate giving rise to a higher normalized wage rate. This suggests that a constant output price but a situation of increasing money wage rates leads to a negative employment effect under new production technology. The positive employment effects of increased use of complementary inputs are almost the same as int the case of Sample I.

For the reasons discussed above, our decomposition model (45) did not yield satisfactory results in the sense that the estimated was substantially different from the actual change in employment. However, the model illustrates in quantitative terms the importance of output price and complementary inputs in generating employment. As we did with the decomposition model (14), let us examine how our decomposition model (45) works under the assumption of Hicks-neutral technical change under which $d\beta_n = d\beta_l = d\beta_f = d\beta_k = 0$. So the entire second bracketed

expression, that is non-neutral component, in equation (45) vanishes. With this modification, the new decomposition equation is stated as follows:

$$\frac{\Delta N}{N} = \left[\frac{\Delta A}{(1-\beta_n)_A}\right] + \left[\left(\frac{-\beta_n}{(1-\beta_n)} - 1\right) \frac{\Delta W1}{W1}\right]$$

$$+ \left[\frac{\beta_f}{(1-\beta_n)} \frac{\Delta F}{F} + \frac{\beta_k}{(1-\beta_n)} \frac{\Delta K}{K}\right] \qquad (47)$$

Results obtained with the decomposition equation (47) are shown in Table IV.8. Four observations may be made from results in Table IV.8. First, of 37.9 percent change in total employment technical change alone by shifting profit function contributes about 20.2 percent. It gives rise to positive employment effect in this framework for the reasons discussed earlier. Second, the negative employment effect (14.5 percent) of higher normalized wage rate under new technology is due to almost the same money wage rate confronting local and Mexican wheat farms, but lower output price for a given unit of Mexican wheat. Third, increased use of complementary inputs under new technology, by shifting the marginal product of labor, alone contributes 49.3 percent increase in employment. Fourth, the estimated (55.0 percent) is higher than the actual (37.9 percent) change in employment. This could perhaps be due to errors in measurement of variables and due to the use of old input levels as the base values for computing percentage changes.

Table IV.8: Decomposition Analysis of Total Difference in Per Acre Employment Between Old and New Production Technology: The UOP Profit Function Framework, 1967/68 [1]

Item	Percentage attributable
Total percentage change in employment[2]	37.9
Sources of change:	
1. technical change;[3]	20.2
2. difference in normalized wage rate;[4]	-14.5
3. difference in input levels:[2]	
fertilizer	42.3
capital	7.0
Total change: due to all sources	55.0

Notes: 1. Details on computation are shown in Appendix II, worksheet 6.
2. Parametric values for computing these items are from Appendix Table II.B.
3. Parametric values for computing this item are from footnote 23.
4. Parametric values for computing this item are from footnote 23 and Appendix Table II.B.

Summary

In broad terms, following findings may be stated as important from the preceding discussion of employment elasticities and decomposition.

(1) The labor demand analysis (Tables IV.1 and IV.2) based on the constrained cost minimization framework, suggests that difference in employment elasticity between old and new production technology with respect to money wage rate may be concluded as statistically not significant, because we cannot reject the null hypothesis, as discussed in chapter III, that the output elasticity of labor between old and new production technology is not statistically significant. The same is true with respect to prices of fertilizer and of land. But, difference in employment elasticity, 0.30 percent versus 0.06 percent, may be concluded to be statistically significant, because we cannot accept the null hypothesis that the output elasticity of capital between old and new technology is the same.

(2) The decomposition analysis (Table IV.3) with equation (14), derived from the Constrained Cost Minimization Framework, suggested that the negative employment effect of technology is more than offset by increased output. This part of the investigation eventhough it illustrated the basic mechanics of our economic model on decomposition, is far from complete in view of substantial difference between the estimated and actual change in employment. The major reason

for this difference may have been the high standard error c β_n of new production technology.

However our decomposition analysis (Table IV.4) with equation (46), assuming Hicks-neutral technical change, clearly demonstrated the effects of technical change, change in output and difference in input prices on employment. Even though negative employment effect of technology alone would have reduced employment by 17.4 percent, it was more than offset by a 49.5 percent positive employment effect of output change. Decomposition analysis, assuming Hicks-neutral technical change also yielded satisfactory results in the sense that the estimated change in employment was close to actual.

(3) The labor demand analysis (Tables IV.5 and IV.6) based on the UOP Profit Function Model, indicated that the difference in employment elasticity with respect to normalized wage rate is not statistically significant. This follows from our earlier discussion in chapter III that we could not reject the null hypothesis on the equality of output elasticity of labor under both old and new production technology. Another main result from this analysis was the increased importance of purchased inputs, fertilizer and capital, in generating employment.

(4) The decomposition analysis (Table IV.7) with equation (45), based on the UOP Profit Function Model, illustrated the effects of technology, normalized wage rate and complementary

inputs on employment. Due probably to high standard error of β_n of new technology, the "unexpected" negative employment effect (74.7 percent) was not offset by positive employment effect (51.0 percent) of complementary inputs. As a result, the estimated change in employment was substantially different from the actual.

The decomposition analysis (Table IV.8) with equation (47), assuming Hicks-neutral technical change, yielded us satisfactory results. The positive employment effects of technology (20.2 percent) and of complementary inputs (49.3 percent) were strong enough to offset the negative employment effect (14.5 percent) of higher normalized wage rate under new technology due to lower price per unit of Mexican wheat.

CHAPTER V

TECHNOLOGICAL CHANGE AND FUNCTIONAL INCOME DISTRIBUTION

The present chapter is concerned with: (1) reviewing income distribution models emphasizing personal and functional income distribution; (2) developing an economic model for analyzin the effects of technological change on functional income distribution; and (3) evaluating the functional income distribution effects of technological change with empirical data.

Review of Income Distribution Models

Scitovsky (1964), in surveying the major competing theories of income distribution, points out that there are four possible subjects that theories of income distribution could deal with: the distribution of income by occupations (agriculture vs. non-agriculture), by size, by factor shares, and by income categories of the official personal income accounts. We add regional distribution involving the division of income by regions within a country. Personal and functional income distribution models are the relevant ones for our study.[1/]

1. Personal Income Distribution Models:

By personal income distribution we mean the division

1/ The present study is not concerned directly with the personal income distribution questions. The intent is to bring out some suggestive implications of changes in functional income distribution to personal income distribution.

of income by size, or more precisely, by size brackets of the income or wealth of economic units. One may distinguish two stages in the evolution of personal income distribution models.[2/]

The first includes efforts to summarize, measure, and interpret the varieties of statistical frequency distributions of income. The second attempt includes the studies using multivariate statistical analysis of "casual" factors associated with size distribution of individual income. Human capital models are gaining importance in this category. Johnson (1973, page 206) distinguishes two kinds of concern with personal income distribution; one with inequality, that is, the dispersion of income about the mean; the other with poverty, that is, the existence of people whose incomes are below some minimum level. Perhaps in the Indian context, the second requires more urgent consideration. More on this later.

2. Functional Income Distribution Models:

By functional distribution we mean the division of income among the different factors of production. Two streams of theory can be distinguished in the income distribution literature.

The first concentrates on the technological laws of production, on individual decision processes of business firms and factor suppliers. It is microeconomic in orientation, and

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2/ See Mincer (1970) for details.

is oriented towards the marginal productivity approach.[3/] The acceptance of the marginal productivity theory of income distribution is closely bound with the aggregate production function. The present study is based on this analytical framework.

The second major stream of theory is macroeconomic in character, and is based on the consumption and saving habits of income receivers. It is in the Keynesian tradition[4/]. The present study is not concerned with this aggregative approach.

How are personal and functional income distributions related? Individuals or households own or control various quantities of primary factors of production--land, labor, capital --which determine their income shares. These functional shares determine the distribution of personal or household income. Technical change could affect personal distribution of income by changing the functional distribution. More on this later.

Economic Model

The main concern here is to decide on an economic model for analyzing the effects of technological change on functional income distribution. Technical change may give rise

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3/ Details on this can be found in Hicks (1964) and Douglas (1948). Kalecki (1954) has advanced an alternative microapproach to functional income distribution. His model relates income distribution to the entrepreneur's pricing policy and profit margin, and thus goes beyond the assumption of competitive factor and product markets.

4/ A detailed exposition of this macro model can be found in Kaldor (1956).

to different dimensions of income distribution problems. First, new technology in wheat production is highly selective in its adaptation to particular ecological zones. There is a technical dichotomy - the division of agricultural regions into those that are suitable for the improved production system and those that are not. So primary productivity gains accrue to farmers in a particular region. Studies by Chowdhury (1970), Santana (1970), and Sen (1969) have dealt with the implications of new production technology for inter-regional income distribution. Second, technical change may affect the pattern of income distribution among various size groups of farmers within a region where the new production technology is adopted. Studies by Kahlon (1970), Singh and Sandhu (1971), and Srivastava, Crown and Heady (1971) have evaluated these effects.[5/] Third, technical change affects the distribution of income among factors of production. This is the concern of the present study.

5/ Kahlon found that because of the divisible nature of new technology farm incomes of the big farmers rose even faster in Punjab and Haryana. However he argues that large farmers spend a greater proportion of their income on purchase of technological inputs which would broaden the income distribution. Using data from 126 farms of Ludhiana district in Punjab state, Singh and Sandhu found some evidence of uneven distribution of income among different farm size groups. Srivastava, Crown and Heady (1971) have provided a theoretical basis on how "Green Revolution" could exaggerate inter-farm income disparities.

Now we turn to the formulation of relevant economic model for the purpose.

Hicks (1936, 1964) provided analytical tools which are useful in evaluating the effects of technical change on factor shares. These analytical tools have been the basis o the neoclassical theory of functional income distribution. The neoclassical approach first assumes that the production function is a useful empirical tool, and it also assumes that factor shares depend on marginal productivities. The assumption of perfect competition in factor and product markets is built into the model. The present study makes use of the neoclassical approach, assuming changes in functional income distribution are revealed in changing production technology in the wheat farming sector of the Punjab.

Two propositions in the neoclassical tradition theory define the relation between technical change, elasticity of substitution (σ), and factor shares.[6/] The first holds that a factor-saving technical change, ceteris paribus, reduces the share of that factor in total income. The second maintains that if the supply of one factor increases more rapidly than another, the elasticity of substitution (σ) will affect relative shares in the following way:

6/ In addition to these two propositions, Brown and Cani (1963) add a third: an increase in the elasticity of substitution reduces the share of the scarcer factor. Kennedy and Thirlwall (1973) have questioned this proposition. For a detailed discussion see Kennedy and Thirlwall (1973).

(a) If $\sigma < 1$, the relative share of plentiful factor will decrease.

(b) If $\sigma = 1$, the shares will stay constant

(c) If $\sigma > 1$, the share of plentiful factor will rise

Since our production function framework is based on the Cobb-Douglas tradition, relative factor shares remain unchanged even with a change in relative factor prices, because the elasticity of substitution between inputs is assumed to be unity. The unitary elasticity of substitution assures that relative income shares of factors will be constant for any change in the relative supplies of factors. If elasticity of substitution is unity, the change in relative price just compensates for relative change in quantity and relative shares are unchanged. So in the Cobb-Douglas framework, technical change alters relative factor shares only when it changes the ratios of the partial elasticity of production. This reduces the evaluation of effects on functional income distribution to evaluating the nature of technical change, neutral versus non-neutral.

We recall from Chapter III that technical change can be classified as Hicks-neutral or Hicks-biased on the basis of changes in the output elasticities. It is also established that in the Cobb-Douglas tradition, the factor share of total

income is equal to its output elasticity.[7/] With this definition, we examine the effects of technical change on factor shares in a two-factor framework and four-factor framework.

1. Two-Factor Model:

If technical change introduced into wheat farming is neutral, the following result will hold for functional income distribution:

$$\left(\frac{S_n}{S_k}\right)_{MW} = \left(\frac{S_n}{S_k}\right)_{LW} \qquad (1)$$

where S_n and S_k are the shares of labor and capital from total income respectively. The absolute share of both factors is increased, but the ratio of relative factor share is unaltered. The effect on income distribution is neutral. If technical change is neutral, the elasticity of substitution and the direction of change in relative input supplies are the only factors governing the behavior of relative shares. Since we are working in a Cobb-Douglas framework, neutral technical change and unitary elasticity of substitution imply

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7/ For the share which labor receives, let WN = the total wage bill paid to labor.
Marginal productivity of labor = β_n (Y/N)

$$WN = N\beta_n \frac{Y}{N} = \beta_n Y$$

$$\beta_n = \frac{WN}{Y}$$

Similarly, for land, fertilizer and capital.

not only that the ratio of relative factor share is unaltered at a point in time, but that it is also unaltered over a period of time for a given technology.

A non-neutral technical change may give rise to the following configurations of income distributions:

(1) Both the absolute and relative share of a given factor, say capital, may be increased; but technical change increase only the absolute income of the other factor, that is, labor. It implies that

$$\left(\frac{S_n}{S_k}\right)_{MW} < \left(\frac{S_n}{S_k}\right)_{LW} \quad \text{and} \quad (S_n)_{MW} > (S_n)_{LW} \qquad (2)$$

(2) Both the absolute and relative share of capital may be ncreased; there is not merely a decrease in the relative hare of labor, but also a decrease in its absolute share. his implies that

$$\left(\frac{S_n}{S_k}\right)_{MW} < \left(\frac{S_n}{S_k}\right)_{LW} \quad \text{and} \quad (S_n)_{MW} < (S_n)_{LW} \qquad (3)$$

This kind of non-neutral technical change is called very or "ultra" capital-biased and labor-saving. In both cases, the relative share imputed to labor is changed in the same direction, but the absolute share moves in an opposite direction. The final outcome depends on how partial output elasticities of these factors of production are affected by technical change.

2. Four-factor Model:

We recall from Chapter III that technical change can be classified on the basis of changes in the output elasticities. In the preceding section, we have shown that output elasticity is identical to factor share in the Cobb-Douglas framework. With these definitions we propose a single measure of effects of technical change on factor share as follows:

$$D_i = \frac{dSi}{dT}\,\frac{1}{Si} \begin{matrix} > \\ = \\ < \end{matrix} 0 \quad \left.\right\} \begin{matrix} \text{Share of factor -i increases} \\ \text{Share of factor -i remains constant} \\ \text{Share of factor -i decreases} \end{matrix} \qquad (4)$$

where D_i is a measure of the proportionate rate of change in factor share, S_i is the income share (output elasticity) of factor i, and dT indicate change in production technology (with T denoting technology) as represented by Mexican wheat production. We propose to make use of the following expression in discrete form for computational purpose. In an arbitrary way D_i is defined as follows:

$$D_i = \frac{(S_i)_{MW} - (S_i)_{LW}}{(S_i)_{LW}} \begin{matrix} > \\ = \\ < \end{matrix} 0 \quad \left.\right\} \begin{matrix} \text{Share of factor -i increases} \\ \text{Share of factor -i remains constant} \\ \text{Share of factor -i decreases} \end{matrix} \qquad (5)$$

In developing our economic framework - the two-factor model as well as the four-factor model - we have assumed constant returns to scale. This is the framework we employ in

evaluating the effects of technical change on functional income distribution in the case of per acre analysis which involves constraining homogeneity to be of degree one. However in evaluating the functional income distribution effects with per farm estimates, we have to incorporate the effects of change in returns to scale on factor shares. In this case, our estimated factor share is the ratio of the elasticity of production of a given input to the sum of the production elasticities. This ratio is called the relative factor production elasticity. It may be expressed as follows for labor (N) in two-factor model as

$$\frac{\beta_n}{\beta_n+\beta_k} \qquad (6)$$

where β_n denotes the elasticity of production with respect to labor, β_k denotes the elasticity of production with respect to capital, and $(\beta_n + \beta_k)$ yields the sum of production elasticities.

Relative factor production elasticity say for labor (N), in four-factor model may be expressed as follows:

$$\frac{\beta_n}{(\beta_n+\beta_l+\beta_f+\beta_k)} \qquad (7)$$

where β_n, β_l, β_f, and β_k denote production elasticities of labor, land, fertilizer and capital respectively, and $(\beta_n + \beta_l + \beta_f + \beta_k)$ denotes the sum of production elasticities.

Therefore, in our four-factor model, following two expressions are used for evaluating the functional income distribution effects.[8/]

$$n = \frac{(S_n)_{MW} - (S_n)_{LW}}{(S_n)_{LW}} \qquad (8)$$

$$D_n = \frac{\left(\frac{S_n}{S_n+S_l+S_f+S_k}\right)_{MW} - \left(\frac{S_n}{S_n+S_l+S_f+S_k}\right)_{LW}}{\left(\frac{S_n}{S_n+S_l+S_f+S_k}\right)_{LW}} \qquad (9)$$

Expression (8) is used for per acre analysis, and (9) for per farm analysis.

Empirical Analysis

An empirical determination of the effects of technical change on factor shares involves three basic questions. First, how different are estimated from actual factor shares? Second, what is the direction and magnitude of change in factor shares between old and new production technology? Third, what is the direction and magnitude of the absolute changes in actual factor shares? These three questions are investigated under three headings.

8/ These expressions are for labor. The same formulation would hold for other inputs with appropriate substitutions.

1. Comparison of Estimated and Actual Factor Shares:

Let us examine one of the most important features of the theory of production and of distribution, namely, the relative degree to which the actual shares received b inputs approximate those which we would expect from the values estimated from the production function. From our earlier discussion, under perfect competition with a production formula of Cobb-Douglas type, we would expect factor to receive as its share of the product, the proportion indicated by its exponent in the case of constant return to scale, and by its relative factor production elasticity if returns to scale differ from unity. With this proposition on hand, we examine the comparability of estimated and actua factor shares. Per farm estimates of relative factor production elasticity are shown in Table V.1 which is self explanatory. In Tables V.2 and V.3 are shown estimated and actual factor shares for per farm and per acre respectively.

Table V.1: Relative Factor Production Elasticity, Per Farm Estimates

Factor of Production	Relative Factor Production Elasticity*		
	1967/68 (LW)	1967/68 (MW)	1967/68-1968/69 (MW)
Land	0.634	0.498	0.550
Labor	0.213	0.088	0.124
Fertilizer	0.093	0.111	0.100
Capital	0.060	0.302	0.225

Note: * Relative factor production elasticities are computed by using expression (7). Parametric values for computation are drawn from Table III.9.

Table V.2: Estimated and Actual Factor Shares, Per Farm Analysis

Sample (1)	Factor of Production (2)	Estimated Factor Share 1/ (3)	Actual Factor Share 2/ (4)	Degree to which the Actual Differs from the Estimated in Terms of Standard Errors 3/ (5)
1967/68(LW)	Land	0.634	0.553	-1.00
	Labor	0.213	0.165	-0.59
	Fertilizer	0.093	0.045	-2.82
	Capital	0.060	0.237	+1.88
1967/68(MW)	Land	0.498	0.570	+0.78
	Labor	0.088	0.153	+0.70
	Fertilizer	0.111	0.070	-0.78
	Capital	0.302	0.207	-0.85
1967/68-1968/69(MW)	Land	0.550	0.472	-1.04
	Labor	0.124	0.192	+0.88
	Fertilizer	0.100	0.084	-0.59
	Capital	0.225	0.252	+0.32

Notes: 1. Column (3) is the same as relative factor production elasticity, So numbers are drawn from Table V.1.

2. Column (4): proportion of income accrued to each factor from gross income:
Let WN = total wage bill
F = Fertilizer bill
K = Capital bill

PY = total gross income from wheat production

$\frac{WN}{PY}$ = labor share

$\frac{F}{PY}$ = fertilizer share

$\frac{K}{PY}$ = capital share

$1 - \left(\frac{WN}{PY} + \frac{F}{PY} + \frac{K}{PY}\right)$ = land share

So land share is treated as a residual, and land a residual claimant. As we stated in Chapter II Punjab agriculture is an economy of peasant proprietors so far as the type of business organization is concerned. So treating land owner-operator as a residual claimant is a reasonable assumption. However we do recognize that part of the residual accruing to landowners may be a return to management.

3. Column (5) is computed as follows:

$$\frac{WN - \beta_{n/\gamma}}{\sigma_n} = t - \text{value (observed)}$$

where:

WN = actual labor share

$\beta_{n/\gamma}$ = estimated labor share (relative factor production elasticity of labor); β_n denotes the output elasticity of labor; and $\gamma = \beta_l + \beta_n + \beta_f + \beta_k$ = returns to scale.

σ_n = Standard error associated with the coefficient of labor input.

So column (5) is <u>approximately</u> the observed t-value. With appropriate substitutions t-values are computed for other inputs as well.

Table V.3: Estimated and Actual Factor Share, Per Acre Analysis 1/

Sample (1)	Factor of Production (2)	Estimated Factor Share 2/ (3)	Actual Factor Share 3/ (4)
1967/68(LW)	Land	0.626	0.553
	Labor	0.216	0.165
	Fertilizer	0.091	0.045
	Capital	0.067	0.237
1967/68(MW)	Land	0.568	0.570
	Labor	0.065	0.153
	Fertilizer	0.092	0.070
	Capital	0.275	0.207
1967/68-1968/69(MW)	Land	0.587	0.472
	Labor	0.103	0.192
	Fertilizer	0.105	0.084
	Capital	0.205	0.252

Notes:

1. Column(5) of Table V.2 is not repeated in Table V.3. The reason is that the observed t-values indicated in column (5) of Table V.2 are almost the same for Table V.3, since estimated factor shares in per farm analysis differ little from per acre analysis and actual factor shares are identically the same.

2. Estimated factor shares in column (3) are the same as relative factor production elasticity. These are computed by drawing parametric values from Table III.10 and by using expression (7). Since the sum of production elasticities adds up to one in the case of per acre production function estimates, relative factor production elasticity of a given input is equal to its output elasticity.

3. Actual factor shares in column (4) are computed on the same lines as explained in note (2) of Table V.2. However the identity of actual factor share for per farm estimates and for per acre estimates needs explanation:

$$\frac{\sum_{i=1}^{j=n} W_i N_i}{\sum_{i=1}^{j=n} P_i Y_i} = \text{per farm actual labor share}$$

where, $W_i N_i$ is the total wage bill of ith farm and $P_i Y_i$ is the gross income of ith farm.

$$\frac{\sum_{i=1}^{j=n} W_i N_i / \sum_{i=1}^{j=n} L_i}{\sum_{i=1}^{j=n} P_i Y_i / \sum_{i=1}^{j=n} L_i} = \frac{\sum_{i=1}^{j=n} W_i N_i}{\sum_{i=1}^{j=n} P_i Y_i} = \text{per acre actual labor share.}$$

where, $W_i N_i$ and $P_i Y_i$ are defined as above; the definition of L_i includes the number of acres operated by ith farm. The above illustration is with respect to labor share. The same applies to other inputs with appropriate substitutions.

With the empirical results shown in Table V.2 and V.3, let us examine the comparability of actual factor share with the estimated ones. In Table V.2 the differences between actual and estimated factor shares are not statistically significant at $\alpha = 0.05$ in the case of all samples except fertilizer share and capital share under local wheat. With these two exceptions, there is a close agreement between what we would have theoretically expected the distribution of the product to be under the Cobb-Douglas production formula and that which actuall oc-----. The degree of agreement seems to suggest that results conform to what normally would be expected to occur under marginal productivity theory.

The t-values represented in Table V.2 suggest that, except in the case of fertilizer and capital under old technology, that we cannot reject the null hypothesis that the actual factor shares are equal to estimated factor shares. In the case of fertilizer, the observed t-value of -2.82 exceeds the critical t-value of 2.576 at $\alpha = 0.005$; for capital, the observed t-value of 1.86 exceeds the critical t-value of 1.645 at $\alpha = 0.05$. This implies that fertilizer appears to be underpaid and capital overpaid relative to their observed prices in comparison with their contribution to output under the old technology. To put this differently, the local wheat farmers, as decision makers, seem to have made allocative errors in the sense that they used less fertilizer and more capital than the quantities warranted by the principle of equating marginal value product (MVP) of these inputs to their respective prices.

Actual factor shares are expected to equal the estimated factor shares if resources are optimally allocated given observed prices. Why are the allocative errors by local wheat farmers whereas the Mexican wheat farmers do not seem to have made this error.[8/] One would expect the absence of allocative errors in the

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	Local wheat	Mexican whea
Marginal value product of fertilizer (MVP_f)	4.44	1.24
Price of fertilizer per kilogram (P_f)	0.84	0.84
Marginal value product of capital (MVP_k)	0.27	1.14
Price of capital (P_k)	1.42	1.43

case of local wheat because farmers have been growing this variety for quite some time. A priori we would expect $(MVP_f - P_f)_{LW} < (MVP_f - P_f)_{MW}$ and $(MVP_k - P_k)_{LW} < (MVP_k - P_k)_{MW}$. This is to mean that we expect $MVP_f \approx P_f$ and $MVP_k \approx P_k$ under old technology, and $MVP_f \neq P_f$ and $MVP_k \neq P_k$ under new technology. Hiebert (1974) pursuasively argues that when a particular innovation such as fertilizer and new seeds are to be adopted, decision makers may perceive the production function parameters of the new technology as early as the old technology. As the innovation process procedes, with additional information and experience decision makers more clearly perceive the production characteristics of the new technology and hence decrease the possibility of making allocative mistakes. So a priori allocative errors are a possibility in the case of Mexican wheat farmers whereas it is apparantly surprising to observe this in the case of local wheat farmers.

One could come out with three possible reasons for $MVP_f < P_f$ in the case of old technology. First, this allocative error is likely to happen if the local wheat farmers have less educational background than the Mexican wheat farmers.[9/] But in the absence of adequate data on difference in educational level, nothing definite can be said on this. Second, the allocative

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9/ Huffman (1974) has demonstrated that the rate of adjustment to disequilibrium in the usage of nitrogeneous fertilizer in the case of Midwestern U.S. farmers is positively related to the level of education of farmers in addition to other things.

errors could happen if opportunity cost of fertilizer confronting local wheat farmers is higher than the price confronting Mexican wheat farmers. There is no reason to accept the validity of this hypothesis, since fertilizer price is government regulated. Third, this allocative error could also happen if growing local wheat is riskier than growing Mexican wheat.[10/] But one tends to think converse as true. In addition to these three explanations, one other possible reason might be that fertilizer was not available in adequate quantity at the government regulated price during the year 1967/68. Why could this "availability hypothesis" be relevant in the case of local wheat farmers alone? This could follow possibly from the "economic power" enjoyed by more progressive farmers who are likely to be early adopters of new technology.

In the case of fertilizer, we have explored four possible reasons for $MVP_f > P_f$ under old technology. In the case of capital MVP_k is less than P_k. This kind of allocation error is possible if educational level of local wheat farmers is low. But, as we discussed already, we dont have adequate data to test this hypothesis. The "differential opportunity cost" hypothesis and "differential risk hypothesis" dont seem to be relevant for this case. So we do not have adequate explanation for this kind of allocative error at this stage.

10/ See Hiebert (1974) on allocative errors caused by risk preferring, risk neutral and risk averting attitudes of decision-makers.

2. Direction and Magnitude of Change in Factor Shar...

The second question which we want to examine has to do with the determination of direction and magnitude of difference in factor shares between old and new production technology. Results are shown in Tables V.4 and V.5. Results in column (3) of Tables V.4 and V.5 indicate the direction and magnitude of change in technology-determined factor share. In broad terms two observations may be made on these results:

First, the relative share of fertilizer (F) and capital (K) has increased, but the rate of increase in capital share is substantial; this follows from the difference in output elasticity of capital under the two production technologies. Since the "slope dummy variable" for capital (K) is significant (Tables III.2 and III.3, Chapter III) the rate of increase in share of capital is significant as well. The "slope dummy variable" for fertilizer (F) is not significant (Tables III.2 and III.3, Chapter III) at any reasonable level. So the magnitude of change in factor share in the case of fertilizer (F) between old and new production technologies is not statistically significant.

Table V.4: Change in Factor Share, Per Farm Analysis

Sample	Factor of Production	$D_i = \frac{(S_{i/\gamma})_{MW} - (S_{i/\gamma})_{LW}}{(S_{i/\gamma})_{LW}}$
(1)	(2)	(3)*
1967/68(LW) versus 1967/68(MW)	Land	-0.215
	Labor	-0.587
	Fertilizer	+0.194
	Capital	+4.033
1967/68(LW) versus 1967/68-1968/69(MW)	Land	-0.132
	Labor	-0.418
	Fertilizer	+0.075
	Capital	+2.750

Notes: * Expression in column (3) is a generalized version of expression (9), where $\gamma = S_l + S_n + S_f + S_k$.

Parametric values for computing column (3) are drawn from Table V.2.

Table V.5: Change in Factor Share, Per Acre Analysis

Sample	Factor of Production	$D_i = \frac{(S_i)_{MW} - (S_i)_{LW}}{(S_i)_{LW}}$
(1)	(2)	(3)*
1967/68(LW) versus 1967/68(MW)	Land	-0.093
	Labor	-0.699
	Fertilizer	+0.011
	Capital	+3.104
1967/68(LW) versus 1967/68-1968/69(MW)	Land	-0.062
	Labor	-0.523
	Fertilizer	+0.154
	Capital	+2.060

Notes: *Expression in column (3) is a generalized version of expression (8). Parametric values for computing column (3) are drawn from Table V.3.

Second, the share of land and labor has decreased; but the rate of decrease is greater for labor. Since the "slope dummy variables" for land (L) and labor (N) are not statistically significant (Tables III.2 and III.3, Chapter III) at any reasonable level, the rates of decrease shown in column (3) of Tables V.4 and V.5 are not statistically significant.

Thus the major conclusion that follows from the above discussion is that with respect to functional income distribution new production technology in wheat production is neutral regarding land, labor and fertilizer, but biased in favour of capital.

3. Direction and Magnitude of Change in Actual Absolute Factor Shares:

So far we have been examining rate and direction of change in technology-determined factor share. The discussion has centered around relative position of a factor in terms of the fraction acrrued to it under two production technologies. We recall from the previous section that the functional income distribution effects of new technology on land, labor and fertilizer are neutral, but biased in favor of capital. But determining the direction and magnitude of change in the actual absolute factor share provides a better perspective on functional income distribution problems. The present section is concerned with this issue. Since we have homogeneity with respect to both the region and the production year, the absolut

change in actual factor share is discussed with per acre results from Sample I. Results are shown in Table V.6.

It can be seen in Table V.6 that all factors in absolute terms stand to gain under new production technology, but the percentage of gain varies. Percentage of gain is greater for land than for labor.

Table V.6: Percentage Change in Absolute Actual Factor Share, Per Acre Analysis, Sample I, 1967/68

Factor of Production (1)	Absolute Share From an Acre of Wheat Total Revenue(LW)* (2)	Absolute Share from an Acre of Wheat Total Revenue(MW)* (3)	Percentage Change in Absolute Factor Share (4)
Land	Rs. 377.55	Rs. 563.00	49
Labor	112.65	151.12	34
Fertilizer	30.72	69.14	125
Capital	161.81	204.46	26

Notes: *Per acre total revenue from an average local wheat farm is Rs 682.73, and from an average Mexican wheat farm it is Rs 987.72. Absolute shares for each factor are obtained by multiplying total revenue by the percentage shares shown in Column (4) of Table V.3.

This has implications to personal income distribution which will be discussed in the next section. The largest percentage gain to fertilizer is consistent with the fact that fertilizer is a basic ingredient of new production technology. The small

percentage gain to capital follows from the earlier discussion that capital appears to be overpaid in comparison with its contribution to output under old production technology.

Summary of Empirical Results and Some Implications for Personal Income Distribution

In broad terms two results from the empirical analysis of the effects of technical change on functional income distribution may be cited. First, the functional income distribution effects of new technology on land, labor, and fertilizer are approximately neutral, but is biased in favor of capital. This is the conclusion suggested by estimated factor shares; Second, if we examine percentage change in absolute factor share, all factors of production stand to gain, but percentage gains to land and fertilizer seem to be greater than the gains to labor and capital.[11/]

Before outlining the implications suggested by the above results on personal income distribution, a review of evidence on personal income inequalities, consumption inequalities, and the percentage of the people below "poverty line" is in order. Ojha and Bhatt (1971) reported that overall income distribution in India is not merely highly skewed at a point in time, but it became slightly more unequal in 1961/64

11/ In appendix III are presented the results on change in functional income distribution under new production technology between two points of time, that is, 1967/68(MW) versus 1970/71(MW).

than it was in 1953/55.[12/] National Sample Survey (NSS) estimates (in Fourth Five Year Plan) for the year 1967/6 indicated that the share of the bottom 10 percent of the population in rural areas was 4 percent of total consumption whereas the share of top 10 percent was about 23 percent. This indicated the relative position of a spending unit in the structure of the consumption hierarchy. Relative poverty is found to exist even in affluent societies. So for a developing country, a useful criterion for income distribution problem is to observe change over time in the percentage of people below a well defined minimum standard of living. This amounts to measuring changes in the absolute or relative incidence of poverty over a period of time. Table V.7 presents a summary of various estimates on the percentage of rural population with an absolute level of poverty. These studies have followed different estimation procedures, and there are differences in their estimates.[13/] It is beyond the scope of

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12/ For a documentation of results from various studies see Abel (1971); and Rajaraman (1974).

13/ In Ojha's study (1970), the difference in terms of quantity between the minimum caloric requirements and the actual consumption for each expenditure group represents the nutritional deficiency. The percentage of deficiency to the estimated norm represents index of poverty. In Bardhan's studie(1970a, 1970b, 1973), those whose consumption expenditure is less than Rs 15 per month in 1960/61 prices come under the category of below poverty line. Bardham employed separate price deflators for the poorer sections of the rural population than the remainder of rural population to get real levels of consumption expenditures in 1967/68. In Rajaraman's study (1974), poverty line is constructed at 1960/61 prices on the basis of a least cost diet determined by a process of linear minimization subject to nutritional and other constraints.

able V.7: Percentage of the Rural Population Below the Poverty Line

Study	Percentage of Rural Population with Absolute Level of Poverty
1. Ojha (1970):	
All India:	
1960/61	51.20
1967/68	70.00
2. Bardhan (1970a, 1970b, 1973):	
All India:	
1960/61	38.00
1967/68	53.00
Punjab:	
1960/61	13.00
1967/68	32.00
3. Rajaraman (1974)	
Punjab:	
1960/61	18.31
1970/71	22.51

this study to comment on methodologies used by these researchers However, one thing that is unmistakenly clear is an increase in the percentage of rural population below whatever poverty line is chosen. The Dandekar-Rath study (1971a) has also found the same trend. It is more disturbing to observe thi trend in Punjab which is said to be a "show case" of the Green Revolution.

From an examination of the above evidence on some dimensions of personal income distribution in India as a whole and Punjab in particular, let us turn to discuss the personal income distribution implications suggested by the empirical results summarized earlier. There are two paths through which technical change affects personal income distribution. First, the nature of technical change, that is, neutral or non-neutral; second, the distribution of productive assets-especially land in our case.

From our earlier discussion we know that the functional income distribution effects of technical change in wheat production are neutral, even though the percentage of gain in actual absolute labor share is a bit lower than that of land. However, the personal income distribution problems arise from the second factor, namely, the distribution of productive assets especially land in the Indian context. We borrow the

following expression[14/] from Meade (1964 Appendix II) to indicate possible personal income distribution problems:

$$Z = [WN] + [VU] \qquad (10)$$

where:

Z = farm family income;

N = number of hours worked;

W = wage rate per hour;

U = amount on non-human property, basically land in our case;

V = the rate of return on property (Land).

It is obvious from equation (10) that a farm family income is the sum of the payments to factors of production owned by it. This framework allows us to analyse farm family income inequality as a function of the distribution of factors of production and the rates of return to them. The distribution of labor earnings (WN) will be influenced significantly by the distribution of working members of the family in our case. In the case of landless farm families, the second bracketed expression vanishes. With the introduction of new production technology an increase in W alone would increase

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14/ Gardner (1969) has used this framework with a transitory component (the transitory component being the unanticipated income) added for analysing farm income inequalities. Martin (1972), using the same framework, examines the correlation between WN and VU and its implication to variance of Z.

farm labor family income from labor alone.[15/] An increase in N alone would increase family income. We know from Chapter IV that there has been over a 37 percent increase in the number of hours employed per acre on Mexican wheat farms compared to local wheat farms. However two important developments may work against the farm labor families. First, higher wage rate may lead to substitution of family labor for hired labor by land owing farm families.[16/] Second, as reported by Billings (1970), farmers in the Punjab have responded to labor shortage during peak seasons by substituting a more capital-intensive technology for certain critical operations.[17/] We have indicated some broad developments which

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15/ It is reported [in Statistical Abstract of Punjab (1974)] that money wages paid to agricultural laborers (men) increased from Rs 3.82 to Rs 6.46 for plowing, from Rs 3.73 to Rs 6.47 for sowing, and from Rs 3.94 to Rs 7.71 for harvesting during the years 1966 and 1970 respectively. Evidences on gains in real wages are conflicting. See Bardhan (1970b) and Herdt and Baker (1972) on this issue.

16/ See Kahlon (1971) on this development.

17/ The study of Billings suggested that the introduction of mechanical harvesting would eventually result in a net decrease of about 90 million man days of employment in Punjab. Sidhu (1972) provided empirical evidence on the fact that there are no differences in over-all economic efficiency and its components (technical and price efficiency) between tractor and non-tractor farms. There is no evidence of significant difference in land productivity but the input composition is different. Farms with tractors use more than 100 percent more capital per acre than farms without tractors; they displace not merely animal power, but human labor as well. This displacement effect of tractor mechanization alone on labor is in the order of about 25 percent per acre.

may alone work against the economic well-being of farm families with nothing but labor to offer.

Let us look more closely at the ways in which the new production technology might operate on the expression (10) in the case of land-owning families. Given N and U, an increase in W and V alone would increase family income. If an increase in W places a premium on leisure and social status, given U, an increase in W, N and V would increase family income. We are particularly interested in V and U because assets (particularly land) play an important role in agriculture.[18/] Table V.8 shows some evidence on the land ownership pattern in Punjab. It is evident in Table V.8 that in the Punjab more than 37 percent of all rural households operated farms of less than 5 acres and accounted for less than 7.5 percent of the area. By contrast, the top 13 percent of the households cultivated holdings of 20 acres or more and controlled over 40 percent of the area. The situation after 1966, when the old Punjab was divided into two states of Punjab and Haryana is less clear.[19/] Given the skewed distribution of land ownership, and given the increase in V by 49 percent (Table V.6), expression (10) implies

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18/ The distribution of asset as a prime determination of income distribution in developing countries is emphasized by Ahluwalia and Chenery (in Cline 1975, p. 373).

19/ Rajaraman (1974) reported that land distribution in the new state of Punjab seems to have worsened over the ten year period, that is, from 1960/61 to 1971/72.

Table V.8: Distribution of Cultivators and Cultivated Areas in Old Punjab State by Size of Operational Holdings, 1961-62

Item	Acres			
	Less than 5.00	5.00-9.90	10.00-19.90	20.00 and above
Percentage of rural households in the group sampled	37.5	24.8	23.8	13.4
Percentage of the cultivated area for the group sampled	7.4	18.3	33.0	40.7

Source: Frankel (1973)

the changing income distribution in favor of land-owning families. With a considerable increase in V the gain in income increases linearly with the amount of land owned. In the absence of offsetting fiscal measures, income distribution problems would come to surface.[20/]

20/ Although the Committee on Taxation of Agricultural Wealth and Income (1972) reported agricultural income per capita in the Punjab to be about twice as high as in the rest of India, the total yield from land revenue, surcharges and special charges, cesses on commercial crops etc amounted to less than 0.4 percent of the net domestic product originating in agriculture compared to nearly 1.0 percent for the country as a whole. See Rao (1974) for some details on inequitable tax policy.

This increase in income to land made possible in part by the introduction of new technology has capitalized into increased land value. Herdt and Cochrane (1966) provided both theoretical and empirical evidence that the expectation of rising income from technological change in conjunction with farm support prices was important in contributing to the rise in farm land prices in the U.S.[21/] In Punjab, the increased land productivity resulting from the introduction of new technology has resulted in increased values at almost no cost to the owner.[22/]

The preceding discussion of the implications of change in functional income distribution for personal income distribution, given labor-displacing trends and skewed distribution of land ownership, may lead one to predict tensions in rural areas. Perhaps one may be led to believe Gray's (1931, p. 189) remarks that " . . . Ricardo provided, all unwittingly, the foundation stones of so-called scientific socialism. The doctrine of rent, especially if one forgets that Ricardian rent is an abstraction, appears as an instigation to agrarian socialism."

21/ Also see Chryst (1965) and Floyd (1965) for interesting discussions of this issue.

22/ See Frankel (1973) for details on this development.

CHAPTER VI

SUMMARY AND CONCLUSION

Considerable growth in output per acre (about 40 percent) accompanied the introduction of new production technology into the Punjab wheat economy during 1967/68. This has given rise to many interesting issues in the fields of growth, employment and income distribution. Questions arise with respect to the sources of this growth in output and the impact of this new technology on employment and income distribution.

The main objective of this study was a quantitative assessment of some of these issues using farm-level primary cross section data from the Indian Punjab for the years 1967/68 to 1970/71. Specifically, the major objectives were: (1) to decompose total difference in per acre output between farms employing new technology and those employing old into two broad forces, namely technological change and change in the volume of (complementary) inputs, (2) to determine employment elasticities with respect to certain key economic variables, (3) to decompose total difference in per acre employment with the introduction of Mexican wheat into relevant forces - technical change, output change, change in input prices and input quantities, and (4) to determine the direction and magnitude of changes in functional income distribution.

For empirical implementation of the objectives listed above, interrelated economic models based on the neoclassical

theory of production and distribution were used. Questions of sources of output growth were approached with the help of aggregate (Cobb-Douglas) production functions. A derived labor demand function provided the theoretical foundation for estimating employment elasticities with respect to output and input prices, and for decomposing total change in employment into technology, output and input prices. A labor demand function derived from the UOP profit function provided the theoretical framework for determining employment elasticities with respect to normalized wage rate and quantities of land, fertilizer and capital, and for decomposing total change in per acre employment into technological changes, and differences in normalized wage rate and quantities of complementary inputs such as fertilizer and capital. The neoclassical theory of distribution, based on the aggregate production function, was used in determining the direction of change in functional income distribution.

The farm level primary data, on which the empirical analyses are based, came from private farms of the Indian Punjab Input-output data, collected by the Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India, for the years 1967/68 and 1968/69 in the Ferozepur district of Punjab, data collected by the Government of Punjab for the year 1969/70 and data collected by Sidhu (1972) for the year 1970/71 provide the data basis for this study.

Sampling methodology used in collecting these data, and definition and measurement of variables used in empirical estimation are discussed in Chapter II.

Empirical Findings and their Policy Implications

Empirical findings and their policy implications are discussed under three headings:

1. Sources of output growth:

The need for efforts to increase the rate of growth of farm output in India requires hardly any emphasis. A 40 percent increase in per acre output on a Mexican wheat farm compared to a local wheat farm has added to the urgency of investigating the sources of this phenomenal growth. The main rationale for this kind of investigation is to gain an increased understanding of sources of output growth, and this increased understanding hopefully indicates the directions in which efforts will have to be made for raising the rates of growth and productivity increases in the agricultural economy. For any production function, the total change in output is brought about by shifts in the parameters that define the function itself and by changes in the volume of inputs. An essential ingredient of technical change is a shift in the production function such that a larger output is obtained from a given level of inputs or a given level of output can be obtained with smaller quantities of inputs. So technical change affe[illegible] the sources of output

growth by shifting the parameters A and β_i's. In Chapter III, measured output growth of about 40 percent per acre with the introduction of Mexican wheat is decomposed into technological change and change in the volume of inputs; about 15 percent of the increase in output is attributable to technical change and 25 percent to increased inputs, the major contribution (15 percent) being made by fertilizer.

A quantitative assessment of the two sources of output growth has two important implications for development policy:

(1) The measured contribution of technology to output growth obviously demonstrates the importance of technical change as an engine of growth. Schultz (1964) suggested that significant growth in productivity cannot be brought about by the reallocation of resources in traditional agricultural system. Significant opportunities for growth become available only through changes in technology - new husbandry techniques, better seed varieties, more efficient sources of power, and cheaper plant nutrients. Investments in agricultural research, leading to the supply of new inputs, and in the education of the farm people who are to use the new inputs provide the bases of technical change and productivity growth. The results of this study support the thesis of Schultz. The dramatic increase in per acre production following the introduction of Mexican wheat varieties suggests the desirability of improving production technologies of other crops and livestock. A continuous stream of new knowledge represents a necessary condition for modern

agricultural development. How to insure a dialectic interaction, as suggested by the Hayami-Ruttan (1971) model of agricultural development, among farmers, research scientists, and research administrators is one of the challenging tasks for development planners in India.

(2) The 25 percent contribution of increased inputs to total change in output indicates a structural transformation in the form of increased dependence of agriculture on off farm inputs. This has implications not only for the need for inputs, but also for the growth promoting interactions between agricultural and industrial development. This sectoral interaction is one of the necessary conditions for general economic growth.

2. Employment Elasticities and Sources of Growth in Employment:

Development economists have begun to emphasize equity as one of the primary goals of economic development and have focussed on employment creation as a major means to achieving increased equity. Given the labor force explosion and the poor performance of the industrial sector in generating employment, it is the fundamental premise of this study that there must be greater provision of employment opportunities within the agricultural sector. The new technology in wheat production is said to have the power of being a catalyst for employment creation. The employment dimensions of new technology are many. The present study is concerned with one dimension of total direct employment, that is, employment effects per growing

season of wheat. To be efffective, any employment policy must have measures of the forces affecting employment. There is need for quantifying the various forces affecting employment and to know how much we must change controllable variables which we can control in order to effectuate the required changes in employment. In Chapter IV, using the constrained cost minimization model and the UOP Profit Functional model, we have derived labor demand functions to estimate employment elasticities and formulated decomposition models to investigate the sources of measured growth in employment.

There are two major conclusions that emerge from employment elasticity and decomposition analyses based on constrained cost minimization framework:

(1) Employment elasticities with respect to money wage rate, rental value of land, price of fertilizer and output are estimated to be the same under old and new production technology. This means that employment response to a given change in these variables will be the same on both Mexican and local wheat farms. Employment elasticity with respect to price of capital is higher (0.30 versus 0.06) on a Mexican wheat farm than on a local wheat farm. This difference is statistically significant, because, we discussed in Chapter III, we cannot accept the null hypothesis that output elasticity of capital is the same under both old and new technology. This means that any variation in price of capital leads to a greater change in employment on a Mexican wheat farm than on a

local wheat farm. We want to qualify this conclusion, because our measure of capital includes expenditure on seeds, irrigation, depreciation, interest charges and bullock labor service. Our study does not provide the answer to the question to the price variations of which of these capital items is employment response on a Mexican wheat farm different than on a local wheat farm. Perhaps this disaggregate analysis would provide a better empirical basis for using price of capital as an instrumental variable for influencing employment creation.

(2) On the problem of decomposing the total observed change in labor input per acre into the separate contributions of constituent forces, we did not meet with much success with one decomposition formulation (equation (14)). However, another decomposition analysis with equation (46) assuming Hicks-neutral technical change yielded satisfactory results. In the constrained cost minimization framework, where the firm is constrained to a given isoquant, technical change alone would have decreased employment by 17.4 percent. But this negative employment effect of technical change is more than offset by a 49.5 percent positive employment effect of output change and 4.5 percent positive employment effects of input price differences. Obviously, output change is more important in generating employment. In this framework, the forces affecting employment are technological progress, variations in output, and relative factor prices. Of these, perhaps output is the variable

most susceptible to control at various policy levels. Hence, in order to achieve a given employment target, we require a measure of the effect on employment of output, holding other forces constant. The measure obtained goes a long way - at least in principle - towards improving the treatment of this policy problem. We do recognize that adverse weather effects on output could affect employment. This was evident from decomposition analysis with the results of Sample II. In this sense, output in agriculture unlike industry is not easily susceptible to control. So use of output as an instrumental variable to influence employment is also subject to limitation. Yet it is incontrovertible that for any initial step in this direction, we must obtain measurements of the relevant forces affecting employment. That is precisely tl attempt made in this study.

Employment elasticity and decomposition analyses based on the UOP profit function model yielded two major results:

(1) Employment elasticity with respect to normalized wage rate (W^1), land (L) and fertilizer (F) between old and new production technology may be concluded to be not significantly different. The reason is that these employment elasticities are derived from output elasticity of labor (β_n), land (β_l) and fertilizer (β_f). Since we cannot reject the null hypothesis that these output elasticities are the same between old and new production technology, we tend to conclude that employment

elasticities are the same. So employment response at the margin to variations in W^1, L and F may be concluded to be approximately the same on both Mexican and local wheat farm Employment elasticity with respect to capital was estimated to be higher under new technology, because output elasticity of capital is significantly higher under new technology. Marginal employment response to one percent change in capital is 0.36 percent on a Mexican wheat farm, only 0.08 percent on a local wheat farm. Our capital variable includes many items of capital expenditures such as seeds, irrigation, depreciation and interest, and bullock labor service. Which of these capital expenditures increases marginal product of labor, shifting the demand for labor more under new technology than under old? This disaggregated analysis would possibly provide a better empirical basis for using capital expenditure as an instrumental variable for influencing employment.

(2) Due to high standard error of β_n of new technology, our decomposition analysis with equation (45) did not yield satisfactory results; the estimated (-37.1 percent) change in employment was substantially different from the actual (37.9 percent). The decomposition analysis with equation (47) that imposed Hicks-neutral technical change, yielded satisfactory results. Of the 37.9 percent total change in employment, technical change alone by shifting the profit function, makes a positive contribution to employment of 20.2 percent. The negative employment effect (14.5 percent) of normalized wage

rate clearly indicates the positive role of output price in creating employment. Attempts to keep output price below the market price would perhaps decrease employment on farms, because a low output price, given the money wage rate, means a higher normalized wage rate to farmers leading to decreased employment. So the present study suggests the use of output price as an instrumental variable for creation of employment. The positive contribution of complementary inputs alone to total change in employment comes to about 49.3 percent This suggests the need for efforts to increase the production and distribution of complementary inputs such as fertilizer, irrigation, pesticides, seeds and farm implements. Thes complementary inputs have made positive contribution to employment via shifting the marginal product of labor.

3. Functional Income Distribution Effects:

The effect of new technology on income distribution is a widely debated question. This is especially true in a country like India where income and consumption inequalities are present. Technical change gives rise to different dimensions of income distribution problems such as regional, farm-size groups and functional. The present study is concerned with an evaluation of effects of technical change on functional income distribution. An analysis of results from Tables V.4 and V.5 suggests that with respect to functional income distribution, new technology is neutral toward land,

labor and fertilizer, but biased in favor of capital. This result follows from Tables III. 2 and III.3 where the output elasticities of land, labor and fertilizer are not statistically different between old and new technology, whereas the output elasticity of capital under new technology is higher and the difference is statistically significant. It is shown in Table V.6 that all factors of production stand to gain under new technology.

Let us assume as under Hicks-neutral technical change that the effects of new technology on income imputed to various factors of production are neutral. So the absolute income imputed to all factors rises in the same proportion and the relative income shares remain unaltered. Even then, income distribution problems could arise from the unequal distribution of productive assets especially land. Given the 49 percent increase in income to land (Table V.6) and the skewed distribution of land ownership pattern (Table V.8), personal income distribution is bound to become more unequal. Now the major challenge confronting policy makers is how to design fiscal measures (short run policy measures) to mobilize part of this increased income for meeting the goals of more equal income distribution.

Before appropriate fiscal measures can be designed an empirical basis has to be developed. In the case of fiscal measures, there are at least five issues that have to be examined. First. how inadequately is the agricultural sector

taxed at present? Second, can the agricultural sector bear additional tax burden without suffering sericusly in terms of agricultural production and investment? Third, to what degree has the taxable capacity of the agricultural sector been increased by the new technology? Fourth, which classes of farmers have the additional taxable capacity? Fifth, how is the surplus likely to be used if left untaxed, that is, is it likely to flow into savings or productive investment within agriculture? We don't deny the need for progressive tax policy as a tool for redistribution. But that policy has to be formulated and implemented after developing a valid empirical basis.

One of the aspects which are relevant in the context of personal income distribution implications of technical change is the policy of subsidizing farm capital equipment. Distortions in capital market may encourage the use of factor proportions which are not in line with the factor endowments of the country. This is likely to happen on large and tractor-operated farms. Not only gains of subsidies are primarily accrued to these farms, but also labor is likely to be displaced through capital substitution. An investigation into the personal income distribution effects of factor market distortions is a potential area for research.

According to the neoclassical view, each individual has at his disposal an endowment of factors, and his income is

merely the sum of the multiplication of these factors by their marginal products. One approach to equalizing income distribution is precisely to accept the neoclassical presumption that factor ownership causes the distribution, and seek ways to transfer factors to the impoverished classes.[1/] With the introduction of new technology, per acre output of wheat increased by 40 percent The increased productivity of land is equivalent to an increase in the effective supply of land. This seems to provide a case for redistribution of land as a policy measure. Here again, as in the case of fiscal measures, careful analysis has to be undertaken before implementing the measure. In formulating land redistribution policy, at least two issues have to be examined. First, is their enough land to redistribute so that every one may employ himself and his family on his own land earn even a minimum desirable living? Who should get the surplus land taken o-er from the present big landowners? Should it go to landless laborers or to the present farmers with very small sized holdings? Second, is there a trade-off between growth and improved distribution? In other words, are small farms as efficient as large farms so that productive efficiency is not affected? Would a redistribution of land from larger to smaller farms raise total output and employment? Would redistribution of land increases output and employment in the short-run, but slow down the growth of output and employment in the long-run owing to the reduction

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1/ Meade (1964) in addition to other things, proposes equalization of property ownership as a step toward equalization of income.

in savings and investment? If we are interested in the question of what would happen to agricultural output and employment under a new agrarian structure with land ceilings and redist we should ideally consider the problem in a general equilibrium framework.[2/]

Once a new agrarian structure has been created with land redistribution, specially designed programs will be required for small farms to function effectively. Policy makers will have to work purposefully through research and extension to place land-saving technology in the hands of small cultivators. How can we ensure the dialectic interaction, implied in the Hayami-Ruttan induced innovation model (1971), among farmers, and research scientists and administrators? Mere transfer of land from large owners to small owners or to landless laborers without examining these issues will threaten the growth of rural economy without which social justice is a mere notion with no operational content.

2/ For more details on these issues see Bhagwati and Chakravarthy (1969), Rao (1972b) and Sinha (1973).

APPENDICES

APPENDIX I

1. Table I.A: Sample Geometric Mean Levels of Per Acre Output and Inputs

Item (1)	Sample 1967/68(LW) (2)	1967/68(MW) (3)	1967/68-1968/69(MW) (4)
Output	8.24	12.32	10.30
Labor	161.00	222.00	213.00
Fertilizer	13.50	69.50	60.00
Capital	166.00	224.00	219.00

2. Decomposition of Total Difference in Output Between New Production Technology of 1967/68 and 1970/71.

In Chapter III, we decomposed the total difference in per acre output between old and new production technology into some constituent forces. In this section, our concern is with the decomposition of per acre output between new production technology of 1967/68 and of 1970/71. The main reason for undertaking this analysis is to see whether sources of output growth have changed over a period of four years under new production technology. Perhaps the period of four years is not adequate for undertaking this kind of study. The results from this analysis may have to be treated as illustrative. Production function estimates are presented in Tables I.B and I.C. Results on decomposition analysis are shown in Table I.D.

Before discussing the results in Table I.E., two preliminary observations should be made. First, the data base for 1967/68(MW) is Ferozepur district of Punjab which is homogeneous in terms of wheat growing conditions, whereas the data base for 1970/71(MW) is whole of Punjab state in which case the assumption of homogeneous growing conditions for wheat is questionable. Second, we recall from Chapter II that output (Y) and labor (N) are measured in physical units, whereas fertilizer (F) and Capital (K) are measured in value (Rupee) terms. So per acre geometric mean levels of output and labor shown in Table I.E don't involve any measurement problems, whereas the geometric mean levels of fertilizer and capital involve measurement problems in view of the fact that these two inputs are measured in value terms and price changes for various components of these two inputs between 1967/68 and 1970/71 may distort the comparison of these two input levels between these two points of time.

After these remarks let us examine results on decomposition analysis in Table I.D.[1/] Per acre wheat output was 13 percent lower in 1970/71 than in 1976/68. Let us investigate the sources of this negative growth in output. As shown in Table I.E, changes in input levels do not seem to account for this because there was no considerable difference

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1/ Decomposition equation (30) of Chapter III is used for the purpose.

in per acre input levels of labor, fertilizer and capital between these two periods of time. Then the main source of negative growth would have come from technological parameters. It is indicated in Table I.D that shift in parameter (A), that is, neutral technical change more than offset non-neutral technical change between two periods of time. The main point is that the downward shift in new production function or 1970/71 was so low compared to that of 1967/68 that even a considerable upward shift (Table I.D, Column (2)) in slope coefficients between two periods of time was not enough to offset the downward drift. This seems to be the main reas for 13 percent lower output per acre in 1970/71 than in 1967/68 under new production technology. Why this downward drift in intercept and upward shift in slope parameters? Were these due to weather, inferior quality of seeds and land? Is this downward shift a temporary phenomenon or a long-run technological regression in the production of Mexican wheat? We don't claim to have answer for these questions. These questions are undoubtedly worth investigating in future studies.

Table I.B: Per Farm Production Function Estimates, 1970/71(MW)

Variables[1/]	Elasticity of Output	Stan. Error[2/]
A (constant)	0.177	0.565
L	0.305	0.099
N	0.473	0.095
F	0.110	0.032
K	0.173	0.072

Returns to scale = 1.061

$\bar{R}^2 = 0.92$

Notes: 1/ Regressions linear in natural logarithms are estimated by least squares. Dependent variable is output of wheat Y, in physical units.

2/ In the case of land (L), labor (N) and fertilizer(F) t-values are significant at $\alpha = 0.005$; t-value is significant at $\alpha = 0.01$ in the case of capital (K) variable.

Table I.C: Per Acre Production Function Estimates, 1970/71(MW)

Variables	Elasticity of output
A (constant)	0.264
L	0.293
N/L	0.423
F/L	0.123
K/L	0.161

$\bar{R}^2 = 0.28$

Notes: 1/ Regression linear in natural logarithms are estimated by least squares restricting estimates to constant return to scale. Output elasticity for land is:

$$\beta_l = (1 - \beta_n - \beta_f + \beta_k)$$

Table I.C (contd.)

2/ For labor (N/L) and fertilizer (F/L), t-values are significant at $\alpha = 0.005$, for capital (K/L) it is significant at $\alpha = 0.025$.

3/ Low $\bar{R}^2$ results from the elimination of land as an explanatory variable.

Table I.D: Decomposition Analysis of Total Difference in Per Acre Output Between New Production Technology of 1967/68 and 1970/71.

Source (1)	Percentage Attributable (2)
1. Total difference in output 1/	-13.00
2. Neutral Technical Change 2/	-160.90
3. Non-neutral Technical Change	+144.90
4. Change in inputs: 1/	
a) Labor	+3.30
b) Fertilizer	-0.30
c) Capital	-0.40
Total: due to change in inputs	+2.60
Total	-13.40

Notes: 1/ Sample geometric mean levels of output and inputs per acre are shown in Table I.E.

2/ Parametric values for computation are drawn from Tables III.10 and I.C.

Table I.E: Sample Geometric Mean Levels of Per Acre Output and Inputs

Item (1)	Sample 1967/68(MW) (2)	Sample 1970/71(MW) (3)
Output	12.32	10.80
Labor	222.00	240.00
Fertilizer	69.50	67.70
Capital	224.00	219.00

APPENDIX II

Table II.A: Sample Geometric Mean Levels of Employment, Output and Input Prices

Item	1967/68 (LW)	1967/68 (MW)	1967/68-1968/69 (MW)
(1) Per acre labor employment in hours	161	222	213
(2) Per acre wheat output in quintals	8.24	12.32	10.30
(3) Wage rate per hour in rupees	0.69	0.68	0.72
(4) Per acre land rent in rupees	133	140	173
(5) Fertilizer price per kilogram in rupees*	0.84	0.84	0.85
(6) Per hour bullock rental value in rupees	1.42	1.43	1.46

*Source: "Fertilizer Statistics" (1973, P.1-247)

Table II.B: Sample Geometric Mean Levels of Employment, Normalized Wage Rate and Inputs

	Item	1967/68 (LW)	1967/68 (MW)	1967/68-1968/69 (MW)
(1)	Per acre labor employment in hours	161	222	213
(2)	Normalized wage rate per hour (in rupees)	0.008	0.009	0.010
(3)	Per acre use of fertilizer (in rupees)	13.5	69.5	60.0
(4)	Capital (in rupees)	16.6	224	219

Worksheet 1: Decomposing Per Acre Change in Employment, Cost Minimization Framework 1967/68 (MW) versus 1967/68 (LW)*

A. $\frac{\Delta N}{N} = 0.379$

B. (1) $\frac{\Delta Y}{Y} = 0.495$

(2) $-\left[\frac{\Delta A}{A}\right] = 0.137$

(3)

$$-\left[\left(1+\ln\frac{\beta_n}{P_n} - \frac{1}{\beta_n}\right)\Delta\beta_n + \left(1+\ln\frac{\beta_l}{P_l}\right)\Delta\beta_l + \left(1+\ln\frac{\beta_f}{P_f}\right)\Delta\beta_f \left(1+\ln\frac{\beta_k}{P_k}\right)\Delta\beta_k\right]$$

$$= -\left[0.72 + 0.25 - 0.001 - 0.43\right] = -0.539$$

(4) $$\left[\beta_l\frac{\Delta P_l}{P_l} + (\beta_n - 1)\frac{\Delta P_n}{P_n} + \beta_f\frac{\Delta P_f}{P_f} + \beta_k\frac{\Delta P_k}{P_k}\right] = 0.045$$

* Values of parameters A and β_i are from Table III.10; Values of N, Y and P_i are from Table II.A of this Appendix.

Worksheet 2: Decomposing Per Acre Change in Employment, Cost Minimization Framework, 1967/68 - 1968/69 (MW) versus 1967/68 (LW)*

A. $\frac{\Delta N}{N} = 0.323$

B. (1) $\frac{\Delta Y}{Y} = 0.250$

(2) $-\left[\frac{\Delta A}{A}\right] = 0.026$

(3)
$$-\left[\left(1 + \ln \frac{P_n}{P_n} - \frac{1}{\beta_n}\right) \Delta\beta_n \left(1 + \ln \frac{\beta_1}{P_1}\right) \Delta\beta_1 + \left(1 + \ln \frac{\beta_f}{P_f}\right) \Delta\beta_f \left(1 + \ln \frac{\beta_k}{P_k}\right) \Delta\beta_k\right]$$
$$= -\left[0.541 + 0.168 - 0.017 - 0.284\right] = -0.408$$

(4) $\left[\beta_1 \frac{\Delta P_1}{P_1} + (\beta_n - 1) \frac{\Delta P_n}{P_n} + \beta_f \frac{\Delta P_f}{P_f} + \beta_k \frac{\Delta P_k}{P_k}\right] = 0.145$

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* Values of parameters A and β_i are from Table III.10; values of N, Y and P_i are from Table II.A of this Appendix.

Worksheet 3: Decomposing Per Acre Change in Employment, Cost Minimization Framework, 1967/68 (MW) versus 1967/68 (LW)

A. $\frac{\Delta N}{N} = 0.379$

B. (1) $\frac{\Delta Y}{Y} = 0.495$

(2) $-\left[\frac{\Delta A}{A}\right] = -0.17$

(3) $\left[\beta_l \frac{\Delta P_l}{P_l} + (\beta_n - 1)\frac{\Delta P_n}{P_n} + \beta_f \frac{\Delta P_f}{P_f} + \beta_k \frac{\Delta P_k}{P_k}\right]$

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* Values of parameters A and β_i's are from chapter IV, footnote 23. The basic assumption underlying these parameters is that technical change is Hicks-neutral. Values of N, Y and P_i are from Table II.A of this Appendix.

Worksheet 4: Decomposing Per Acre Change in Employment, UOP Profit Function Model, 1967/68 (MW) versus 1967/68 (LW)*

A. $\frac{\Delta N}{N} = 0.379$

1. $\frac{\Delta A}{(1-\beta_n)_A} = -$

2. $\left[\frac{\Delta\beta_n}{\beta_n\,(1-\beta_n)} + \left\{\frac{\ln A + \ln \beta_n}{(1-\beta_n)^2}\right\}\Delta\beta_n + \ln W^1\left\{\frac{-\Delta\beta_n}{(1-\beta_n)^2}\right\} + \ln F\left\{\frac{(1-\beta_n)\Delta\beta_f + \beta_f\,\Delta\beta_n}{(1-\beta_n)^2}\right\}\right.$

$\left. + \ln K\left\{\frac{(1-\beta_n)\,\Delta\beta_k + \beta_k\,\Delta\beta_n}{(1-\beta_n)^2}\right\}\right] = -0.572$

3. $\left[\left(\frac{-\beta_n}{(1-\beta_n)} - 1\right)\frac{\Delta W^1}{W^1}\right] = -0.134$

4. $\left[\frac{\beta_f}{(1-\beta_n)}\,\frac{\Delta F}{F} + \frac{\beta_k}{(1-\beta_n)}\,\frac{\Delta K}{K}\right] = 0.510$

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* Values of parameters A and β_i are from Table III.10; values of N, W^1, F and K are from Table II.B of this Appendix.

Worksheet 5: Decomposing Per Acre Change in Employment, UOP Profit Function Model, 1967/68 - 1968/69 (MW) versus 1967/68 (LW)*

A. $\frac{\Delta N}{N} = 0.323$

B. 1. $\frac{\Delta A}{(1-\beta_n)_A} = -0.033$

2. $$\left[\frac{\Delta\beta_n}{\beta_n(1-\beta_n)} + \left\{\frac{\ln A + \ln \beta_n}{(1-\beta_n)^2}\right\}\Delta\beta_n + \ln W^1\left\{\frac{-\Delta\beta_n}{(1-\beta_n)^2}\right\} + \ln F\left\{\frac{(1-\beta_n)\,\Delta\beta_f + \beta_f\,\Delta\beta_n}{(1-\beta_n)^2}\right\}\right.$$
$$\left. + \ln K\left\{\frac{(1-\beta_n)\,\Delta\beta_k + \beta_k\,\Delta\beta_n}{(1-\beta_n)^2}\right\}\right] = -0.502$$

3. $$\left[\left(\frac{-\beta_n}{(1-\beta_n)} - 1\right)\frac{\Delta W1}{W1}\right] = -0.279$$

4. $$\left[\frac{\beta_f}{(1-\beta_n)}\frac{\Delta F}{F} + \frac{\beta_k}{(1-\beta_n)}\frac{\Delta K}{K}\right] = 0.476$$

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* Values of parameters A and β_i are from Table III.10; values of N, W^1, F and K are from Table II.B of this Appendix.

Worksheet 6: Decomposing Per Acre Change in Employment, UOP Profit Function Model, 1967/68 (MW) versus 1967/68 (LW)*

A. $\frac{\Delta N}{N} = 0.379$

B. 1. $\frac{\Delta A}{(1-\beta_n)_A} = 0.202$

2. $\left[(\lambda_1 - 1)\frac{\Delta W^1}{W^1}\right] = \left[\left(\frac{-\beta_n}{(1-\beta_n)} - 1\right)\frac{\Delta W^1}{W^1}\right] = -0.145$

3. $\left[\frac{\beta_f}{(1-\beta_n)}\frac{\Delta F}{F} + \frac{\beta_k}{(1-\beta_n)}\frac{\Delta K}{K}\right] = 0.493$

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* Values of parameters A and β_i are from Chapter IV, footnote 23. The basic assumption underlying these parameters is that technical change is Hicks-neutral. Values of N, W^1, F and K are from Table II.B of this Appendix.

APPENDIX III

CHANGE IN FUNCTIONAL INCOME DISTRIBUTION UNDER NEW PRODUCTION TECHNOLOGY BETWEEN 1967/68 - 1970/71

The purpose of this section is to indicate empirically what has happened to functional income accrued to various factors of production under new production technology over a period of four years. Any explanation of why a new pattern of functional income distribution has emerged, if it has, is far from complete. Following the same method of analysis as in Chapter V, we examine three basic questions. First, how comparable are estimated and actual factor shares? Second, what is the direction and magnitude of change in factor shares under new production technology between two points of time? Third, what is the direction and magnitude of absolute changes in actual factor shares? An investigation into these basic questions is attempted under three broad headings.

1. Comparison of Estimated and Actual Factor Shares:

Results of the comparison are presented in Tables III.A and III.B. As we have already discussed in Chapter V, the differences between actual and estimated factor shares are not statistically significant for the year 1967/68. So we cannot reject the null hypothesis that actual factor shares are equal to estimated ones in this case. However, the same cannot be said with respect to 1970/71 results. In the case of land,

fertilizer and capital, we cannot reject the null hypothesis that actual factor shares are equal to estimated shares at $\alpha = 0.05$; but in the case of labor we reject the null hypothesis that actual share is equal to estimated shares at $\alpha = 0.025$. This implies that labor was underpaid under new production technology during 1970/71. The explanations for the actual deviating significantly from the estimated may take different forms such as inaccurate measurement of labor variable, irrationality in the employment of labor by firms and so on, but it does not seem possible to identify the specific set of forces giving rise to this disequilibrium.

2. Direction and Magnitude of Change in Factor Share:

The second issue has to do with the determination of direction and magnitude of changes in factor shares as revealed in production function estimates. Results on this issue are shown in Tables III.C and III.D. Two observations may be made on these results:

First, the relative share of labor has increased substantially. This is also supported by results shown in Table III.E; the difference between output elasticity with respect to labor between the years 1967/68(MW) and 1970/71(MW) is significant at $\alpha = 0.005$. Since we reject the null hypothesis that $(\beta_n)_{1970/71} = (\beta_n)_{1967/68}$, the difference in relative share of labor under new production technology of 1970/71 from that of 1967/68 is concluded as statistically significant.

Table III.A: Estimated and Actual Factor Shares, Per Farm Analysis

Sample	Factor o Producti	Estimated Factor Share[1]	Actual Factor Share[2]	Degree to Which the Actual Differs from the Estimated in Terms of Standard Errors.[3]
(1)	(2)	(3)	(4)	(5)
1967/68(MW)	Land	0.498	0.570	+0.78
	Labor	0.088	0.153	+0.70
	Fertilizer	0.111	0.070	-0.78
	Capital	0.302	0.207	-0.85
1970/71(MW)	Land	0.287	0.397	+1.11
	Labor	0.446	0.250	-2.06
	Fertilizer	0.104	0.098	-0.19
	Capital	0.163	0.255	+1.28

Notes:
1. Column (3) is computed by using the expression (7) of Chapter V. Parametric values are drawn from Tables III.9 and I.B.
2. Same procedure as explained in Chapter V (Table V.2) is followed in computation.
3. Computational procedure is the same as in Chapter V (Table V.2)

Second, the changes in shares of land, fertilizer and capital are not statistically significant at $\alpha = 0.005$, since the "slope dummy variables" as shown in Table III.E are not significant at $\alpha = 0.005$. These are not even significant at $\alpha = 0.05$. So we tend to conclude that we cannot reject the null hypothesis there have been no statistically significant changes in factor shares accrued to land, fertilizer, and capital.

Table III.B: Estimated and Actual Factor Shares, Per Acre Analysis1/

Sample (1)	Factor of Production (2)	Estimated Factor Share2/ (3)	Actual Factor Share 3/ (4)
1967/69(MW)	Land	0.568	0.570
	Labor	0.065	0.153
	Fertilizer	0.092	0.070
	Capital	0.275	0.207
1970/71	Land	0.294	0.397
	Labor	0.423	0.250
	Fertilizer	0.123	0.098
	Capital	0.160	0.255

Notes: 1. Same details as in Table V.3 (footnote 1).

2. Estimated factor shares are computed by drawing parametric values from Table III.10 (1967/68), and from Table I.C (1970/71 - Appendix I) Other details are same as in Table V.3 (footnote 2).

3. Same details as in Table V.3 (footnote 3).

Table III.C: Change in Factor Share, Per Farm Analysis

Sample	Factor of Production	$\frac{(S_i/\gamma)_{70/71} - (S_i/\gamma)_{67/68}}{(S_i/\gamma)_{67/68}}$
(1)	(2)	(3)*
1970/71(MW) versus 1967/68(MW)	Land	-0.424
	Labor	+4.068
	Fertilizer	-0.063
	Capital	-0.460

Note: * Expression in Column (3) is a generalized version of expression (9) in Chapter V, where $\gamma = S_l + S_n + S_f + S_k$. Parametric values for computing column (3) are drawn from Column (3) of Table III.A.

Table III.D: Change in Factor Share, Per Acre Analysis

Sample	Factor of Production	$D_i = \frac{(S_i)_{70/71} - (S_i)_{67/68}}{(S_i)_{67/78}}$
(1)	(2)	(3)*
1970/71(MW) versus 1967/68(MW)	Land	-0.482
	Labor	+5.508
	Fertilizer	+0.337
	Capital	-0.418

Notes: * Expression in Column (3) is a generalized version of expression (8) in Chapter V. Parametric values for computation are drawn from Column (3) of Table III.B.

Table III.E: Testing the Hypothesis on Equality of Parameters Between 1970/71 (MW) and 1967/68 (MW) Production Function Estimates.

Variables[1/]	OLS Coefficients	Stan.Error	Computed
A (Constant)	-1.733	0.724	-2.393
L	0.305	0.127	2.397
N	0.473	0.121	3.898
F	0.110	0.041	2.648
K	0.173	0.092	1.873
DVA[2/]	1.432	0.854	1.677
DVL[3/]	0.226	0.148	1.523
DVN[3/]	-0.379	0.143	-2.641
DVF[3/]	0.008	0.059	0.136
DVK[3/]	0.149	0.130	1.143

$\bar{R}^2 = 0.94$

Notes:
1. Dependent variable is the output of wheat in physical units.
2. DVA is the "intercept dummy variable" with a value of one for 1967/68 Mexican wheat and zero for 1970/71 Mexican wheat.
3. DVL, DVN, DVF and DVK are the "slope dummy variables" for land (L), labor (N), fertilizer (F) and capital (K) with a value of one for 1967/68 Mexican wheat and zero for 1970/71 Mexican wheat.

Thus the major conclusion that follows from the above discussion is that functional income distribution as revealed by production function estimates has not altered fundamentally under new production technology, except in the case of labor, between 1967/68 and 1970/71.

3. Direction and Magnitude of Change in Absolute Factor Shares:

The preceding discussion has centered around changes in factor shares as revealed by production function estimates. In this section we are concerned with determining percentage change in actual absolute share acruing to various factors under new production technology between 1967/68 and 1970/71.

Table III.F: Percentage Change in Absolute Factor Share, Per Acre Analysis, 1970/71(MW) versus 1967/68(MW)

Factor of Production (1)	Absolute Share from an Acre Total Revenue* (1967/68) (2).	Absolute Share from an Acre Total Revenue* (1970/71) (3)	Percentage Change in Absolute Factor Share (4)
Land	Rs. 563.00	Rs. 339.76	-0.40
Labor	151.12	213.96	+0.42
Fertilizer	69.14	83.87	+0.21
Capital	204.46	218.24	+0.07

Notes: *Per acre total revenue from an average 1967/68 Mexican wheat farm is Rs 987.72, and from that of an average 1970/71 Mexican wheat farm it is Rs 855.83. Absolute shares for each factor are obtained by multiplying total revenue by the percentage shares shown in Column (4) of Table III.B.

It is shown in Table III.F that labor has improved its relative income position much more than fertilizer and capital; but land has suffered a loss in its relative position. We don't know whether the conclusion would have been different if we had treated land in the same way as other inputs instead

of treating it as a residual claimant. We have indicated what has happened to the pattern of absolute factor shares between two periods of time, but explanation on why a new pattern has emerged is far from complete.

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