ALLOCATIVE EFFICIENCY, TENURE AND TECHNOLOGY IN IRRIGATED AGRICULTURE: A CASE STUDY OF THE PAKISTAN PUNJAB

by

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DECLARATION

Except where otherwise indicated, this dissertation is my own work.

Haq Nawaz Shah

Haq Nawaz Shah

August, 1982

Dedicated to

Kanwal, my youngest child

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ABSTRACT

This study attempts to highlight and quantify the impact of tenure, farm size and mechanization on allocative efficiency of a sample of 54 farmers in the Punjab Province of Pakistan.

Production function approach is used to estimate production elasticities of inputs from the farm accounts data for the year 1978-79.

The estimated Cobb-Douglas production function showed that land, labour, fertilizer and non-draft animals are significant variables. Statistical tests showed that an average sample farm is experiencing constant returns to scale.

Production functions estimated separately for different types of farms indicate that the labour factor is not significant on tenant/small/ non-mechanized farms; livestock is not significant on large farms; and fertilizer is not significant on mechanized farms. These results imply that tenure, farm size and mechanization significantly affect resource use pattern.

Marginal value products for each input were calculated for different types of farms and statistically tested for their equalities with opportunity factor costs. The tests showed that tenants/non-mechanized farms are using less than optimal amounts of fertilizer. On the other hand both the large farms and mechanized farms are allocatively efficient in labour-use. It is observed that all types of farms are overstocking farm animals.

A major conclusion of the study is that further research is needed on the impact of mechanization on labour and fertilizer use and on the relationship of livestock with the farm and farm households.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The study analyses the allocative efficiency of different types of farmers in selected districts of the Punjab Province of Pakistan. The motivation is to improve understanding of the relationship between the decision making process of a farmer and the underlying socio-economic system.

It is believed that measurement of the departure of actual resource allocation from the optimal allocation will enable us to better identify the resource constraints faced by the farmer.

Recent studies of Pakistan agriculture[1] show that there is discrimination against the small farmer in access to modern inputs. The present study, based on a full year's farm accounts data of a sample of 54 farms in the Punjab, is aimed at investigating the problem of resource constraints of the farmer through studying his resource allocation behaviour.

1.2 The Hypotheses and Objectives

The study of efficient utilization of resources (technically, economically or allocatively) is based on the assumption that farmers in developing countries are economically rational, i.e. they use their resources to maximize profits. Schultz advanced the hypothesis that in traditional agriculture:

> "Given the land at disposal of farmers and the state of their knowledge, they are not underutilizing the land by the way they farm. Nor are they misallocating the reproducible material capital at their disposal - their

---

1 Khan and Maki (1980), used data for only two crops, rice and wheat. On the other hand, Mahmood and Haque (1981) based their study on macro data of the Punjab.

> draft animals, implements, wells and ditches for irrigation and other useful structures...They are not misallocating their own labour nor other labour that is available to them." (Schultz, 1965:16)

It was argued by Schultz (1965) that allocative efficiency in traditional agriculture was achieved by farmers through an experimentation process with their environment over a long period of centuries.[1]

The hypothesis was important because if farmers are already efficient in their resource use under the existing technology, information and resource constraints, growth could be brought about only by changing the techniques of production. Secondly, economic incentives could be provided to induce adoption of new technologies. In other words, if Schultz's hypothesis is accepted, growth could be made possible only by generating additional resources for investment in improved methods of cultivation and resource use.

On the other hand,

> "if farmers are inefficient in the use of their scarce resources, there certainly exists an unexploited potential for increasing farm incomes and generating surpluses which can serve as an inexpensive source of economic growth." (Saini, 1979:3-4)

Thus Schultz (1965) hypothesis stimulated interest in studying the behaviour of traditional farmers with respect to resource use as well as resource allocation.[2]

Results of research have generally proved that the traditional farmer is responsive to price changes and attempts to maximize profits (Yotopoulos, 1968). Individual farms may show some inefficiencies but,

---

1 For an initial criticism on restrictive assumptions and limited relevance of Schultz' hypothesis to problems of agricultural development in developing countries see Beckford, (1966:1013-1015).

2 A large number of studies have been undertaken since 1964. Some of them may be mentioned in chronological order; Hopper (1965), Welsh (1965), Falcon and Gotsch (1971), Lau and Yotopoulos (1969), Khan and Maki (1980). For an exhaustive list of efficiency studies see Saini (1979).

> "our test is mainly a test of whether individual firms attempt to be efficient, i.e. maximize profits." (Yotopoulos, 1968:134)

Farmers may have different objective functions; minimization of risk, (Anderson, et al, 1977) or maximization of utility, (Sen, 1962, 64,66). Even this behaviour is justified on the basis of rationality.

The present study is aimed at testing the allocative efficiency hypothesis on a sample of farms in the Punjab (Pakistan), not with a view to test the rationality of the traditional farmer, but to identify resource constraints.

1.2.1 Objectives of the Present Study

The objective of the study is to study the effect of tenure, farm size and mechanization on allocative efficiency of farmers.

1.2.2 Hypotheses to be Tested

The hypotheses will be tested that the following are allocatively efficient:

(1) Tenant farms.

(2) Owner-cultivated farms.

(3) Small farms.

(4) Large farms.

(5) Tractor/Tubewell owner farms.

(6) Non-Tractor/Tubewell owner farms.

1.3 Methodology

> "A resource or input factor is considered to be used most efficiently if its marginal value product is just sufficient to offset its cost." (Saini, 1979:42)

This definition of allocative efficiency implies that:

> "A significant difference between marginal product and opportunity cost is accepted as evidence of inefficient resource utilization." (Yotopoulos, 1968:126)

A test of allocative efficiency of resource use, therefore, involves testing the following hypothesis:

$$H_0: \; MVP_i = MFC_i \qquad i = 1,2,\ldots,n \text{ factor inputs}$$
$$H_A: \; MVP_i \neq MFC_i$$

where MVP = marginal value product

MFC = marginal factor cost

The abovementioned hypothesis will be tested for each input on each type of farms listed in Section 1.2.2.

Marginal value products of resources will be derived by using production function approach. However, since the data were cross-sectional prices of inputs and outputs will be considered to be the same for all farms.

1.4 Description of Data

1.4.1 Source of Data

The data were obtained from the Punjab Economic Research Institute, Lahore, Pakistan. The data set, called Farm Accounts and Family Budgets, is collected every year from a sample of villages, selected by using appropriate sampling techniques. The Institute publishes an annual report which contains statistical tables prepared from the data.

1.4.2 Objectives of Data Collection

The objectives of Farm Accounts and Family Budget Report of the Institute are described as follows (Ali and Rehman, 1979):

(1) To provide information about farm resources and expenditure, input-use and returns in order to determine returns to various farm activities.

(2) To ascertain the financial position of rural households by studying their family budgets.

(3) To suggest feasible measures to improve farm productivity.

1.4.3 Sampling Design

1.4.3.1 Selection of Sample Areas

The Punjab province was stratified into the following three major regions on the basis of soil, cropping pattern and irrigation sources:

> "1- Irrigated tract with loam and sandy loam soils;
> 2- Canal-cum-tubewell irrigated areas; and
> 3- Sub-mountainous 'barani' [rainfed] areas."
> (Ali and Rehman, 1979:7), brackets added.

In the Punjab, the proportion of cultivated area accounted for by each of the above zones is Zone 1, 71.43 per cent; Zone 2, 18.57 per cent; and Zone 3, 10.00 per cent.

Constrained by financial and manpower resources, the Institute could select only seven sample areas in the province. Therefore, five sample sub-divisions[1] (71%) were randomly selected from Zone 1, and one each from Zones 2 and 3 (Table 1.1 and Map 1.1).

1.4.3.2 Selection of Villages

Three villages were purposively selected from each sample sub-division in a radius of about seven miles so that the field worker might be able to travel to each of them at least twice a week.

1.4.3.3 Selection of Farmers

From each village three farmers were purposively selected on the basis of their willingness to participate in the project. One in each three farmers was to be a tenant in accordance with the proportion of tenants, (29%) in total number of farms in the Province.

---

1 A sub-division is an administrative unit in a district.

TABLE 1.1

SAMPLE SUB-DIVISIONS AND DISTRIBUTION
OF SAMPLE FARMERS

No.	Name of Sub-Division	District	No. of Observations	Ecological Zone
1	Hasilpur	Bahawalpur	9	1
2	Chichawatni	Sahiwal	9	1
3	Okara	Sahiwal	9	1
4	Faisalabad	Faisalabad	9	1
5	Sumandari	Faisalabad	9	1
6	Wazirabad	Gujranwala	9	2
7	Pindighaib[a]	Attock	9	3
Total			63	

Note: a This sub-division, relating to rain-fed areas of the Punjab, was excluded from the present study.

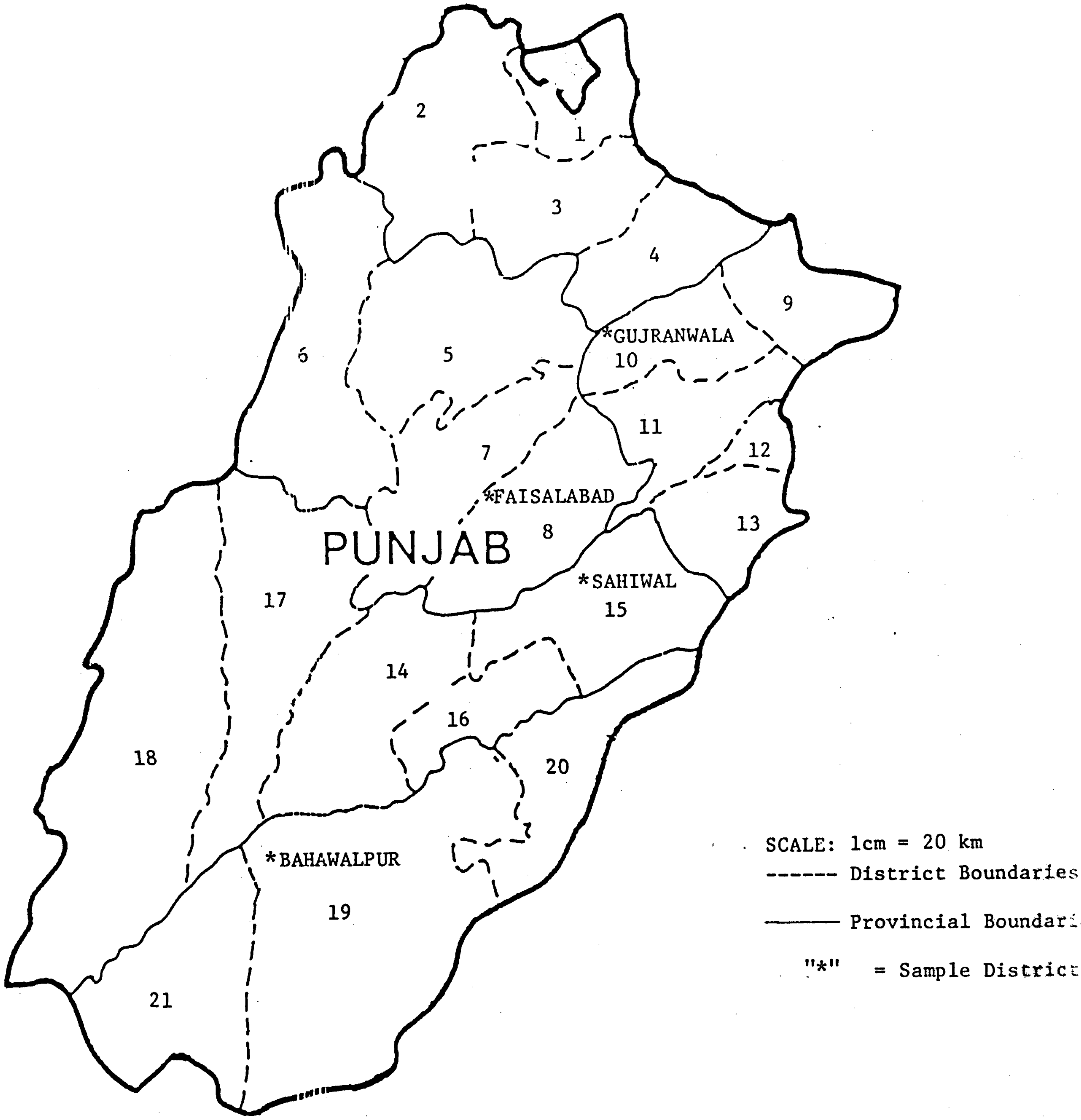
Source: Ali and Rehman (1979:7).

Stratification of farmers is given in Figure 1.1.

Figure 1.1 shows classification of the sample farms with respect to tenure, farm size and ownership of tractor/tubewell. The figure shows that the sample is almost equally distributed between small and large farmers. In the Punjab, however, 72 per cent of farmers are small and 28 per cent large. The stratification of sample farms on the basis of ownership-tenancy, however, conforms to population characteristics. On the other hand, there are 34 non-mechanized and 20 mechanized farms. In the population, however, the proportion of mechanized farms may be negligible. Thus, in a small sample of 54 farms, it was not possible to satisfy sampling requirements. The estimates may, therefore, have some bias.

MAP 1.1

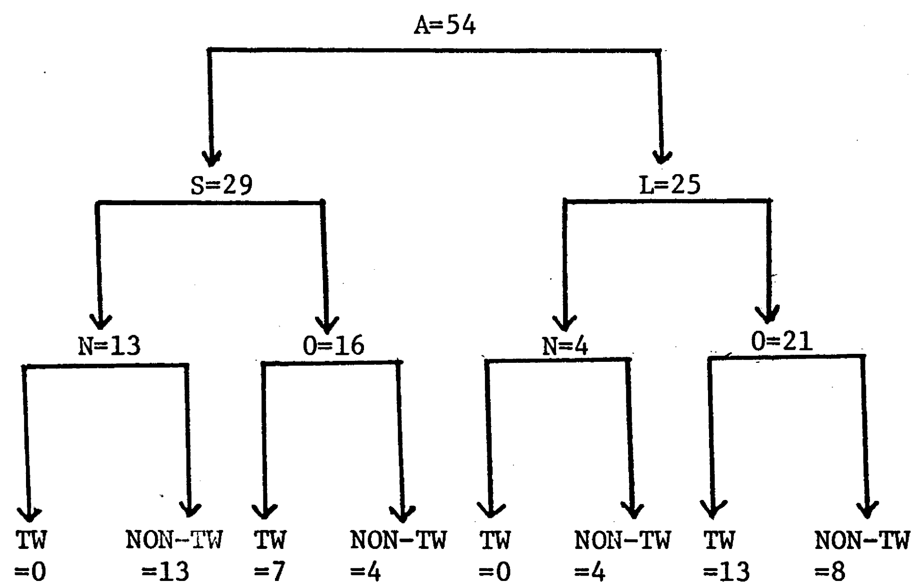
SAMPLE DISTRICTS IN THE PUNJAB



DISTRICTS
1- RAWALPINDI
2- ATTOCK
3- JHELUM
4- GUJRAT
5- SARGODHA
6- MIANWALI
7- JHANG
8- FAISALABAD
9- SIALKOT
10- GUJRANWALA
11- SHEIKHUPURA
12- LAHORE
13- KASUR
14- MULTAN
15- SAHIWAL
16- VEHARI
17- MUZAFFARGARH
18- D.G. KHAN
19- BAHAWALPUR
20- BAHAWAL NAGAR
21- R.Y. KHAN

FIGURE 1.1

CLASSIFICATION OF SAMPLE FARMERS ON THE BASIS OF TENURE, FARM SIZE AND MECHANIZATION



where A = Number of all observations

S = Small farmers, i.e. size of farm ≤ 12.5 acres

L = Large farmers, i.e. size of farm > 12.5 acres

N = Tenant-cultivator

O = Owner-cultivator

TW = Owner of tubewell or tractor or both

Non-TW = Owns neither a tractor nor a tubewell

1.4.4 Relationship of Sample with Population

Taking a sub-division as the population, the relationship of sample household with the population is shown in the following table (Table 1.2).

The table shows that the sample size is negligible relative to a sub-division's area and number of farms. Since there were 77 sub-divisions

TABLE 1.2

RELATIONSHIP OF SAMPLE WITH POPULATION

Characteristic	Unit of Measurement	Punjab Total[a]	Average Per Sub-division[b]	Percentage of Sample in Sub-division
(1)	(2)	(3)	(4)	(5)
Villages	Number	24871	323	0.929
Farm Households	Number	3233076	41988	0.021
Net Area Sown	Acres	9919987	128831	0.506

Notes: a There were 77 sub-divisions in the Punjab Province in 1971-72 Population Census.

b Figures in Column 3 calculated from G.O.P. (1972b) and G.O.P. (1980b).

in the Punjab, the proportion of the sample in relation to the province is very small.

1.4.5 Cropping Patterns in Sample Districts

Table 1.3 compares cropping patterns of sample districts with the average cropping pattern for the whole province of Punjab. The cropping pattern of the Province also includes that of rain-fed areas, although in our sample, only irrigated areas are included. In the rain-fed areas, cotton, sugarcane and rice are not grown, whereas in irrigated areas, these crops are the major Kharif (summer) crops.

Secondly, the Gujranwala district specializes in a rice-wheat rotation. Since rice is a food crop, the percentage of cash crops for this district is low. For all other districts, the proportion of area under different categories of crops does not differ much from the Punjab average.

TABLE 1.3

CROPPING PATTERNS IN SAMPLE DISTRICTS

(CASH AND FOOD CROPS)

(% of Cropped Area)

Farm Size Groups	Per Cent Distribution of Cropped Area Under									
	Food Crops					Cash Crops				
	Districts					Districts				
	Punjab	Baha-walpur	Sahiwal	Faisal-abad	Gujran-wala	Punjab	Baha-walpur	Sahiwal	Faisal-abad	Gujran-wala
All Farms	50	41	44	49	70	21	36	31	28	6
1	56	37	45	54	47	13	31	18	16	6
2	58	46	47	52	61	16	32	26	23	5
3	57	46	44	51	67	18	32	28	25	5
4	56	43	43	50	71	19	34	29	27	5
5	54	42	44	49	70	20	35	30	28	6
6	50	39	43	48	69	21	36	30	29	7
7	46	39	44	48	69	21	36	32	29	7
8	42	42	47	44	75	20	35	34	33	5
9	42	41	43	50	84	27	46	43	33	4

Notes: (a) Food Crops = Wheat, barley, paddy, (maize, jowar and bajra) for grain.

(b) Cash Crops = Cotton, sugarcane, tobacco, orchards and oilseeds.

(c) For size of farm in each farm size group, see Table 2.1.

The relative importance of food crops across farm size is almost the same. But the percentage of cash crops rises sharply for farm group 9 (i.e. farm > 150.0 acres).[1] Differentials of cropping patterns across regions may be more significant than that across farm size. Mahmood and Haque (1981:167) tested differentials across farm sizes and found that they were not significant.

1 It may be noted that no sample farm is larger than 40 acres.

A typical cropping pattern for the Central Punjab is also shown in Figure 1.2. It is observed that, except for sugarcane, no crop stands on the soil for more than six months. Moreover, many crops compete for land and other resources, e.g. the rice-wheat crop rotation competes with the cotton-oilseeds rotation. This provides ideal conditions for studying allocative efficiency of farmers since costs of mismanagement may be high.

1.4.6 Seasonality in Sample Data

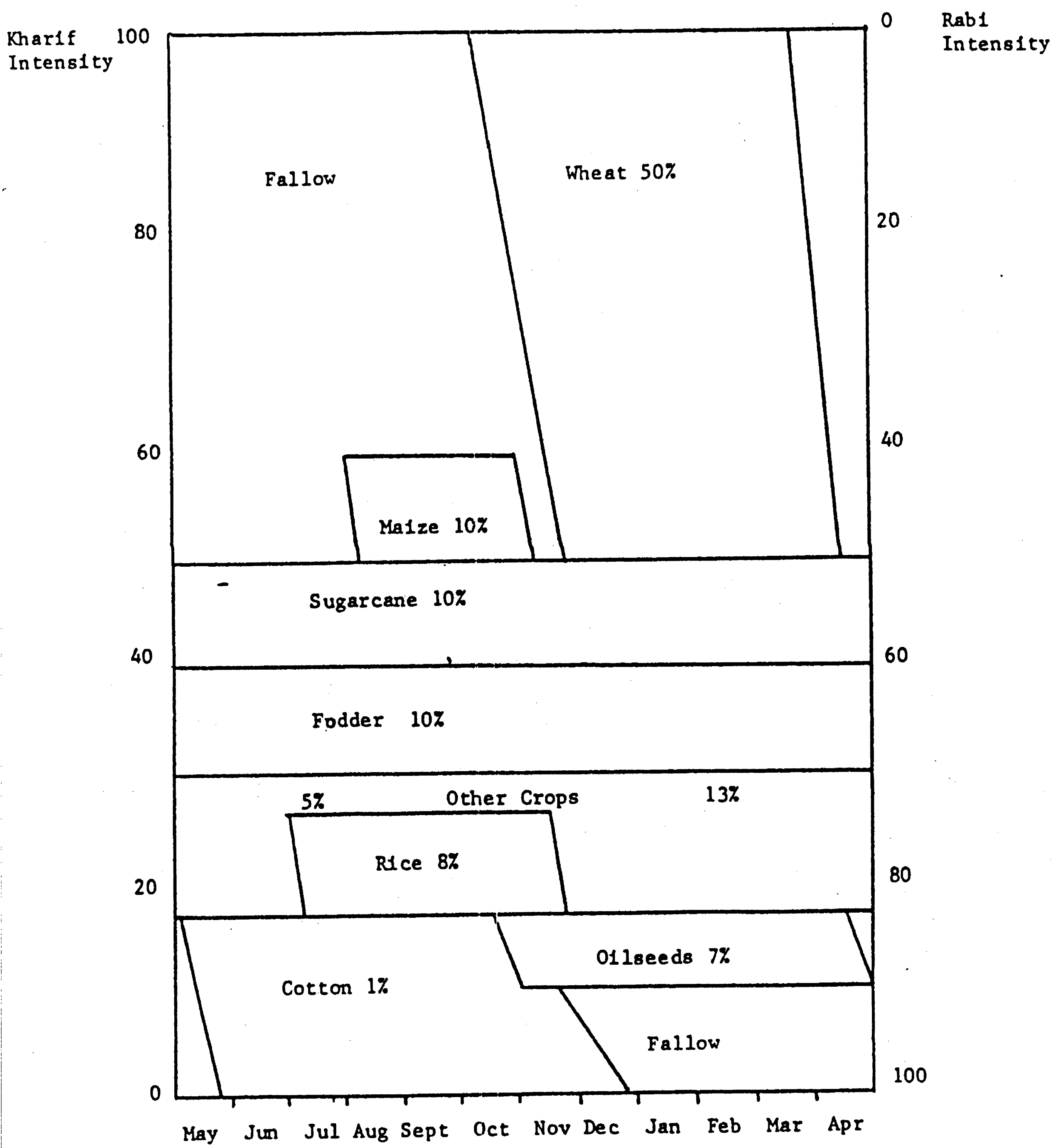
Since the sample data is cross-sectional, it is important to note the behaviour of seasonal factors in 1978-79 with respect to a "normal" year. Monthly rainfall record was available for only two major cities in the Central Punjab (Table 1.4). The table shows that the average rainfall during the survey year was not much different from the normal year. However, in the Punjab, canal irrigation contributes 60 per cent to total cultivated area and 70 per cent to total irrigated areas. Changes in the release of canal water are influenced by rainfall in the catchment areas. Table 1.5 represents the amount of canal water available at farm gate for 14 years. It is observed that 1978-79 was not an abnormal year.

1.5 Relevance of Data for the Present Study

The data was not basically collected for an efficiency study. It is a farm accounts survey data. It covers most of the information related to farm business, without going into detailed technicalities of formulating scientific sampling designs and measuring inputs like management, expectations and risk. The data is based on a full year survey and can usefully be analysed to understand the farm business. Statistical tests will be applied to test bias resulting from excluded variables.

FIGURE 1.2

TYPICAL CROPPING PATTERN, CENTRAL PUNJAB CANAL PLUS TUBEWELL OVERALL INTENSITY 150%



Source: Gotsch and Brown (1980:73).

TABLE 1.4

AVERAGE MONTHLY RAINFALL AT SELECTED STATIONS IN THE PUNJAB IN 1978-79

(MM)

Month	Lahore		Multan	
	1978-79	Normal Year	1978-79	Normal Year
J	13.50	31.20	12.20	10.70
F	52.20	23.10	31.20	7.60
M	68.50	24.40	52.00	22.60
A	4.60	15.70	10.00	10.40
M	37.60	8.10	4.60	12.70
J	38.90	38.90	0.00	5.80
J	98.69	121.70	1.20	33.80
A	51.40	122.90	55.70	32.00
S	56.60	80.00	1.00	22.90
O	4.50	9.90	0.00	0.80
N	0	3.60	6.40	1.80
D	4.50	10.70	6.30	4.60
Total	430.99	490.20	180.60	158.70

Source: G.O.P.(1980b:107-110).

TABLE 1.5

CANAL WATER AVAILABILITY AT FARM GATE IN PAKISTAN

(million acre feet)

Year	Amount of Water	Deviation From Average
1966-67	57.57	-0.15
68	56.82	-0.90
69	58.99	1.27
70	59.91	2.19
71	52.42	-5.30
72	51.99	-5.73
73	60.54	2.82
74	57.64	-0.08
75	51.86	-5.86
76	59.35	1.63
77	58.40	0.68
78	61.20	3.48
79	57.98	0.26
80	63.40	5.68
Total	808.07	
Average	57.72	

Source: G.O.P., Agricultural Statistics of Pakistan,1980b:105-106.

CHAPTER 2

CONSTRAINTS ON SMALL FARMERS' ACCESS TO MODERN TECHNOLOGY

In a recent study on efficiency in Pakistan agriculture, it was observed that large farmers in the country are technically more efficient than small farmers (Khan and Maki, 1980).[1] One of the major reasons identified for higher productivity on large farms was the greater use of modern inputs. It was further noted that:

> "There is considerable evidence that large farms in Pakistan enjoy preferential access to physical inputs, credit and markets. It is likely that without unequal access enjoyed by large farms they would be far less efficient than small farms." (Khan and Maki, 1980:64)

The aim of this chapter is to identify factors which might discriminate against the small farmer. These factors may include:

(1) Distribution of Land.

(2) Feedback Effects of Mechanization.

(3) Institutional Constraints.

(4) Role of Government.

2.1 Distribution of Land

In this section it will be observed that the use of modern technology is closely associated with the distribution of land-ownership in the Punjab. One of the factors promoting this relationship may be that, since modern inputs are purchased,[2] surplus income must be generated to buy them. Generally the amount of surplus generated for investment will be

1 The study further observes that while large farmers were also allocatively efficient in labour use, small farmers in the Sind Province of Pakistan were allocatively inefficient.

2 Most of the traditional inputs are produced by farm products (wood, labour, animals and skills, for instance).

positively related to farm size (Column 5, Table 2.1). The table shows that average household income increases rapidly with increasing farm size.

TABLE 2.1

DISTRIBUTION OF LAND AND INCOME IN THE PUNJAB, 1971-72

Farm Size (Acres)	Number of Farms			Cultivated Area			Average Size of Farm (Cultivated Acres)	Average Farm Income Per Farm (RS)
	Number	%	Cumulative %	Area (Acres)	%	Cumulative %		
(1)		(2)			(3)		(4)	(5)
< 1.0	93913	3.95	3.95	42584	0.15	0.15	0.5	154.94
1.0- 2.5	208348	8.77	12.70	320669	1.16	1.31	1.5	464.82
2.5- 5.0	316767	13.34	26.06	1075742	3.89	5.20	3.4	1053.59
5.0- 7.5	361641	15.22	41.28	2077159	7.50	12.70	5.7	1766.32
7.5- 12.5	564465	23.76	65.04	5238142	18.92	31.62	9.3	2881.88
12.5- 25.0	549158	23.12	88.16	8322284	30.06	61.68	15.2	4710.17
25.0- 50.0	209352	8.81	96.97	5826916	21.05	82.73	27.8	8614.66
50.0-150.0	64588	2.72	99.69	3689365	13.33	96.06	57.1	17694.14
≥150.0	7137	0.30	99.99	1093750	3.95	100.01	153.3	47504.59
TOTAL	2375369	100.00	100.00	27686611		100.00		

Notes: a. Column 5 = Column 4 x 309.88

where 309.88 = net value of output added in Pakistan's Agric. Sector in 1971-72

÷ All Cultivated Area of Pakistan in 1971-72

b. The year 1971-72 is used because that was a census year.

Sources: (1) G.O.P. (1972b:1)

(2) G.O.P. (1980a:13, Statistical Annexures)

Assuming that the size of household is not significantly different across farm size categories, large farmers are expected to generate larger surplus resources for investment than small farms.

The skewed distribution of land may also affect allocative efficiency by constraining the utilization of fixed assets. Table 2.2

TABLE 2.2

USE OF SELECTED INPUTS BY SIZE OF FARM IN PUNJAB

Farm Size (Acres)	Per Cent of Farmers Using Tractors	Per Cent of Farmers Using Tubewells	Per Cent of Cropped Area Fertilized	Number of Work Animals Per 1000 Acres
Average in Punjab	22.07	42.38	43.00	136.00
Under 1.0	19.91	26.57	34.00	70.75
1.0 to Under 2.5	24.85	32.44	43.00	412.62
2.5 to Under 5.0	20.40	36.80	43.00	355.17
5.0 to Under 7.5	18.63	39.46	44.00	277.09
7.5 to Under 12.5	17.67	42.47	43.00	199.75
12.5 to Under 25.0	21.87	46.27	43.00	136.60
25.0 to Under 50.0	30.79	54.60	42.00	79.85
50.0 to Under 150.0	50.61	64.56	43.00	38.82
> 150.0	67.03	69.78	55.00	16.69

Source: G.O.P. (1972b), Pakistan Agricultural Census.

shows that on farms smaller than 12.5 acres,[1] the number of work animals per 1000 acres increases as farm size decreases.[2]

2.1.1 Concentration of Tractor Ownership

Most of the tractors in Pakistan are owned by landlords owning more than 100 acres (86%). However, the concentration increases further with increasing farm size (Table 2.3). The table shows that 52 per cent of tractor-operated area is owned by landlords with farm size exceeding 500 acres. On the other hand, only 0.4 per cent of tractor-operated area is owned by farmers owning less than 25 acres.

There is evidence that custom-hiring market for tractors has not adequately developed. This may be inferred from a high density of bullocks on small farms and the low percentage of small farmers

1 In canal irrigated areas of the Punjab 12.5 acres of land is considered as the minimum requirement for fully utilizing the capacity of a pair of bullocks (Alvi,1976:324).

2 There is, however, no evidence that custom-hiring market for bullocks exists in the Punjab. (The term custom-hiring refers to the system whereby farmers purchase services of assets from one another, such as tractors.)

TABLE 2.3

DISTRIBUTION OF TRACTORIZED AREA BY SIZE OF FARM

Size of Holdings (Acres)	Proportion of Total Acres (%)	Size of Average Holding (Acres)	Cultivated Area Per Tractor
500 & over	52.3	1317	714
200 - 499	25.4	342	270
100 - 199	11.9	156	145
50 - 99	6.9	81	79
25 - 49	2.5	43	42
Under 25	0.4	-	21

Source: Alvi (1976:340).

who reported having used a tractor (Table 2.2). Moreover, relatively large farm areas per tractor on very large farms (Table 2.3) may be limiting the development of custom-hiring market for tractors.

On the other hand medium sized landlords (50-100 acres) who own tractors may be interested in increasing their farm size in order to maximize utilization of their tractors (Burki, 1976). Instead of hiring out tractors, they force their neighbours to sell/rent their lands to them (Alvi, 1976).

There is already evidence that farm size of tractor owners has been increasing during the last 20 years. Burki (1976) found that both small and large farmers had sold lands to tractor owners of size category 50-100 acres during the period 1959-60 to 1969-70.

McInerney and Donaldson (1975) found that the farm size of tractor-owners had increased by 2.4 times during the period 1968-69 to 1971-72. Forty-two per cent of the increase in farm size was contributed by displacement of tenants (Table 2.4).

TABLE 2.4

SOURCE OF INCREASE IN FARM SIZE IN IBRD TRACTOR MECHANIZATION STUDY IN PAKISTAN

Land Previously Uncultivated	22 Per Cent
Land Previously Rented Out	42 Per Cent
Land Newly Rented In	24 Per Cent
Land Newly Purchased	12 Per Cent
Total	100 Per Cent

Source: McInerney and Donaldson (1975) quoted in Gotsch and Brown (1980:31).

The implications of concentration of tractor ownership for small/ tenant farms are clear:

(1) Tenants are being evicted and the farm parcels rented out to tenants are being reduced in size (Alvi, 1976).

(2) Reduced availability of land to tenants has further constrained the profit maximising combination of labour with other fixed factors of production.

(3) Small farmers are forced to sell their lands to their large neighbour farmer who owns a tractor but does not have enough land to fully utilize its capacity.

(4) Every tractor displaces 4.5 tenants (Binswanger, 1978) and 12 pairs of bullocks (Alvi, 1976) in Pakistan. This may increase population pressure on land and induce a drastic change in factor proportions used.

(5) Alvi (1976) reports that the share of tenants in farm output decreased from 50 per cent to 30 per cent due

to increased competition for land and decreased bargaining power of tenants.

2.1.2 Availability of Institutional Credit

Total amount of institutional loans to the agricultural sector has been rapidly increasing during the period 1973-74 to 1979-80 (Table 2.5). But the composition of loans has considerably changed in favour of large borrowers and tractor purchasers.

Table 2.5 shows that the proportion of loans advanced for purchasing seed and fertilizer decreased from 33.0 per cent in 1973-74 to 7.1 per cent in 1979-80. This may have limited the access of small/tenant farmers to modern agricultural inputs.

2.1.3 Distribution of Fertilizer and Tubewells

It is observed that the relative distribution of area irrigated with tubewells and treated with chemical fertilizer does not show large variation across farm size (Table 2.2). One of the reasons may be that these inputs, particularly fertilizer, are not as expensive as tractors. However,

> "there is some difference between large and small farmers in the level of use of fertilizer." (Gotsch, 1976:253)

Mahmood and Haque (1981) also observed that farms of size 25-50 acres were operating on a higher production function than farms of size less than 25.0 acres, primarily due to greater use of fertilizer. It is concluded that small farmers have limited access to tubewell water and fertilizer and that potential remains for further profitable increases in fertilizer[1] use for all farm size categories.

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1 The rate of fertilizer use was 44 kg. per hectare in 1978-79, compared to 79 kg. in USSR, 106 kg. in USA and 450 kg. in Japan (G.O.P., 1980b:118).

TABLE 2.5

TRENDS IN THE AMOUNT AND COMPOSITION OF LOANS ADVANCED BY AGRICULTURAL DEVELOPMENT BANK OF PAKISTAN TO FARMERS IN THE PUNJAB

Year	Amount (RS) in Million	Per Cent of Short Term Loans	Per Cent of Medium Term Loans	Per Cent of Long Term Loans	Number of Borrowers	Per Cent Share of Loans For Seeds	Per Cent Share of Loans for Fertilizer	Per Cent Share of Loans for Tractors	Per Cent Share of Loans for Tubewells	Average Amount of Loan Per Borrower (RS)
1973-74	236.5	54.0	16.6	29.4	97662	1.5	31.80	21.30	14.90	2422
1974-75	224.5	29.5	11.1	59.4	46083	2.9	22.90	44.70	21.10	4872
1975-76	353.9	14.7	6.2	79.1	39023	0.3	14.00	71.50	10.00	9069
1976-77	454.6	26.8	5.6	67.6	110286	1.1	22.70	55.30	5.50	4122
1977-78	329.0	9.5	2.7	87.8	21307	0.3	8.90	74.90	3.50	15446
1978-79	292.1	7.2	7.3	85.5	19824	0.2	8.70	78.90	3.60	14735
1979-80	538.4	8.6	6.8	84.6	19369	1.1	6.00	67.20	1.60	27797

Source: G.O.P.: Agricultural Statistics of Pakistan (Various Issues).

2.2 Secondary Effects of Mechanization

One of the potential dangers of concentration of technology on large farms may be that higher incomes generated by modern technology may be used for not only expansion in farm size but also for further modernisation of farms which further increases income inequality.

There are at least three sources for this tendency. Modern technology has increased productivity of land relative to labour. This may generate further incentive for accumulation of land. Kikuchi and Hayami (1980) studied a village in Central Luzon, Philippines, which had experienced rapid mechanization during the decade 1968-1979. They found that the village society had been completely polarized into the poor landless and small farmers and the rich landlords. They observe that:

> "underlying the polarization in this village was the increasing gap between economic rent and the actual rent, reflecting a rise in the rate of return to land relative to that of labour due to growing population pressure on land. In general, the higher rate of return to land provides strong incentives to accumulate more land. The concentration of landholdings induced by the higher rate of land rentals makes the income distribution more skewed, which encourages the further concentration of land - a vicious circle that promotes polarization." (Kikuchi and Hayami, 1980:363)

One of the counteracting measures suggested by Kikuchi and Hayami (1980) is that land-saving and labour-using technologies may be developed so that wage rates rise relative to land rent.

The above observations are very relevant to the present situation in Pakistan. As noted in Section 2.1.1 not only is landlords' share in production (rent) increasing but, due to displacement of labour, real wages in rural areas may be falling. Hence the landlords may have large incentives to buy more land and modernize their farms (Table 2.4).

Binswanger (1978) observes that, initially, tractors may replace bullocks in those agricultural operations which have a large power requirement or a need for timeliness. But eventually tractors may displace labour by, say, mechanizing harvesting and threshing operations. Krishna (1976)[1] found that threshing contributed 70 per cent to labour displacement compared to 5 per cent contributed by replacing bullock-ploughing by tractor ploughing in the Indian Punjab.

The conclusion is that concentration of modern technology on big farms is a potential threat by generating feedback effects which further worsen income inequality.

2.3 Institutional Constraints

Modern technology has been transplanted to a traditional society without developing appropriate institutions which facilitate the transition. The existing social structure in rural areas is essentially feudalistic as is evident from the skewed land distribution (Table 2.1) and from the fact that 29 per cent of farmers who operate 46 per cent of cultivated areas are tenants (G.O.P., 1972a:24).

> "The tenants, the share croppers and the landless labourers are in a weak position to bargain with the landlord ... [They] must behave differentially towards the landlord and their disinclination to kick against the status quo, even when legislation seems to justify such reaction, is understandable."
> (Johnson, 1979:152)

Availability of modern technology, especially tractors, coinciding with measures taken by Bhutto's government (1971-77) which:

> "tended in the direction of increasing the bargaining power of labour and tenants with landlords."
> (Johnson, 1979:151)

has further weakened the financial position of tenants and also restricted access to wage justice under the new situation.

Lack of institutions also affects the small independent peasants. Most of the rural population is poor and unskilled, divided into factions

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1 Quoted in Binswanger, (1978:54).

based on caste and sources of patronage provided by big landlords.

> "The dominant social values of rural society emphasise non-democratic attitudes." (Ahmad, 1976:22)

Hence the weak may not be able to compete with the strong in obtaining limited supplies of inputs. During his field work in Pakistan's rural areas Alvi (1976:34) observed that:

> "tubewell owners refused to sell water to small neighbours at critical times ... and pressed them to sell their land."

> Thus,

> "there is little evidence that the current institutional structure is capable of insuring that all farmers have access to those inputs that are, by their nature, infinitely divisible." (Gotsch, 1976:262)

It is concluded that in order to relax the constraints which may cause inefficiency in resource allocation it will be necessary to develop appropriate institutions charged with the responsibility of identifying the resource requirements of small farmers and providing the necessary supplies of inputs.

2.4 Role of the Government in Promoting Technological Development

Gotsch and Brown (1980) suggest that in Pakistan the government has played a facilitating role in expanding the adoption of modern technologies. They conclude that:

> "the increases in productivity associated with purchased inputs appear, on the whole to have been sufficient to provide the necessary incentives for relatively rapid increases in their use." (Gotsch and Brown, 1980:48)

Similarly Burki (1976) concluded that the newly emerging landlords who owned between 25 and 100 acres of land and who had acquired tractors, were the group most anxious to increase their wealth by using modern inputs and acquiring more land.

Alvi(1976) on the other hand thinks that big landlords (farm size > 100 acres) were the main beneficiaries of modern technology.

However, there are important contributions made by the government in promoting the Green Revolution. In the Second Five Year Plan, 1960-61 to 1964-65, for instance, not only were the sectoral terms of trade of agriculture improving but also real prices of fertilizer and tractors were declining (Gotsch and Brown, 1980:36,43,47). The improvement was brought about by support prices for agricultural products and subsidies on inputs. These provided the initial incentive to farmers to adopt modern technology

Secondly, in order to develop water and power resources, the biggest constraint in the Punjab, the government established the Water and Power Development Authority (WAPDA). The Authority was asked to provide electrical connections to tubewells in rural areas on a preferential basis. As a result, the Third Plan (1965-66 to 1969-70) target of installing 40,000 tubewells was achieved.

Thirdly, when the output of wheat doubled in two years, from 1967-68 to 1968-69, the government entered the market to procure the additional marketable surplus. Had the farmers been left to market mechanism, the price of wheat would have fallen to low levels causing a reduction in incomes of farmers.

Fourthly, although the government has not been able to remove the subsidy element from any input, the ratio of total subsidies to taxes in the agricultural sector is steadily tending towards parity (Gotsch and Brown, 1980).

There are, however, important areas where the government can make contributions:

(1) Since the use of fertilizer is now well established, subsidies may be withdrawn completely. To offset this, credits could be provided to small farmers to buy fertilizers, and institutions could be established to ensure that the supplies in fact reach the small farmer.

(2) Underground water could be declared public property. Continuous pumping of water out of the ground will ultimately lower the water table everywhere, and turbine pumps will be required to pump it out from higher depths. Small farmers will not be able to afford such pump sets. The government could charge water rates on tubewell water and use these funds to provide small farmers with irrigation facilities.

(3) The subsidy on tractors could be withdrawn. Since a tractor displaces about a dozen pairs of bullocks, the landlords could be made to pay a certain (lump sum) amount of tax money which could be used to rehabilitate the displaced tenants.

(4) A maximum ceiling on land-ownership could be fixed so that inequalities are not further worsened.

(5) Progressive taxation on agricultural income could be introduced.

(6) A progressive land tax could be introduced.

(7) Cooperative movements could be strengthened so that the small farmers can benefit from mechanical technologies.

(8) Investment in those industries may be increased which create employment opportunities.

(9) Employment and income distribution policies could be made an integral part of rural development policy.

CHAPTER 3

LITERATURE REVIEW ON SPECIFICATION OF PRODUCTION FUNCTION

The aim of this chapter is to review literature on specification problems of production functions with special reference to the sample data.

3.1 Concept of Production Function

A production function has been variously defined.

> "It is a mathematical expression describing the maximum technical relationship between input resources and product output." (bin Sepien, 1978:40)

Algebraically, a production function may be expressed as follows:

$$Y = f(X_i) \quad i=1,2,\ldots n \qquad (3.1)$$

The algebraic form of the function varies with the biological and mechanical process. The number of inputs may also vary with different situations.

> "In general it is impossible to list all the input factors involved in producing a particular crop or livestock product. We have to use only the more important input factors." (Ferguson, 1975:2)

Specification of variables and determination of appropriate algebraic form of the function and selection of techniques of estimation are determined by the logic of production process, economic theory and empirical research already done on the problem.

3.1.1 Important Assumptions of Production Function Approach

Some of the basic assumptions of the production function approach may be noted:

1) A production function is generally assumed to be:

> "continuously differentiable, so that the partial derivatives are continuous." (Intriligator, 1978:251)

In reality some inputs may not be perfectly divisible (a pair of bullocks used for ploughing, for instance). Or they may be linearly related with the dependent variable (seed and cropped area, for instance, other things remaining the same). Linear programming approach is used to study linear and discontinuous relations because this technique can incorporate joint production and intermediate inputs into the model. However, the linear programming (LP) technique may be more appropriate when the intention is to estimate a frontier production possibility curve from production data for a given set of farms. Secondly, LP technique requires more detailed data on each farm. The technique is generally used when farm level adjustments in resource combinations may be desired.

2) The production function approach assumes that there exists an "average firm which represents all firms in the sample. The implication is that production functions of individual firms need to be similar; in the limiting case, they must be identical so that the average function can replace each of them.

> "In general, if the different firms use essentially similar techniques of production and produce essentially the same combination of products, it is not unreasonable to expect the production function of individual firms to closely resemble the inter-farm function." (Plaxico, 1955:672)

In the present study, a production function approach will be used. Different strata of farms will be identified which may use similar techniques of production and may have similar cropping patterns. Average production functions will be estimated for each strata separately. Then appropriate statistical tests will be used to test if the differences in separate average productions are significant. If these differences are not significant, the sub-groups will be pooled for estimation purposes.

3.2 Sources of Specification Bias

Correct specification of a production function is possible only if all relevant variables have been included in it and a correct algebraic form of the function has been estimated by using appropriate statistical techniques. In practice, a true function cannot be estimated owing to lack of knowledge of all relevant variables, conceptual problems in the specification and measurement of known variables, ambiguous guidance from economic theory about the proper mathematical form of the production function, inadequate facilities for computation and lack of data. It is, therefore, common in empirical work:

> "to compromise, and use second best methods or variables. Hence, we exclude variables, accept approximations, aggregate and commit various other sins of omission and commission. The statisticians call these specification errors." (Griliches, 1957:8)

In the next section, important sources of specification bias will be discussed with special reference to the sample data.

3.3 Excluded Variables

Exclusion of relevant variables leads to overestimation of coefficients of included variables and underestimation of returns to scale (Griliches, 1957) provided that the excluded variables are positively correlated to the included variables.

In the present data some of the relevant variables have been omitted because the original data were not collected for an efficiency study. Some of the omissions are general in nature and they are common to many other survey data (e.g. omission of management input). These omissions will be briefly discussed in the following.

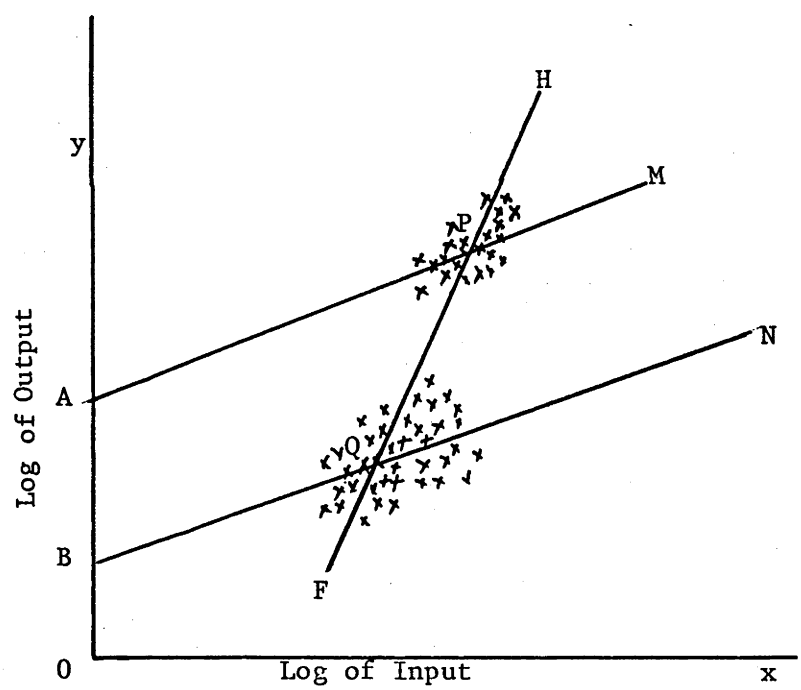
3.3.1 Management Bias

Management bias refers to the bias introduced in estimated coefficients of a production function due to the exclusion of the management input in production. The statistical problem arises due to the fact that both the dependent variable (value of output) and the independent variables (inputs) get functionally related to an unobservable factor of production, called management.

Massell (1967:498) shows that better managers not only tend to produce more output per unit of input, but also tend to use more of each input than other producers (Figure 3.1).

FIGURE 3.1

AVERAGE PRODUCTION FUNCTIONS OF FIRMS
WITH DIFFERENT LEVELS OF MANAGEMENT INPUTS
(Hypothetical)



Assume Group A of firms has better management than Group B. Then the former will be operating on the production function AM and the latter on BN. The average difference in efficiency between the two groups of firms is equal to the difference between their intercepts, i.e. AB.

Since Group A is superior to Group B in terms of management, the former operates at P, using more average amounts of inputs and producing more average amounts of output than Group B. If an average function is estimated without taking into consideration the differences in managerial input, we will end up with the function FH, which is not representative of either of the two groups of firms' average production functions. Griliches (1957) showed that omission of management may lead to underestimation of returns to scale and overestimation of capital returns, because better management is more likely to be reflected in the amount of capital used in production.

The problem of management bias results from the fact that:

> "a generally applicable scale for measuring management has not yet been devised." (Heady and Dillon, 1961:224)

If management could be satisfactorily measured, it could be included in the production function like any other input. This would have accounted for efficiency differentials caused by differences in entrepreneurial ability.

Some proxy variables may be used such as level of education, or ratings constructed on the basis of intelligence tests. But,

> "there is a danger that the management index may tend to measure the managerial potential or capability of the entrepreneur rather than his actual management input over the production period being analysed." (Heady and Dillon, 1961:225)

Mundlak (1961) and Hoch (1958) suggested a method of eliminating management bias from a production function which uses pooled cross-section and time series data. Massell (1967) suggested that even from cross-section data management bias can be eliminated by using analysis of covariance technique provided that the production functions can be estimated for each farm activity separately, and assuming that these functions are not interrelated. This, however, requires more detailed data and a larger sample than is available in this study.

A limitation in the present set of data is that detailed information on the apportionment of input costs between crops is not reported.

The number of literate persons per household was used as a proxy variable for management in this study, but the coefficient turned out to be negative and non-significant. The results (not reported) indicate that the variable in our data was not well specified.

In conclusion, it may be noted that the estimates of the coefficients in the sample may be biased due to exclusion of management input.

3.3.2 Fragmentation of Land Holdings

In the Punjab, fragmentation of land holdings is a serious problem. In 1972, 62 per cent of all farms, 59 per cent of owner-operated farms and 92 per cent of tenant farms were fragmented. Moreover, the number of fragments per farm increases with farm size (G.O.P., 1972a:26).

Fragmentation affects efficiency via choice of technology, cropping pattern and labour time used in travelling between different fragmented parcels of land. In general fragmentation may be considered as a proxy for inefficiency (Bardhan, 1973).

Since all farms are not equally fragmented, exclusion of this variable may cause bias in estimated coefficients. The labour coefficient may be overestimated because a part of labour used in farming is accounted for by non-productive use of time in travelling between fragmented farms.

3.3.3 Other Omissions

Other important variables which, but for lack of data, could have been included in the production function and which may have improved specification of other variables include: sale and purchase of fodder, labour used in irrigation, capital invested in irrigation facilities, education level of farm workers, hours of tractor hired out and marketing costs of outputs and inputs. Similarly, the influence of institutional variables (extension, for instance) has been omitted.

However, the abovementioned omissions are not peculiar to this study. Most important variables have already been included, i.e. farm income, land, labour, draft animals, non-draft animals, seed, water and fertilizer, but it was important to note these omissions because they could have caused bias in estimated coefficients.

3.4 Problems of Measurement of Variables

Measurement problems of variables include:

(1) Quality of Inputs.

(2) Capital Measurement.

(3) Valuation of Family Labour.

Problems associated with these variables will be discussed in the following sub-sections.

3.4.1 Measuring Quality of Inputs

Amount of an input is augmented by its quality in the production function. Measurement of inputs in physical units without adjusting for quality differentials can lead to misspecification of variables. Labour is generally measured in manhours or mandays. This quantity-measure implicitly assumes that all labour units are equally productive. Since labourers differ in quality and in specialization in specific agricultural operations, the measurement of labour input in physical quantity underestimates the labour input of more efficient workers.

> "It is doubtful if farmers with twice the capital or labour as their neighbours enjoy twice the quality of labour." (Griliches, 1957:15)

Similar arguments apply to land input. Quality of land varies considerably between farms and within a farm. Hence, measurement of land in acres may not be very accurate (Heady and Dillon, 1961:223). On the other hand, rent is a much more deceptive measure of land than wages for labour, because rent contains some proportion accounted for by location and scarcity of land and imperfections in its market caused by social and psychological factors. Which specific units of measurement of an input are used, depend on the availability of data. Griliches (1963) measured land input in terms of price, although he recognized the limitations of his assumptions. On the other hand, Saini (1979) measured land in acres. Standardization of land acres on the basis of revenue assessment by the government departments was used by Singh and Patel (1973).[1]

3.4.2 Measurement of Capital Input

Among the variables included in a production function,

> "the one that creates the most problem is the capital input." (Intriligator, 1978:263)

Some of these problems arise from durability of capital assets and periods longer than that in which the partial production process is completed; limited custom-hiring markets for most of the tools and equipments; obsolescence of capital assets aiming to technological change and inability of farmers to liquidate their obsolete assets quickly; lack of data on capacity utilization, imperfect records of depreciation due to tax avoidance practices and different vintages and qualities of a large number of tools and equipments of different kinds (Upton, 1979:181-183).

> "In many production function studies most, if not all, of these problems are ignored, capital stocks are used as a proxy variable for the service provided and arbitrary methods of valuation based on the valuer's judgement are used to provide a measure of the aggregate. It is questionable whether much meaning can be attached to the resultant measure." (Upton, 1979:184)[2]

1 Land acres were multiplied by the amount of land revenue as assessed by the revenue department.

2 Methods of valuation of capital in stock or service flow are well discussed in Yotopoulos (1967).

> "The theoretically proper variable for durable inputs is capital service flow." (Yotopoulos, 1968:127)

However, since adequate data for obtaining service flow measure from capital may not be available, stock measures of capital are used as proxy variable for service flow.

> "This practice is correct only if these rather restrictive assumptions are satisfied:
>
> (1) All assets involved have the same durability;
> (2) they have an even age or vintage distribution; and
> (3) the magnitude of productive service derived from the asset does not vary with assets' age."
> (Yotopoulos, 1968:127)

It is further observed that:

> "none of these assumptions is satisfied in micro-economic agricultural research," (Yotopoulos, 1968:127)

because of different durabilities and pattern of depreciation over the age of the asset. For instance, livestock and trees appreciate for some time, reach their maturity age, when the service flow from them is maximum, and then they start ageing. Physical capital assets, on the other hand, start depreciating from the beginning and service flow per unit of time does not increase with age. The implications are that different assets may be subject to different methods of measurement of service flow.

3.4.3 Valuation of Family Labour

In Pakistan, family members are the main source of farm labour. Permanently hired workers constituted only 4 per cent of total agricultural workers in the country in the 1972 Census of Agriculture (G.O.P., 1972a:46). Although views differ on whether family labour should be valued at market wage rates (Saini, 1979:54) or at some measure of real cost of labour in terms of marginal rates of substitution between utility of additional income and disutility of additional work (Sen, 1966), an implicit wage rate of family labour can be determined if we have information on current market wage rate, and the probability of getting a job. Sen (1964) suggested that the expected opportunity cost ($\bar{w}$) of labour is a function of the wage rate (w) expected from alternative employment and the probability (p) of securing that employment. This can be expressed as follows:

$$\bar{w} = w \cdot p \qquad 0 \leq p \leq 1 \qquad (3.2)$$

Thus when the rate of employment is high, $p \approx 1$, and $\bar{w} \simeq w$; when the rate of employment is low $p \simeq 0$, and $\bar{w} \simeq w$ In the slack season p will be low, hence $\bar{w}$ will be lower than it is in the busy season.

In the absence of information on probability of getting alternative employment, it is impossible to determine implicit wage rates of family labour. Following Saini (1979) it will be assumed that the market wage rate of permanently hired labour applies to family labour as well.

3.4.4 Measurement of Variables in the Sample Data

In the light of problems of measurement of variables discussed in sub-sections 3.4.1-3, and on the basis of information available in the sample data, variables were measured in the following ways:

1) Land

Following Saini (1979)[1] land input in the sample data is measured in acres. Since all sample areas come from irrigated areas, variation in land productivity is not expected to be high. On the assumption that more fertile land may be cultivated more intensively, a proxy variable, the ratio of cropped acres to cultivated acres, is also used to account for quality differentials in land. Statistical tests will also be used to test for the significance of regional variation in farm income (Section 4.5).

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1 The reference does not imply that Saini had justified the measure of land input in acres. His data related to a single district in Indian Punjab. The present data comes from four districts of Pakistan Punjab, but all are irrigated. Even then the limitations of our assumption are recognized.

2) Labour

Two types of labour were identified - family labour and non-family labour. Family labour was measured in hours and then standardized into adult man hours on the basis of age and sex. Following Dhawan and Bansal's (1977) study on allocative efficiency in Indian Punjab, adult man hours were calculated as follows (Table 3.1):

TABLE 3.1

ADULT MAN HOURS EQUIVALENTS OF LABOUR WORK HOURS ON SAMPLE FARMS

Sex	Age (Years)	One Man Hour Equivalent
Man	≥16	1.00
Woman	≥16	0.67
Child(any sex)	10-16	0.50

Source: Dhawan and Bansal (1977).

Griliches (1963) had also discounted man hours of people older than 65 years of age to 67 per cent of an adult man hour, but information on age distribution of people older than 16 years was not available in the sample data. Bardhan (1973) suggests that hired workers may be more productive than family workers due to greater specialization and better diet. Relevant data were not available to account for such productivity differentials in the sample data.

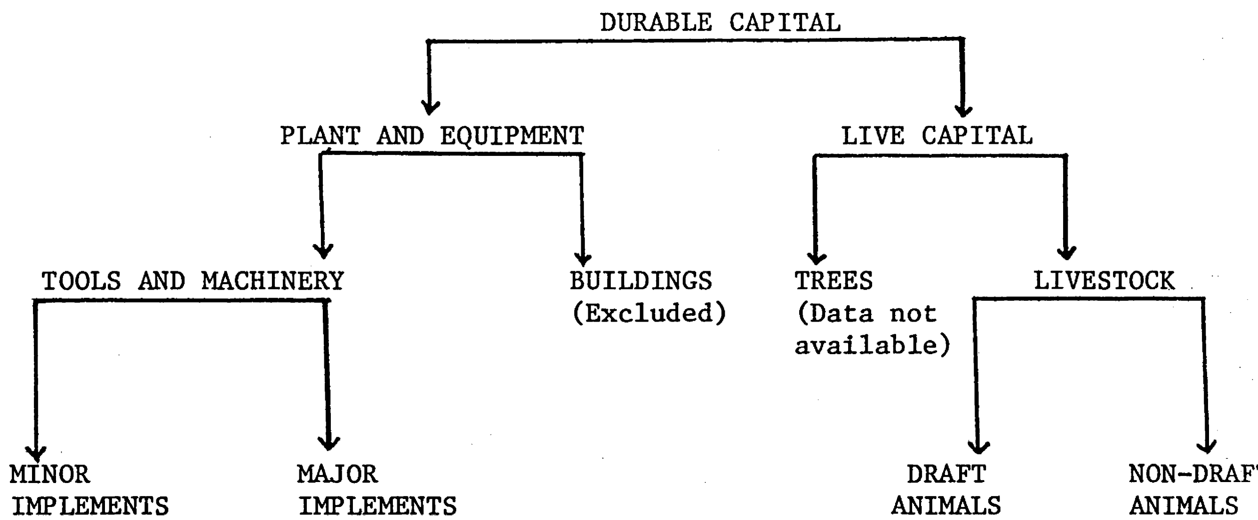
Non-family labour was measured in terms of value of payments made to it in cash or kind.

3) Durable Capital Inputs

Following Yotopoulos (1967,1968), capital inputs were classified into the following categories (Figure 3.2).

FIGURE 3.2

CLASSIFICATION OF DURABLE CAPITAL INPUTS



These variables were measured and aggregated as described below.[1] Durable capital was defined as any capital asset whose expected life was greater than one year.

Physical capital assets and live capital assets were treated separately. In the former, buildings were excluded from the production function, because in rural areas of the Punjab, valuation of houses involves a high degree of value judgement owing to a lack of rural markets for houses. Minor tools included all those tools whose expected life was one to five years. All others were classed as major tools. Expected working lives of different tools and implements were obtained from the farmers. These expected working life figures were used to depreciate all tools at a constant

1 All the assumptions made involve value judgements. Conditions of Punjab agriculture were kept in mind when making assumptions.

rate. Generally, rates of depreciation varied from 30 per cent to 20 per cent on minor tools and 5 per cent (cane-crushing tools) to 10 per cent (tractor, thresher) for major tools. A rate of 12 per cent was charged on the replacement cost of assets to account for opportunity cost of investment in assets. Both depreciation and interest rates were added to get the service flow on physical assets. All of the individual service flows were then added to obtain total service flow from all physical assets (except tractors, to be discussed below).

Two broad categories of livestock were identified - bullocks and non-draft animals.

Since most of the animals are produced on farms, their purchase price data were not available. But current market values were estimated according to the rates prevailing in the sample areas. Price of an animal was generally determined by the farmer himself. For bullocks it was assumed that their working life was 15 years (Crotty, 1980:169) and that their age distribution was normal. Current market values were used as a proxy for acquisition costs. Then the service flow was obtained by the same method as described above for physical assets. To the service flow from bullocks was added the cost of ploughing own fields by own tractors, by valuing tractor hours at the prevailing rates of custom-hiring. This aggregation defined the variable "Draft Power".

Other livestock were measured by the stock concept of capital, on the assumptions that their current values vary in proportion to their productivity. These inputs were used in the same proportion as their relative market values across farms.

3.5 Aggregation Bias

Since the possible number of inputs and outputs in a multipleproduct[1] multiple-input farming system is very large, some form of aggregation is required to derive an estimating equation. If the aggregation is sub-optimal, estimates of coefficients will be biased.

3.5.1 Aggregation of Inputs

Plaxico (1955) suggested the following principles for achieving optimal aggregation of inputs.

Inputs may be aggregated which satisfy the following conditions:

(1) They are perfect substitutes.

(2) They are used in fixed proportions.

For instance, family labour and hired labour may be aggregated because they are close substitutes. Similarly human and animal labour used in ploughing may be aggregated, because both of them are used in fixed proportions. Thus various sub-groups of inputs may be identified on the basis of above rules and aggregated into separate categories. However, one must take care that:

> "inputs in one group should not be associated in fixed proportions with inputs in another group."
> (Plaxico, 1955:17)

because this will introduce the element of covariance between any two input categories.

3.5.2 Aggregation of Outputs

Different outputs may be aggregated if the following conditions are satisfied (Plaxico, 1955):

(1) Products are produced in fixed proportions. This implies that cropping pattern is the same across farms.

---

1 In this sample, 20 crops were enumerated which had been grown by one or the other of farms. These crops are as follows: wheat, rice, maize, sugarcane, cotton, jowar, barley, oats, berseem, chillies, tobacco, watermelon, melons, onions and vegetables and fruits of many kinds.

(2) Products are affected in the same way by each input category. This implies that the response of each product to a given change in the amount of a given input is the same.

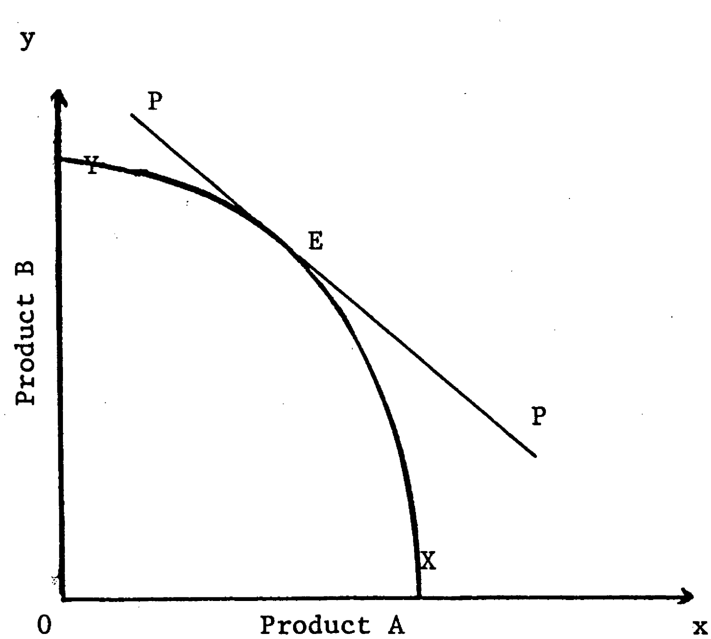
The above two conditions can be satisfied only if the following assumptions are satisfied:

(1) The aggregated outputs must substitute for each other at constant rates.

(2) The firms must be assumed to be in equilibrium by producing outputs at points on the production possibilities curve XY at which slope of the curve (marginal rate of substitution of products) is equal to ratio of product prices (Figure 3.3).

FIGURE 3.3

EQUILIBRIUM OF A MULTI-PRODUCT FIRM



A profit-maximizing firm will attain equilibrium at point E because the slopes of the two curves are equal.

If it is assumed that firms are profit maximizing, assumption (2) is easily satisfied. However, it is difficult to satisfy assumption (1).

Alternative approaches to solve aggregation problems of outputs may be described in the following:

(1) Separate production functions for each product may be estimated (Heady and Dillon, 1961). This requires not only detailed information on allocation of inputs to each product and, therefore, large sample size, but also the assumption that:

> "the productivity of a resource relative to a specific type of output is uninfluenced by the level of resource use associated with the other products produced by the firm." (Heady and Dillon, 1961:227)

(2) Separate production functions for relatively homogeneous firms may be estimated (Heady and Dillon, 1961). If separate production functions for each product cannot be estimated due to data limitations,

> "The distortions caused by output aggregation may be minimized by deriving separate functions for groups of firms producing the various outputs in approximately fixed proportions." (Heady and Dillon, 1961:227)

This approach implies that relatively homogeneous groups of farms may be identified. If cropping pattern does not differ across farms, as in perennial crops, separate functions may be estimated for private peasant holdings and estates, for instance. This approach may be convenient but requires a large sample if sample farms exhibit heterogeneity in cropping pattern, techniques of production and tenure.

(3) A joint production of the following type may be specified (Plaxico, 1955):

$$Y_1^{\alpha_1}, Y_2^{\alpha_2}, \ldots, Y_n^{\alpha_n} = \beta_0 X_1^{\beta_1} X_2^{\beta_2}, \ldots, X_K^{\beta_K} \quad (3.3)$$

where Y's are products and X's inputs. For estimating production function for any particular product, say Y_1, other products may be held at their mean levels. This method is not only complicated but also requires the assumption that resource productivities are strongly related.

In practice, it is frequently observed that either all farm products[1] or two major enterprises (crop and livestock)[2] are aggregated.

Aggregation of products is effected in monetary terms. This requires the assumption that prices of products do not vary across farms. The assumption may not be realistic if the sample comes from a large region. However,

> "the use of value rather than quantity leads to little bias in the results if the cross-sectional relative price differences are not too large." (Griliches, 1963:420)

---

1 Shih, Hushak and Rask (1977), for instance, aggregated crop products, livestock products, poultry and income from processed farm products.

2 Griliches (1963), for instance.

3.5.3 Aggregation of Inputs and Outputs in Sample Data

In the sample data, different variables were aggregated in the following ways:

(1) Following Griliches (1963), both crop products and livestock products were aggregated in value terms by using the prices prevailing in sample areas at the time at which each of the products was produced.[1] Aggregation bias may be introduced into the data by the following sources:

(i) All sample observations do not come from a single homogeneous area, but from six different areas, 300 miles across from south to north. Although statistical tests showed that regional variation was not significant, equal prices may not have prevailed for different products at a point of time in all sample areas.

(ii) Livestock enterprise contributes substantially to farm income (one third to value added in Pakistan agriculture), but its relative importance across regions and farm sizes may vary. For instance, a survey report on one of the projects in a Punjab district (G.O.P., 1967:55) finds that low income and

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1 Sample data is not based on actual sales of products, but on production data.

tenant-farmers are constrained to maintain milch animals while large farms kept large numbers of (low quality) milch animals. Aggregation of livestock enterprise with the crop enterprise, therefore, may overstate the importance of livestock for smaller/ tenant farms.

(2) In the case of inputs, close substitutes and complements were aggregated separately. Canal water was added to tubewell water (in money terms). Ploughing by tractors was added to that by bullocks (in money terms) and family labour to hired and casual labour. All non-draft animals were defined as a separate category because they are not close substitutes for bullocks. Similarly, tools and implements of all types were aggregated (in terms of service flow) among themselves. Since irrigation, seed and fertilizer are complementary inputs, they were aggregated, but the estimated production was not satisfactory (Table 4.1) due to high multicollinearity between seed and area and fertilizer and draft power. Therefore, each of these inputs were treated as a separate input.

3.6 Choice of Functional Form

Economic theory has relatively little to say in choosing between various possible forms of production function.

"The variety of equations that may validly represent a production function is virtually limitless."
(bin Sepien,1978 :41, quoting Ferguson, 1975)

3.6.1 Main Considerations in Selecting a Functional Form

Some of the most important considerations in selecting an appropriate functional form are as follows:

1) Logic of Economic Theory

The algebraic form must conform to the principles of economic theory, particularly to the law of variable proportions.

A frequent comparison is made between a function linear in variables,

$$Y = \alpha + \sum_{i=1}^{n} b_i X_i \qquad i=1,2,\ldots n, \tag{3.4}$$

which gives constant marginal productivity to a variable input but varying elasticity of output with respect to that input, and a function linear in logarithms:

$$\ln Y = \ln A + \sum_{i=1}^{n} b_i \ln X_i \quad 0<b_i<1, \qquad i=1,2,\ldots n \tag{3.5}$$

which gives varying marginal productivity to an input but constant elasticity.

The actual choice of functional form depends upon the purpose of the study and the nature of data. If the range of inputs is small, a linear production function may be used, if degrees of freedom are small, log-linear function may be used.[1]

2) Degrees of Freedom

Degrees of freedom in estimation may limit choice of preferred

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1 Other alternatives are: Translog function which gives all three stages of variable proportions (Christensen, Jorgenson and Lau, 1973); constant-elasticity of substitution function (Arrow, et al, 1961); constant-ratio-of-substitution (Mukerji, 1963); homothetic functions (Clemhout, 1968); and variable-elasticity-of-substitution (Revankar, 1971).

functional form. The preferred functional form may not be feasible because they use more degrees of freedom such as a quadratic or translog function.

3) Statistical Manageability

Some functions may involve more costs in terms of time of the researcher and that of the computer than others.

> "Algebraic forms which can be handled using conventional least squares method have in general been employed for ease of comprehension and computation." (Jarrett, 1957:70)

4) Statistical Fit

Since economic theory does not specify functional forms for different phenomena, the sample data may be subjected to different types of functional forms in order to choose the most preferred one on statistical and economic theory grounds. Statistical and econometric techniques are used to test the validity and reliability of estimates (Heady and Dillon, 1961:104).

3.6.2 Model Specified for the Sample Data

For the sample data, a conventional unrestricted Cobb-Douglas production function has been selected.

The function is defined as follows:

$$Y_j = \beta_0 \prod_{i=1}^{9} \prod_{j=1}^{t} X_{ij}^{\beta_i} e^{U_j} \quad 0<\beta_i<1 \quad \begin{matrix} i=1,2,\ldots,9 \text{ inputs} \\ j=1,2,\ldots,t \text{ farm households} \end{matrix} \qquad (3.6)*$$

where Y = Value of farm outputs of crop and livestock enterprises (in rupees).

$X_1 \Rightarrow$ A = Farm area in acres.

$X_2 \Rightarrow$ L = Value of labour input from all sources, i.e. household and hired in money terms.

$X_3 \Rightarrow$ D = Draft power which is the sum of service flow from draft animals and value of ploughing by tractors, if any.

$X_4 \Rightarrow$ M = Values of non-draft animals (in rupees).

*Equation 3.6 can also be written as:

$$Y_j = \beta_0 A^{\beta_1} L^{\beta_2} D^{\beta_3} M^{\beta_4} F^{\beta_5} I^{\beta_6} S^{\beta_7} W^{\beta_8} T^{\beta_9} e^{U_j}$$

$X_5 \Rightarrow$ F = Value of chemical fertilizer (in rupees).

$X_6 \Rightarrow$ I = Cropped area in acres per cultivated area on a farm (CA/A).

$X_7 \Rightarrow$ S = Value of seed (in rupees).

$X_8 \Rightarrow$ W = Sum of cost of irrigation water from any source, i.e. canal or tubewell (in rupees).

$X_9 \Rightarrow$ T = Value of all tools and implements, measured in rupees as a service flow.

U_j = The stochastic error term.

β_i = Parameters associated with the i^{th} factor of production to be estimated.

β_0 = Intercept to be estimated.

It is assumed here that the parameters β_i are the same for all firms, and differences among firms are summarized by the disturbance term U_j.

The function was estimated in log linear form:

$$\ln Y_j = \ln \beta_0 + \sum_{i=1}^{9} \sum_{j=1}^{t} \beta_i \ln X_{ij} + U_j \qquad (3.7)$$

by using ordinary least square method.

Main considerations in selecting a Cobb-Douglas production function for the data were as follows:

(1) The function conforms to production theory that marginal returns to a variable input diminish as its quantity is increased, while other inputs are held constant.

> "Under the usual conditions of crop and livestock production, there seems to be no strong empirical evidence for the existence of any but diminishing returns." (Ferguson, 1975:3)

Since a necessary condition for optimization is that the marginal returns to a variable input are diminishing, the use of a Cobb-Douglas production is reasonable.

(2) Convenience in Estimation and Interpretation:

A log-linear form can be linearised in logs and estimated by using ordinary least square method. Secondly, coefficients of a Cobb-Douglas production function are interpreted as elasticities of output with respect to corresponding inputs, and are easy to interpret. The estimated coefficient $\hat{b}_1$, for instance, says that if the input X_1 is increased by one per cent, while all other inputs are held constant, the output Y will increase by $\hat{b}_1$ per cent. Another important property of the Cobb-Douglas production function is that the sum of estimated coefficients ($\Sigma\hat{b}_i$) shows the percentage response of total output to a proportionate increase in all inputs simultaneously. This type of response is called returns to scale. If,

$$\Sigma\hat{b}_i \gtreqless 1 \ \{\text{returns to scale}\}\ \underset{\text{are}}{} \ \begin{matrix}\text{increasing}\\ \text{constant}\\ \text{decreasing}\end{matrix} \qquad (3.8)$$

This property is, however, based on the assumption that all relevant variables have been included in the production function. If some relevant variables (which are positively correlated to the included variables) are omitted, the estimated coefficients of included variables are overestimated and returns to scale underestimated (Griliches, 1963).

(3) Economy in the Use of Degrees of Freedom

In the present study not only is the overall sample size small (54 observations) but, since we are interested in studying allocative efficiency for sub-groups of farms, the size of sub-samples decreases further (Table 3.2).

TABLE 3.2

SIZE OF SAMPLE FOR DIFFERENT TYPE OF FARMERS

Type of Farmers	Number
All	54
Tenants	17
Owner Cultivators	37
Small Farmers	29
Large Farmers	25
Owners of Tractor/Tubewell	20
Non-Owners of Tractors/ Tubewells	34

Thus, for this study, economy in the use of degrees of freedom is crucial. A quadratic or translog production function cannot be estimated for this sample owing to limited degrees of freedom. On the other hand, a linear function gives constant marginal productivity to variable inputs. This assumption is less realistic than the Cobb-Douglas assumption of constant elasticity of output with respect to variable inputs.

3.7 Limitations of the Cobb-Douglas Production Function

A Cobb-Douglas production has some important limitations which may be noted here.[1]

(1) The Cobb-Douglas production function (C-D) assumes that elasticity of output with respect to an input (b_i) is constant for all levels of the input. The assumption implies, for instance, that the response of output to a doubling of the amount of an input, say fertilizer, will be the same whenever the initial level of the input is 10 units or 40 units. Intuitively, it may be argued that the output response may be larger at lower levels of input use than at higher levels.

(2) Essentiality of Inputs

Another limitation of a C-D function is that it assumes that every input is essential. This is because the function is multiplicative. If any of the input is not applied, the product of inputs reduces to zero. This problem can be solved by assigning small arbitrary values (say .005) to the input whose amount is zero.

(3) Inter-Firm and Intra-Firm Production Function

Redder (1943) distinguishes between inter-firm and intra-firm production functions and argues that the latter relate to real firms whereas the former to imaginary firms. A C-D is classed as an inter-firm production function. Redder (1943) particularly notes the following two points:

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1 For a detailed review of literature on Cobb-Douglas production function see Walters, A.A. "Production and Cost Functions: An Econometric Survey", Econometrica, (1963), 31:1-66.

(i) The laws of profit maximisation are applicable to intra-firm production functions, not to some average function. A single firm attains equilibrium at a single point on its cost-revenue curves. All other points on its curves represent hypothetical outputs. On the other hand, an average production function is a locus of equilibrium points of all firms in the sample and it is assumed that all of them are maximizing profits.

(ii) In a case of a single firm, the production function can be expressed in physical quantities. In case of an inter-firm, quantities, especially those of output have to be aggregated in value terms. It is shown by Redder (1943) that even if all individual firms in the sample are equating marginal factor cost to marginal value product (i.e. maximizing profits), the MVP of a variable input derived from an inter-firm function will not equal its MFC, because of price variation among firms. However,

> "the use of value rather than quantity data leads to little bias in the results if cross-sectional relative price differences are not too large." (Griliches, 1963:420)

Sampath (1979), supporting Redder, observes that in developing countries, techniques of production are not the same across farm categories due to dualistic markets.

> "The capitalist farming is based on hired labour and is market oriented. In contrast, subsistence farming is predominantly based on family labour and is not so market oriented because of low level of production and comparatively high level of consumption. And as such using a common input-output coefficient matrix and a common objective function coefficient vector for all the farmers is unrealistic." (Sampath, 1979:25)

It is clear that the above objections are general in nature and may apply to any "average" production function. An alternative solution may be to make the sample, or sub-samples, if different farms are to be compared, as homogeneous as possible.

(4) Assumption of Unitary Elasticity of Substitution

One of the most important properties of a Cobb-Douglas production function relates to substitutability of inputs for one another. A local measure of such substitutability is the elasticity of substitution σ, defined as:

> "the ratio of the proportionate change in the ratio of factor inputs (called 'factor proportions') to the proportionate change in the ratio of marginal products (the marginal rate of technical substitution at given levels of inputs):

$$\sigma = \frac{d \ln (K/L)}{d \ln (MPL/MPK)} = \frac{d \ln (K/L)}{d \ln (MRTSLK)} \quad (3.9)$$ "

(Intriligator, 1978:265)

In this definition the numerator involves the ratio between the amount of capital K and labour L, whereas the denominator involves the inverse of the ratio of their marginal productivities, ensuring that σ is non-negative. Assuming perfect competition and profit maximization,

$$\frac{MPL}{MPK} = \frac{PL}{PK} \qquad (3.10)$$

where PL = Price of labour service; and

PK = Price of capital service.

Then EQN 3.9 can be written as:

$$\begin{aligned} \sigma &= \frac{d \ln (K/L)}{d \ln (W/\gamma)} \\ &= \frac{d(K/L)/(K/L)}{d(W/\gamma)/(W/\gamma)} \\ &= \frac{d(K/L)/(W/\gamma)}{(K/L)\ d(W/\gamma)} \\ &= \frac{\text{Percentage Change in Factor Proportions}}{\text{Percentage Change in Factor Prices}} \end{aligned} \qquad (3.11)$$

Thus σ is a measure of:

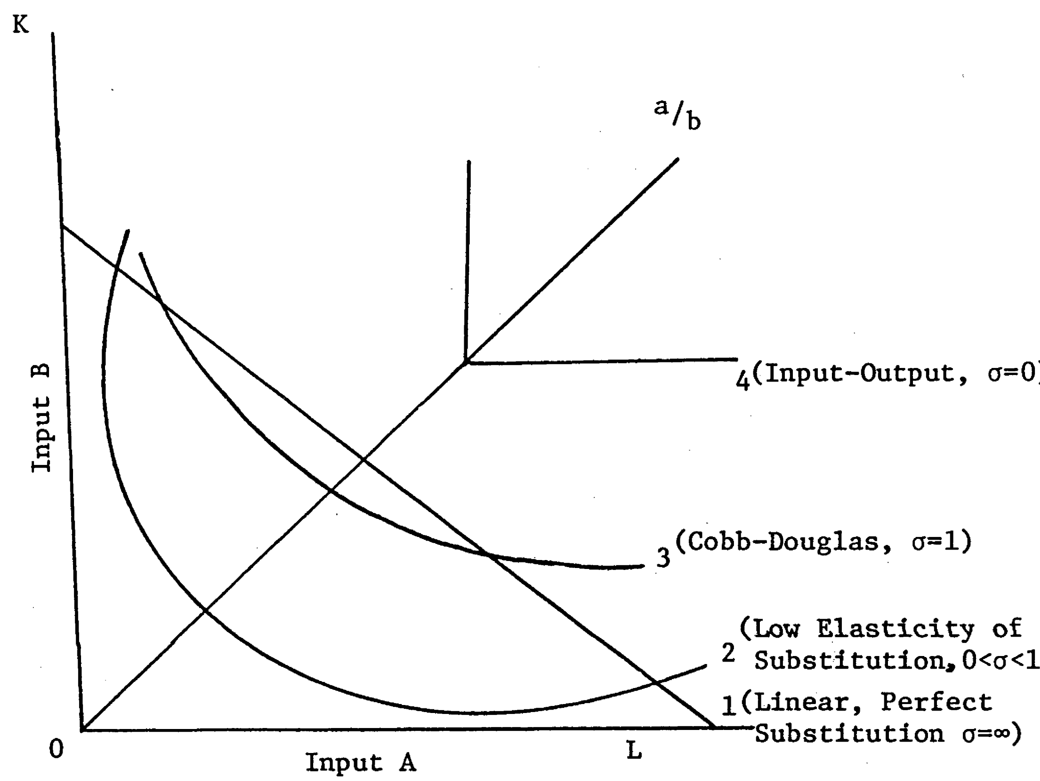
> "how rapidly factor proportions change for a change in relative factor prices." (Intriligator, 1978:265)

σ is, therefore, a measure of curvature of the iso-quant curve (Figure 3.4).

Figure 3.4 shows four iso-quants for different values of elasticity of substitution. Curve 1 is a linear function showing that a small percentage change in factor prices (suppose labour becomes relatively cheaper) will lead to infinite substitution, i.e. only labour-intensive techniques of production will be adopted. On the other hand, curve 4 shows that factor proportion $\frac{a}{b}$ will remain constant whatever the relative prices of factors

FIGURE 3.4

ISO-QUANTS SHOWING DIFFERENT VALUES
OF ELASTICITY OF SUBSTITUTION



of production. Iso-quant 3 represents a special case, with $\sigma=1$. This implies that if factor price ratios change by one percent, factor proportions will also change by one per cent and so on.

Since the assumption of unitary elasticity of substitution is very restrictive, Cobb-Douglas production should not be used unless the assumption has been statistically tested.

3.8 Method of Testing Unitary Elasticity Assumption of Cobb-Douglas Production

A general method of testing the value of elasticity of substitution for any class of constant elasticity of substitution (CES) functions (i.e. $\sigma=1$, $\sigma=0$), is to specify a CES[1] production function of the form:

$$Y = A[\delta L^{-\beta} + (1-\delta)K^{-\beta}]^{-1/\beta} \tag{3.12}$$

where A = Scale parameter, $A>0$

δ = Distribution parameter, $0<\delta<1$

β = Substitution parameter.

In this model, σ varies with K and L. Assuming σ is constant, however, and solving the resulting differential equation yields, in the constant-returns-to-scale case, precisely the CES function, where:

$$\sigma = \frac{1}{1+\beta} \tag{3.13}$$

One can then test if $\beta=0$. If β is not significantly different from zero,

$$\sigma = 1$$

which is a Cobb-Douglas case.

A direct method of testing the estimated value of σ, is to estimate the CES production function by using profit-maximizing conditions, i.e.

$$\frac{\partial Y}{\partial L} = MPL = \frac{W}{P_0} \text{ ; and}$$

$$\partial Y/\partial K = MPK = \gamma/P_0$$

where W = Wage rate

P_0 = Price of product

γ = Rate of interest

From EQN 3.12:

$$MPL = \frac{\partial Y}{\partial L} = A_0 \left(\frac{Y}{L}\right)^{1+\beta} \tag{3.14}$$

Setting marginal product of labour equal to real wage gives:

$$A_0\left(\frac{Y}{L}\right)^{1+\beta} = \frac{W}{P_0} \tag{3.15}$$

---

1 See Arrow, Chenery, Minhas and Solow "Capital-Labour Substitution and Economic Efficiency", Review of Economics and Statistics (1961), 43: 225:35.

Solving for average productivity of labour $Y/_L$:

$$\frac{Y}{L} = A_0 \left(\frac{W}{P_0}\right)^{1/(1+\beta)} \tag{3.16}$$

Taking log on both sides:

$$\ln(Y/_L) = \ln A_0 + \frac{1}{1+\beta} \ln \left(\frac{W}{P_0}\right) \tag{3.17}$$

where $\frac{1}{1+\beta} = \sigma$. The EQN can be written as:

$$\ln(Y/_L) = \ln A_0 + \sigma \ln \left(\frac{W}{P_0}\right) \tag{3.18}$$

From this equation it is easy to test if $\sigma=1$. The function is also expressed in quantities for which data may be available.

A general limitation of the above procedure is that when a production function has more than two explanatory variables, it cannot be estimated. Secondly, aggregation at a higher level may not be optimal, particularly if the sample size is small.

In the present study, data on wage rates were not available. Hours of work were recorded and a constant wage rate prevailing in the sample areas in that year was used to value labour in terms of money. For non-family labour, hours of work were not given, but payments were made in cash or kind. Most of the non-family labour in the Punjab is used for harvesting, and threshing of crops. The use of permanently hired labour in Pakistan is low. It is only 4 per cent of all agricultural work force. Thus it is not possible to derive the index $W/_{P_0}$, and hence, we could not test the assumption

One empirical study (Bardhan, 1973) tested the unitary elasticity of substitution assumption of C-D on a set of farm data from District Ferozepur of Indian Punjab. He found that the above mentioned assumption was satisfied. Following Bardhan (1973), we assume that the assumption was satisfied in Pakistan Punjab.

In conclusion it should be noted that although C-D has many limitations, it was selected for this study in view of the small sample size, lack of information on relevant data, and of its frequent applicability in Indian agriculture.

3.9 Concluding Remarks

In this chapter, problems of specification of a production function were described, and the following conclusions were reached:

(1) Production function approach was preferred to linear programming because detailed farm data for each farm activity were not available.

(2) It was recognized that data on some important variables was not available and results may be biased to that extent.

(3) The main interest of the study is in studying allocative efficiency on different types of farms. Since the number of observations in each strata of farms was limited (ranging from 17 to 37), our choice of functional form was limited, and the Cobb-Douglas type was selected because it saves degrees of freedom.

(4) Although the Cobb-Douglas production has certain restrictive assumptions, it conforms to a priori reasoning and is widely used by economists. Therefore, despite its limitations, the choice may not be inappropriate.

CHAPTER 4

EMPIRICALLY ESTIMATED PRODUCTION FUNCTIONS

In this chapter, the model specified in Section 3.6.2 is used to estimate an average production function for the sample data as a whole. Statistical tests are applied to select the most satisfactory estimating equation. Results are interpreted in Section 4.3.

4.1 Assumptions of the Model

The model specified in Section 3.6.2 is based on the following assumptions:

(1) Farmers are profit maximizers.[1] In the context of the Punjab, this assumption is realistic because

> "several commodity studies have concluded that West Pakistan's[2] farmers are price and income conscious." (Falcon and Gotsch, 1971:164)[3]

It is assumed that farmers tend to change resource allocation when relative prices of inputs and products are changed.

(2) As the production function approach is based on the assumption that the function is continuous, it implies that the adjustment in resource allocation is not only instantaneous but also costless.

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1 The hypothesis that farmers are profit-maximizers, is controversial. In a recent study on profit maximizing behaviour of farmers in the Indian Punjab, it was discovered that the neo-classifical assumption of competitive profit function worked poorly for both the small and the large farmers (Junankar, 1980).

2 Pakistan as it exists to-day, was called West Pakistan before the separation of Bangladesh (the then East Pakistan) in 1971.

3 For other studies supporting profit maximization behaviour of Punjab farmers see Krishna (1964), Saini (1979) and Khan and Maki (1980). Some studies have also found that farmers may be maximizing utility (Sen, 1966, for instance).

However, in cross-section data, perfect competition may be a good approximation.

(3) The data do not provide any information on risk-aversion characteristics of sample farmers. It is, therefore, assumed that farmers are risk neutral and make all decisions under certainty.[1]

(4) Since technology and resource constraints of farmers are constant in a cross-section study, the test of allocative efficiency is only of a short-run nature. Over time, resource constraints of farmers may change.

(5) It is assumed that techniques of production across sample farms are homogeneous. The assumption implies that the estimated average production function represents all sample farms.[2]

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1 For further details see Anderson, Dillon, Hardaker (1977).

2 The assumption, however, does not imply that production functions of all farms are identical. In such a case there will be no scatter of points and no regression (Yotopoulos, 1968).

4.2 Model Estimation for the Sample

Ordinary Least Square (OLS)[1] method was used to estimate the model specified in Section 3.6.2. The best fit of the estimated coefficients and related statistics is summarized in Table 4.1. Regression equations 1 to 6 represent unrestricted Cobb-Douglas production functions estimated by regressing the vector of natural logs of farm output in the vector of natural logs of inputs. In contrast EQN.7 represents a linear homogeneous production function estimated by regressing vector of natural logs of output per acre on vector of natural logs of inputs per acre.

The initial model (EQN.1) included all the independent variables specified in Section 3.6.2. The results show that, although the included variables explain 88 per cent of variation in farm output ($R^2 = 0.88$), four of the variables are not significant and two of these have incorrect signs.

Negative coefficients of a particular input imply that the farmer is operating in the third region of the production function according to the law of variable proportions. Negative marginal products, though not common, may be theoretically possible if the farmer applies too much of an input to the crops. However, since a Cobb-Douglas function is an exponential function, negative coefficients of inputs in this function are not feasible. Incorrect signs of production elasticities in a Cobb-Douglas production function may occur due to multicollinearity (Sahota, 1968:592) or due to sub-optimal aggregation (Griliches, 1957:109). Both of these reasons may be responsible for negative

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1 For a detailed description of the assumptions of OLS see Koutsoyiannis (1977:55).

TABLE 4.1

RESULTS OF ESTIMATED AVERAGE PRODUCTION FUNCTION
FOR FULL SAMPLE (DEPENDENT VARIABLE IS VALUE OF FARM OUTPUT)

Number of Variable	Parameters	Estimated Coefficients						
		Regression Number						
		1	2	3	4	5	6	7
	Natural Log of Intercept	5.572*	5.551*	5.459*	5.832*	5.746*	5.440*	4.631
		(0.864)	(0.852)	(0.852)	(0.803)	(0.654)	(0.757)	(0.495)
1	Area	0.490*	0.489*	0.451*	0.513*	0.501*	0.464*	-
		(0.119)	(0.118)	(0.114)	(0.103)	(0.078)	(0.095)	
2	Labour	0.119***	0.120***	0.110***	0.105***	0.107***	0.099	0.198*
		(0.078)	(0.077)	(0.077)	(0.078)	(0.076)	(0.079)	(0.069)
3	Draft Power	-0.058	-0.060	-0.048	-0.0136	-	-	-
		(0.078)	(0.077)	(0.077)	(0.072)		0	
4	Non-Draft Animals	0.121*	0.127*	0.122*	0.118*	0.115*	0.108*	0.131*
		(0.047)	(0.043)	(0.043)	(0.043)	(0.041)	(0.042)	(0.042)
5	Fertilizer	0.115*	0.119*	0.115*	0.141*	0.141*	-	0.153*
		(0.051)	(0.049)	(0.049)	(0.044)	(0.044)		(0.046)
6	Cropping Intensity	0.332*	0.326*	0.268**	0.254**	0.251**	0.259**	0.241**
		(0.132)	(0.129)	(0.119)	(0.119)	(0.117)	(0.131)	(0.123)
7	Seed	0.134	0.141	0.139	-	-	-	-
		(0.111	(0.110)	(0.110)				
8	Water	-0.044	-0.043	-	-	-	-	-
		(0.038)	(0.038)		-			
9	Tools	0.011	-	-	-	-	-	-
		(0.036)						
	FSW	-	-	-	-	-	0.195	-
							(0.078)	
	R^2	0.881	0.881	0.877	0.873	0.873	0.863	0.607
	$\bar{R}^2$	0.857	0.859	0.858	0.857	0.860	0.849	0.574
	SSE	0.166	0.165	0.165	0.166	0.165	0.171	0.173
	RSS	1.219	1.221	1.257	1.301	1.302	1.400	1.466
	F-Statistic	36.162*	41.502*	46.905*	53.790*	65.860*	60.544	18.889*
	Degrees of Freedom	9,44	8,45	7,46	6,47	5,48	5,48	4,49
	Σb_i	-	-	-	-	1.115	-	0.723

Notes: Figures in brackets are standard errors of estimate coefficients.

* Significant at the ≤ 1 per cent level of significance.
** Significant at a 1-5 per cent level of significance.
*** Significant at 5-10 per cent level of significance.

FSW = Fertilizer + Seed + Water

signs of variables DRAFT POWER and WATER in this data. DRAFT POWER has high simple correlation with AREA and SEED variables (Table 4.2A). On the other hand, WATER was an aggregation of canal and tubewell water whose prices are determined under a different institutional set up. Hence the variables bullock power[1] and water were dropped in subsequent analysis.

The SEED and TOOLS variables have the correct signs in each equation but are not statistically significant. One explanation may be that costs of seed and (service flow from) tools are small proportions of total costs of production and show little variation with farm size.[2]

The non-significant variables (draft power, water, seed and tools) in EQN.1 were dropped one by one in descending order of their t-values and the results reported as EQNS. 2 to 5. Table 4.1 shows that the F-ratio gradually improved from 36.12 in EQN.1 to 65.86 in EQN.5. Exclusion of insignificant variables did not affect the magnitude of coefficients of land, labour and non-draft animals, but the coefficient of fertilizer variable increased from 0.115 in EQN.1 to 0.141 in EQN.5. This may be due to complementarity between the use of fertilizer, seed and water. In EQN.6, therefore, a new variable (FSW) was defined as the sum of expenditures on fertilizer, seed and water. But the results of EQN.6 show that the aggregation was not optimal as it decreased $\bar{R}^2$ and rendered the labour input non-significant. Hence, EQN.6 was considered not to be an improvement on EQN.5.

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1 Saini (1979:38) had obtained a significant negative production elasticity for bullocks. There was high multicollinearity between bullocks and human labour in this function. He dropped the bullock power variable to reduce multicollinearity.

2 Coefficients of variation of seed and tools per acre were 5.00 per cent and 3.00 per cent respectively.

TABLE 4.2A

MATRIX OF SIMPLE CORRELATION COEFFICIENTS BETWEEN VARIABLES IN EQN.1, TABLE 4.1

	Income	Area	Labour	Draft-Power	Non-Draft Animals	Fertilizer	Seed	Irrigation Water	Tools	Cropping Intensity
Income	1.000	-	-	-	-	-	-	-	-	-
Area	0.846	1.000	-	-	-	-	-	-	-	-
Labour	0.654	0.708	1.000	-	-	-	-	-	-	-
Draft Power	0.738	0.803	0.534	1.000	-	-	-	-	-	-
Non-Draft Animals	0.604	0.479	0.440	0.565	1.000	-	-	-	-	-
Fertilizer	0.714	0.519	0.345	0.473	0.323	1.000	-	-	-	-
Seed	0.819	0.845	0.565	0.789	0.433	0.652	1.000	-	-	-
Irrigation Water	0.568	0.524	0.419	0.434	0.395	0.551	0.505	1.000	-	-
Tools	0.613	0.542	0.426	0.507	0.539	0.524	0.594	0.399	1.000	-
Cropping Intensity	0.273	-0.054	-0.097	0.105	0.200	0.514	0.105	0.411	0.115	1.000

In EQN.5, however, the simple correlation coefficient between land and labour is 0.708 (Table 4.2A) which is rather high.[1] After testing for constant returns to scale (Section 4.4), the linear homogeneity restriction was applied to EQN.5. Then EQN.7 was estimated by regressing the vector of natural logs of output per acre on the vector of natural logs of inputs per acre.[2] Intriligator (1978:269) suggests that if returns to scale can be assumed to be constant, a linearly homogeneous production function should be prefered to an unrestricted production function because the former reduces the estimational problems of multicollinearity and heteroskedasticity. The Correlation Coefficient Matrix (Table 4.2B) of the variables included in EQN.7 shows that the simple correlation coefficients between all independent variables have been decreased. (Compare Table 4.2A with Table 4.2B.) Another advantage of estimating linearly homogeneous production function (EQN.7) is that it saved one more degree of freedom.

One important implication of the restricted production function estimated by EQN.7 is that:

> "the coefficient of land becomes a residual coefficient, attributable, in part, to those variables that may be left out, but are correlated with land." (Sahota, 1968:587)

Hence in further analysis, land coefficient is not reported.

4.3 Interpretation of Results

The results of the final estimating equation (see equation 7 of Table 4.1) are interpreted in this section.

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1 Multicollinearity problem in the data is not, however, serious because the square of simple correlation coefficient between land and labour $r^2 = 0.501 < R^2 = 0.873$. This rule of thumb for testing the presence of serious multicollinearity was suggested by Klein (1962:101).

2 The new equation is: $\ln (Y/A) = \ln b_0 + \ln (L/A) + \ln (F/A) + \ln (M/A) + \ln (CA/A) + U_j$

For definitions of these variables, see pages 48-49.

TABLE 4.2B

MATRIX OF SIMPLE CORRELATION COEFFICIENTS

VARIABLES INCLUDED IN EQUATION 7

(TABLE 4.1)

	Income Per Acre	Labour Input Per Acre	Non-Draft Animals Per Acre	Fertilizer Input Per Acre	Cropped Area Per Acre
Income Per Acre	1.000				
Labour Input Per Acre	0.359	1.000			
Non-Draft Animals Per Acre	0.492	0.282	1.000		
Fertilizer Input Per Acre	0.591	0.039	0.132	1.000	
Cropped Area Per Acre	0.553	-0.041	0.262	0.636	1.000

The results show that a one per cent increase in labour input is expected to make a 0.198 per cent increase in farm output. That the elasticity of output with respect to human labour input turned out to be not only positive but also fairly large and statistically significant is a matter of some importance in view of the common assumption in the development economics literature of a very low (or near-zero) marginal productivity of labour.[1]

Our results contrast with Mahmood and Haque (1981) who found in their productivity study on the Punjab that the production elasticity of labour was insignificant for all farm size groups. However, the Khan and Maki (1980) study on allocative efficiency in Pakistan showed labour to be

1 See, for example, Lewis (1954).

a significant variable input. A significant coefficient of fertilizer on sample farms implies that farm output can be increased by increasing fertilizer availability to farmers.[1]

Non-draft animals are another highly significant variable in EQN.7, indicating that a substantial share of farm output is contributed by farm animals. In this sample, the average contribution to farm output made by non-draft animals was 20 per cent.

Other studies on productivity/efficiency of Pakistan agriculture, Mahmood and Haque (1981) and Khan and Maki (1980), have excluded this variable from the production function. The present results suggest that non-draft animals are an important source of farm income.[2]

In conclusion, the results show that:

(1) Labour, fertilizer and non-draft animals on the sample farms are significant variables in explaining variation in farm income.

(2) Returns to scale in Punjab agriculture are constant.

4.4 Statistical Test for Returns to Scale

Returns to scale refer to the rate of increase in farm output when all inputs are increased simultaneously by the same proportion. Returns to scale are measured by the sum of elasticities of output with respect to all inputs in a production function.

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1 G.R. Saini using 1956-57 data for the Indian Punjab, had obtained a production elasticity of 0.013 for the fertilizer variable and interpreted that "a noteworthy feature of agriculture in the mid-fifties is the negligible contribution of manures and chemical fertilizers." (Saini, 1979:39) to production.

2 In Pakistan, livestock contributed 28.75 per cent to net value added in the agricultural sector in 1979-80 (G.O.P.,1980b:187).

$$\text{Returns to Scale are } \begin{pmatrix}\text{increasing}\\ \text{constant}\\ \text{decreasing}\end{pmatrix} \text{ if } \Sigma b_i \begin{matrix} > \\ = \\ < \end{matrix} 1 \qquad (4.1)$$

(Intriligator, 1978:264)

The economic implication of the concept is that returns to scale determine incentives for expansion of the firm as well as distribution of income among factors of production. Increasing returns to scale, for instance, imply that if the producer increases all inputs by a certain proportion, total output will increase by a greater proportion. Hence, there will be a strong incentive to increase the size of the firm if there are increasing returns to scale. On the other hand, constant returns to scale imply that all output is exhausted in making payments to factors of production, including entrepreneurship.

The issue is important to Punjab agriculture, because while Khan and Maki (1980) found increasing returns to scale on large farms, Mahmood and Haque (1981) found constant returns to scale. The estimated model was used to test the following hypothesis:

$$H_0: b_1 + b_2 + \ldots + b_n = 1 \qquad i = 1,\ldots,n \text{ inputs}$$

$$H_A: \Sigma b_i \neq 1$$

where b_i is the estimated coefficient of the i^{th} variable included in EQN.7 (Table 4.1).

The following t-statistic was used to test[1] the hypothesis:

$$t = |\Sigma b_i - 1| \div ((\Sigma \text{ VAR}(b_i) + \Sigma\ 2 \text{ COV}(b_{ij}))^{\frac{1}{2}}, \quad i \neq j$$

1 The hypothesis of constant returns to scale can also be tested by using F-test, see Koutsoyiannis (1979:70).

The results show that returns to scale are not significantly different from unity. These results also conform to the results obtained by Saini (1979) and Yotopoulos (1968).

4.5 Statistical Test for Regional Variation

The data come from six different regions located in four different districts (Table 1.1). It is necessary to test if regional factors such as soil, climate and cropping pattern were significant in causing variations in farm output. As the number of observations in each sample area is very small (nine), analysis of variance (ANOVA) technique was used.[1]

In the ANOVA technique the basic problem is to establish that all samples are drawn from the same population. The hypothesis is to test if the mean farm output in all sample areas is not significantly different from each other.

The following hypothesis is tested:

$$H_0: \bar{Y}_1 = \bar{Y}_2 = \bar{Y}_3 \ldots = \bar{Y}_6$$

H_A: $\bar{Y}$ not all equal $j = 1, \ldots, 6$ are sample regions,

where $\bar{Y}$ = Population mean income

$\bar{Y}_j$ = Mean income in area j

The test involves computing the following F-Statistic:

$$F^*_{V_1, V_2} = \frac{\text{Estimated Variance From 'Between' - the Mean Variation}}{\text{Estimated Variance From 'Within' - the Samples Variation}}$$

where V_1 = Number of samples less one; and

V_2 = Total number of observations in the pooled sample.

(Koutsoyiannis, 1979:147)

1 A more powerful test would have been F-ratio test which is based on estimation of the same production function for each region and computing F-Statistic from the sum of residual squares. For detailed description see Koutsoyiannis (1979), Chapter 8.

The results of ANOVA (Table 4.3) show that the computed $F^* = 0.788 < F_{5,48} = 3.70$ at one per cent level of significance. It is concluded that regional factors are not statistically significant in explaining variations in the farm output. Hence, the pooled function can be used to represent all farms in the sample.

TABLE 4.3

ANALYSIS OF VARIANCE

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F^*
Between - the samples	$\sum_{j}^{k} nj(\bar{Y}_j-\bar{Y})^2$ = 931241401	$V_1 = k-1$ 6-1 = 5	$\frac{931241401}{5}$ ≃ 186248280	$F^* = \frac{\sum_j nj(\bar{Y}_j-\bar{Y})^2/K-1}{\sum\sum_{ji}(Y_{ji}-\bar{Y}_j)^2/(N-K)}$ $= \frac{186248280}{236325560} = 0.788$
Within - the samples	$\sum\sum_{ji}(Y_{ji}-\bar{Y}_j)^2$ 11343626908	$V_2 = (N-K)$ = 54-6 = 48	$\frac{11343626908}{6}$ = 236325560	
Total	12274868000	5+48 = 53		From Table, $F_{5,48(.01)} = 3.70$

Notes: Y = Total farm output measured in value terms

n = Number of observations in sub samples

N = Number of observations in the total sample

k = Number of sub samples j = 1,2...k=6

i = Number of observations in the sample i = 1,2,...54

CHAPTER 5

AVERAGE PRODUCTION FUNCTIONS FOR DIFFERENT FARM TYPES

5.1 Estimated Functions

As the main objective of the study is to study and compare allocative efficiency of different types of farms, this chapter is devoted to estimating average production functions for tenants, owner-cultivators, small farmers, large farmers, tractor/tubewell owners and non-tractor/ tubewell owners. EQN.7 (Table 4.1) was used to estimate separate production functions for each of these sub-groups. Results are presented in Table 5.1.

In general, the functions are well-estimated. R^2's are high and F-ratios are highly significant. All coefficients have correct signs and at least two out of four explanatory variables in each of the estimated equations are significant.

However, there are some important differences to be noted in the magnitude of the production elasticities of some inputs between various types of farms:

(1) Production elasticity of labour is not significant for tenants, small farmers and non-mechanized farms but it is significant for owner, large, and mechanized farms respectively.

(2) Non-draft animal variable is not significant for large farms.

(3) Fertilizer variable is not significant for the mechanized farms.

TABLE 5.1

AVERAGE PRODUCTION FUNCTIONS FOR DIFFERENT TYPES OF FARMS

(Dependent Variable is Farm Output Measured in Rupees)

Parameters / Number of Cases	Estimated Coefficients of Variables						
	Types of Farms						
	All Farms	Tenant Farms	Owner Cultivated Farms	Small Farms	Large Farms	Non-TW Farms	TW Farms
	54	17	37	29	25	34	20
Natural Log of Intercept	4.631*	5.474*	4.324*	5.116*	4.855*	5.472*	4.046*
	(0.495)	(0.923)	(0.638)	(0.569)	(1.377)	(0.700)	(1.004)
Labour	0.198*	0.003	0.226**	0.096	0.196***	0.090	0.284**
	(0.069	(0.115)	(0.087)	(0.088)	(0.147)	(0.109)	(0.111)
Non-Draft Animals	0.131*	0.187**	0.132*	0.177*	0.070	0.115**	0.162**
	(0.042)	(0.077)	(0.051)	(0.046)	(0.074)	(0.058)	(0.066)
Fertilizer	0.153*	0.192*	0.167**	0.133*	0.187***	0.146*	0.150
	(0.046)	(0.049)	(0.078)	(0.045)	(0.122)	(0.052)	(0.123)
Cropping Intensity	0.241**	0.124	0.273***	0.312**	0.158	0.340**	-0.117
	(0.122)	(0.176)	(0.163)	(0.148)	(0.198)	(0.144)	(0.279)
R^2	0.606	0.826	0.576	0.803	0.561	0.680	0.559
$\bar{R}^2$	0.574	0.767	0.523	0.770	0.530	0.636	0.444
SSE	0.173	0.128	0.186	0.128	0.215	0.160	0.197
RSS	1.466	0.195	1.105	0.394	0.727	0.745	0.582
F-Statistic	18.889*	14.195*	10.871*	24.492*	8.25*	15.400*	4.764*
Degrees of Freedom	4,49	4,12	4,32	4,24	4,20	4,29	4,15

Note: For explanation, see footnote Table 4.1.

Results will be interpreted after statistical tests have been performed to test equalities of production functions and differences of production elasticities between various types of farms (Sections 5.2 and 5.3 respectively).

5.2 Test of Equality of Production Functions Between Farm Types

Before two farm groups are compared with respect to allocative efficiency, it is necessary to test if they operate on the same production function. A significant difference between production functions of two types of farms will imply that they are structurally different from each other. In this case conditions of equilibrium may be different for each group and comparisons cannot be made.

The following hypotheses were tested:

$$H_0: \; b_i^{(1)} = b_i^{(2)} \qquad i = 1,\ldots,4$$

H_A: Not all b_i are the same for the two types of farms being compared.

where b_i = parameter of the i^{th} input and the superscript denotes group number. For instance, group 1 may be tenant and group 2 may be owner-cultivator.

The procedure is to estimate the same production function for each type of farm separately and to compute the following F-Statistic which has F-distribution with V_1, V_2 degrees of freedom (Maddala, 1977:197-199).

$$F^{*}_{V_1,V_2} = \frac{(RSSp - \sum_{i=1}^{2} RSS)/(K+1)}{\sum_{i=1}^{2} RSS/(n_1+n_2-2K-2)}$$

where RSS = Residual sum of squares

p = Pooled function

i = 1,2 individual production functions of the two groups to be compared

n_1 = Number of observations in Group 1

n_2 = Number of observations in Group 2

K = Number of explanatory variables in the estimated function

V_1 = K+1

V_2 = (n_1+n_2-2K-2)

The computed $F^{*}_{V_1,V_2}$ is tested against the theoretical F_{V_1,V_2} at α level of significance. If $F^{*}_{V_1,V_2} > F_{V_1,V_2}$, the hypothesis that the farm groups have the same production function is rejected.

For the sample data the above hypotheses were not rejected at 10 per cent level of significance for the following groups compared:

Tenants vs Owner-cultivators

Small vs Large farms

Non-mechanized vs Mechanized farms

The economic implication is that if all types of farms face the same factor and product prices, marginal value products of the same inputs can differ between farm groups only if one or both of those farm categories are allocatively inefficient.

5.3 Test of Difference of Production Elasticities Between Farm Types

Although tests used in Section 5.2 showed that different farm groups are on the same function, they may still differ in factor-utilization and output-input ratios. These differences may arise due to non-homothetic production functions, as well as differences in: (1) technical efficiency; (2) market conditions; and (3) allocative efficiency (Yotopoulos, et al, 1970:44-45).[1] The following tests were applied to test if the differences were significant:

$$H_0: \; b_i^{(1)} = b_i^{(2)} \qquad i = 1,2,\ldots,4 \text{ inputs}$$
$$H_A: \; b_i^{(1)} \neq b_i^{(2)}$$

where b_i = Parameter of the i^{th} input and the super-scripts show the group number to be compared.

The following t-statistic was used to test the above hypothesis:

$$\overset{*}{t} = \left(b_i^{(1)} - b_i^{(2)} \right) \div \left(\frac{DF^{(1)} \, V(\hat{b}_i^{(1)}) + DF^{(2)} \, V(\hat{b}_i^{(2)})}{n_1 + n_2 - K_1 - K_2 - 2} \right)^{\frac{1}{2}}$$

which has t-distribution with $(n_1+n_2-K_1-K_2-2)$ degrees of freedom,

where DF = degrees of freedom

i = 1,2,...,4 inputs

V = variance

Results of these tests are shown in Table 5.2. The results are as follows:

1) Production elasticity of labour on tenant and on non-mechanized farms is significantly less than that on the owner and mechanized farms respectively. However, the labour coefficient is not significantly different between small and large farms. The results imply that the effect of tenancy and mechanization on labour use may be stronger than the effect of size of farm. On the basis of these results no generalization can be made. More information and further research is needed to test these hypotheses further.

1 The discussion of all these sources of differences in production elasticities between groups of farms is not possible here due to limitations of time.

TABLE 5.2

COMPARISON OF PRODUCTION ELASTICITIES OF SAME INPUTS ON DIFFERENT TYPES OF FARMS

Comparable Farm Categories	Differences in Elasticity Coefficients of			
	Labour	Non-Draft Animals	Fertilizer	Intercept
Tenants VS Owner-Operated	-0.223** (0.107)	0.055 (0.067)	0.025 (.078)	1.15*** (.819)
Small VS Large	-0.100 (0.132	0.107*** (0.067)	-0.054 (0.099)	0.261 (1.136)
Non-TW VS TW	-0.194*** (0.122)	-0.047 (0.068)	-0.004 (0.095)	1.426*** (0.915)

Notes: (a) TW = Farms owning tractor or tubewell.

(b) For other explanations, see footnote Table 4.1.

2) The pattern of fertilizer use is the same across farm categories. This result is supported by secondary data (Table 2.2), which shows that the proportion of area fertilized does not vary much across farm size categories. In this sample the use of fertilizer per acre does not show significant differences between different types of farms except for mechanized vs non-mechanized farms (Table 5.3).

3) The production elasticity for non-draft animals on small farms is significantly greater than that of the large farmers. This implies that the income of small farmers can be increased by enabling them to increase the number of livestock on their farms.

Our results are supported by the findings of a livestock survey[1] conducted in Muzaffargur district of the Punjab.

1 G.O.P. (1967).

TABLE 5.3

USE OF FERTILIZER PER ACRE ON DIFFERENT TYPES OF SAMPLE FARMS

Type of Farm	Average Amount of Fertilizer Used Per Acre (RS)
Tenant Farm	161
Owner-Cultivator	195
Small Farmer	200
Large Farmer	167
Non-Mechanized Farm	162
Mechanized Farm	223

The survey finds that, unconstrained by land resources, the large farms keep a large number of low quality animals, and maximize milk production per unit of land. On the other hand, small farms keep fewer animals and get higher yield by substituting labour and concentrates for land (Table 5.4).

It is concluded that:

(1) The estimated production function is stable across farm types.

(2) Separate production functions for different types of farms show important differences in characteristics of sub-groups within the sample which the pooled function did not.

(3) The production elasticity of fertilizer is not significant for mechanized farms. This result supports the findings of recent studies on agricultural productivity in Pakistan,

TABLE 5.4

MILK PRODUCTION PER FARM AND PER ANIMAL
ON DIFFERENT FARM TYPES

Item	Small Farms[b]	Medium Farms[b]	Large Farms[a]
Number of Milch Animals Per Farm	1.6	1.0	
Milk Production Per Farm (lbs)	99.9	267.0	
Milk Production Per Milch Animal (lbs)	619.9	267.0	
Percentage of Milk Sold	34.0	-	

Notes: a Milk production for large farms not given in the original table.
b Average farm sizes were 8.5 acres for small farms and 18.6 acres for large farms.

Source: G.O.P., 1967:98.

that mechanized farms are over-using fertilizer (Mahmood and Haque, 1981, for instance). Binswanger (1978) also showed that tractor farms are associated with larger use of inputs.

CHAPTER 6

ALLOCATIVE EFFICIENCY ON SAMPLE FARMS

6.1 Computation of Marginal Value Products

In the Cobb-Douglas production specified for this study (Section 3.6.1):

$$MP_i = \partial Y / \partial X_i = \hat{b}_i \; Y / X_i \qquad (6.1)$$

where $\hat{b}_i$ is the estimated production elasticity of the i^{th} input. By multiplying both sides of EQN (6.1) by the price of product P_0, we obtain the value of marginal physical product (MVP):

$$MVP_i = P_0 \times MP_i = \hat{b}_i \times Y / X_i \qquad (6.2)$$

In the sample data all farm outputs had been aggregated in terms of money. Hence MVP_i was estimated by using the estimated equations given in Table 5.1.

In a Cobb-Douglas production function:

> "the most reliable estimate of marginal productivity is obtained by taking X_i at its geometric mean; i.e. at the value where log X_i assumes its arithmetic mean. Also $\hat{Y}$ should be the estimated level of output when each input factor is held at its geometric mean." (Heady and Dillon, 1961:231)

Following Heady and Dillon (1961), predicted values of farm output ($\hat{Y}$) were calculated by substituting arithmetic means of natural logarithms of each input (Table 6.1) into the estimating equation:

$$\hat{y} = a + b_L \bar{l} + b_F \bar{f} + b_M \bar{m} + b_I \bar{i} \qquad (6.3)$$

where lower case letters represent natural logs of the following independent variables:

TABLE 6.1

ARITHMETIC MEANS OF NATURAL LOGS OF AMOUNTS OF INPUTS USED PER ACRE BY DIFFERENT TYPE OF FARMS

Type of Farms	Number of Farms	Inputs				
		Labour RS	Non-Draft Animals (RS)	Cropping Intensity	Fertilizer (RS)	Output
All Farms	54	6.629 (0.359)	6.607 (0.614)	0.312 +	5.067 (0.675)	7.657 (0.265)
Tenant	17	6.683 (0.282)	6.458 (0.492)	0.262 -	4.841 (0.922)	7.665 (0.264)
Owner-Cultivator	37	6.604 (0.390)	6.675 (0.657)	0.335 -	5.170 (0.508)	7.654 (0.269)
Small	29	6.776 (0.304)	6.736 (0.597)	0.327 -	5.114 (0.808)	7.743 (0.268)
Large	25	6.457 (0.346)	6.457 (0.611)	0.294 -	5.012 (0.489)	7.558 (0.230)
Non-TW-	34	6.720 (0.280)	6.606 (0.525)	0.229 -	4.900 (0.759)	7.628 (0.266)
TW-	20	6.472 (0.427)	6.607 (0.757)	0.453 -	5.351 (0.371)	7.707 (0.264)

Note: Figures in parentheses show standard deviations.

L = Labour per acre (RS)

F = Fertilizer per acre (RS)

M = Non-draft animals per acre (RS)

I = Cropped area per acre

Y = Output per acre

The "-" indicates that the independent variables are fixed at arithmetic means of natural logs (Table 6.1).

Using coefficients estimated in Table 5.1, the estimated values of $\hat{Y}$ for different farm categories are given in Table 6.2. The value 2120.70 in the first row column 3, for instance, calculated for the whole

TABLE 6.2

PREDICTED AND GEOMETRIC MEAN VALUES OF FARM OUTPUT FOR DIFFERENT TYPES OF SAMPLE FARMS

Type of Farm	Geometric Mean of Farm Output	Predicted Farm Output[a]
(1)	(2)	(3)
All Farms	2115.40	2120.70
Tenant Farms	2132.39	2129.53
Owner Farms	2109.06	2105.80
Small Farms	2305.38	2300.67
Large Farms	1916.01	1912.67
Non-Mechanized Farms	2054.94	2058.54
Mechanized Farms	2223.86	2217.27

Note: a Prediction based on coefficients estimated in Table 5.1 and arithmetic mean levels of natural logs of independent variables given in Table 6.1.

sample, was obtained as follows:

$$\hat{y} = a + b_L \bar{l} + b_M \bar{m} + b_F \bar{f} + b_I i$$

$$= 4.631 + .198\ (6.629) + .131\ (6.607) + .153\ (5.067) + .241(0.312)$$

$$= 7.66$$

$$\hat{Y} = e^{7.66}$$

$$= 2120.70$$

Now marginal value product of labour MVP_L for the whole sample will equal the product of production elasticity of labour $\hat{b}_L$ and estimated and average product of labour $\hat{Y}/_L$ i.e.:

$$MVP_L = \hat{b}_L\ (\hat{Y}/_L)$$

$$= 0.198\ (2120.70/e^{6.629})$$

$$= 0.55 \text{ rupees}$$

The results are presented in Table 6.3.

TABLE 6.3

MARGINAL VALUE PRODUCTS OF DIFFERENT INPUTS USED PER ACRE BY DIFFERENT TYPES OF FARMS IN THE SAMPLE

Type of Farms	Number of Farms	Marginal Value Products of		
		Labour	Non-Draft Animals	Fertilizer
All Farms	54	0.55** (0.195)	0.38 (0.536)	2.04** (0.616)
Tenant Farms	17	-	0.62*** (0.257)	3.23* (0.830)
Owner-Cultivated Farms	37	0.64*** (0.249)	0.38* (0.136)	2.00 (0.936)
Small Farms	29	-	0.48* (0.126)	1.84 (0.634)
Large Farms	25	0.59 (0.442)	-	2.38 (1.557)
Non-TW-Farms	34	-	0.32* (0.161)	2.24** (0.799)
TW-Farms	20	0.97 (0.383)	0.49** (0.198)	-

Notes: (a) Blank columns represent those elasticity coefficients which were not significant in the production functions (Table 5.1).

(b) * = MVP significantly different from unity at $\leq$ 1 per cent level of significance.
** = significant at 1-5 per cent level of significance.
*** = significant at 5-10 per cent level of significance.

(c) Figures in parentheses represent standard errors of respective MVP's. These standard errors were calculated by using the following formula given by Massel (1968:49):

$$\hat{Var}(f_i) = \left(\frac{\hat{Y}}{\tilde{X}_i}\right)^2\left(\hat{Var}(b_i) + \frac{(S_i)^2(b_i)^2}{n}\right)$$

where $\hat{Var}$ = (standard error)^2
f_i = marginal product of the i^{th} input
$\hat{Y}$ = estimated farm output in value terms
$\tilde{X}_i$ = geometric mean level of the i^{th} input
b_i = elasticity coefficient of the i^{th} input
S_i = unexplained variance in log Y
n = number of observations

6.2 Interpretation of Results

The following conclusions are made from the results of allocative efficiency tests[1] presented in Table 6.3:

1) All Sample Farms

Marginal value product of labour is significantly less than wage rates. This implies that more than the optimum amount of labour is being used on sample farms. Withdrawal of part of the labour input from an average farm will increase farm profits. These results contrast with those of Saini (1979) for the Indian Punjab. Saini found that MVP_L was more than the wage rate (implying shortage of labour). Khan and Maki (1980) found that farmers in Pakistan were generally allocatively efficient in labour use. However, Khan and Maki (1980) had studied only two crops (rice and wheat) while the present study is based on all crops grown in the sample areas as well as the livestock enterprise.

In contrast, marginal value product of fertilizer is significantly greater than the price of fertilizer. This implies that profits of an average farm can be increased by increasing the use of fertilizer. The results conforms to the proposition that:

> "even with the marked increases in fertilizer use since the 60's,[2] the <u>level</u> of use remains below international standards and crop requirements. The constraint to expansion is domestic production, import levels and distribution bottlenecks." (Musharraf, 1980:33)

In the use of non-draft animals, however, marginal value product does not significantly differ from factor cost. The results imply that the average farm in the sample is allocatively efficient in the use of non-draft animals. This is an important finding of this study. Our results

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1 See Sections 1.2.2 and 1.3 for the hypotheses to be tested. The following t-statistic was used to test each hypothesis: $t^* = (MVP_i - MFC_i) \div SE(MVP_i) \sim n-K-1$ degrees of freedom where K = Number of independent variables in the equation. Since all inputs have been measured in rupees, MFC=1 for each input.

2 See Musharraf (1980:168) for a trend in fertilizer use in the Punjab for the period 1950-78.

however, contrast with an FAO opinion that in Pakistan,

> "management and feeding of livestock is inadequate, and there is serious overstocking in certain areas as fodder and feed supplies have not kept pace with the rise in livestock numbers." (FAO, 1973:3)

2) Tenants vs Owner Cultivator Farms

The results show that tenants are allocatively inefficient in the use of both the livestock and fertilizer. Livestock is overstocked while fertilizer use is less than optimal. Fertilizer is a purchased input which the (poor) tenants may be constrained to buy. Increased availability of fertilizer to tenants may enable them to increase potential economic gains.

Overstocking of non-draft animals on tenant farms, however, is difficult to explain. On a priori basis, insecurity of tenure must result in fewer non-draft animals. But the insecurity may also work the other way round. Animals may serve as a source of accumulated savings which can be converted into cash in bad times. The latter view is more plausible in the context of Punjab agriculture, where farm animals:

> "play an important role in farm business as a source of farm power, supply of proteins and fats ... and serve as a reserve on which farmers can fall back upon during failure of crops or other emergencies." (G.O.P., 1967:55)

The implication is that if tenants are burdened with animals as a counter measure for insecurity, only institutional reforms can induce them to reduce their number.

The allocative pattern of owner-cultivators is quite different from that of the tenant farmers. For tenants, labour is a redundant factor of production (with insignificant production elasticity) while for the owner-cultivators labour is a critical input. However, owner-cultivators are also facing excessive supply of labour because MVP_L is less than the market wage rate. Increased labour input is expected to increase farm output, but not profits of the farm business.

In the use of fertilizer, however, owner-cultivators are using optimal quantities. Thus while tenants have been unable to use profit-maximizing quantities of any input, owner-cultivators are at least allocatively efficient in the use of fertilizer.

3) Small vs Large Farms

Labour input is not significant on small farms, livestock is being overstocked and the use of fertilizer is optimal. On the other hand, large farmers are allocatively efficient in the use of both labour and fertilizer. However, large farms are also overstocking farm animals. It is difficult to explain why two groups of farms with different resource constraints have similar livestock patterns. One of the possible explanations of overstocking may be employment of household labour on small farms and higher consumption of milk per capita in large farm households. A survey report finds that:

> "The number of milch animals....did not vary in accordance with the size of family members. In the low group, one milch animal was available for 5.6 persons as against one animal for 3.5 persons in the medium group and one animal for 0.7 persons in the high group." (G.O.P., 1967:55)[1]

Khan and Maki (1980), studying only two crops, rice and wheat, had observed that while large farms were allocatively efficient in labour-use in two provinces of Sind and the Punjab in Pakistan, small farmers in the Sind faced excessive supply of labour. Our results suggest that if the farm business as a whole (livestock + crop sector) is taken into consideration, small farms even in the Punjab may face surplus labour problems.

4) Non-Mechanized vs Mechanized Farms

The comparison of these two categories is very important because non-mechanized farms may still be using primitive techniques of production

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1 Average farm sizes of various size groups mentioned in the quotation were as follows:

Low Group	=	8.7 acres
Medium Group	=	12.7 acres
High Group	=	42.0 acres

while mechanized farms may be relatively modern. The results conform to our maintained hypothesis that the resource use pattern on two types of farms will reflect the resource constraints of different farm groups.

The results show that the traditional farmer is facing the most severe resource constraints. On a traditional farm labour is surplus, and on a mechanized farm,fertilizer is surplus (a purchased input!). On the other hand, a mechanized farm is allocatively efficient in labour use but on the traditional farm,sub-optimal quantities of fertilizer are being used. In case of livestock, however, both types of farms are overstocking.

5) Conclusion

The tests of allocative efficiency hypotheses have shown very useful results -

(1) In studying labour-use pattern, size of farm may not be the only relevant variable. The effect of tenure and mechanization may be more profound.

(2) The importance of livestock in the socio-economic system should be recognized. Farmers of all types in the Punjab seem to be overstocking animals.

(3) Tenants/traditional farmers are more constrained in buying the required quantities of fertilizer than owner-cultivators/mechanized farms.

(4) Large farmers are allocatively efficient in both labour and fertilizer use whereas small farmers are allocatively efficient only in fertilizer use.

(5) The insignificant coefficients of labour on non-mechanized farms and fertilizer on mechanized farms, respectively, imply that the former maximise output

with respect to labour while the latter maximize output with respect to fertilizer.

(6) Finally, the allocative efficiency results show the possibilities for improving resource allocation in the Punjab agriculture.

6.3 Limitations of the Study

Although the study has shown that, in general, there are possibilities for increasing resource-use efficiency on the "average" sample farm the following limitations may be noted:

(1) Number of observations for sub-groups of farms was small. Further research may be needed before the relationships produced by this study could be generalized.

(2) Our analysis was ex-post while farmers make their decisions on the basis of expectations. It is quite possible that allocative efficiency could not be achieved by the farmer due to factors beyond his control.

(3) Some of the constraints result from indivisibilities. For instance, overstocking observed in non-draft animals may be due to indivisibilities of the input.

(4) Non-economic considerations such as employment of women and children, sources of saving, security and prestige may be involved in overstocking of animals. The study could not identify these factors due to lack of relevant data.

(5) Some of the constraints may relate to institutional factors rather than to farm planning. For instance,

the use of less fertilizer than optimum on a tenant farm may not be due to inferior management or entrepreneurship of a tenant, but to his inability to offer collateral for loans for fertilizer, or to other restrictions on access to supplies of fertilizer.

(6) Sen (1966)[1] advanced the hypothesis that the implicit wage rate for the family labour may be lower than the market wage rate. For our sample, small farmers may be equating marginal value product of their labour to their implicit wage rates rather than to the market wage rates.

(7) The results are based on the use of Cobb-Douglas production function which was fitted to the data without testing its implicit assumptions.

6.4 Policy Implications

With the limitations described in Section 6.3 in mind, the following policy implications are suggested:

(1) Labour Policy

Tenants/small farmers/non-mechanized farms are facing excess supply of labour. The effect of tenure and technology in labour-use seems to be more profound

1 "By comparing the estimated marginal products of land and labour for both small and large farms with land rentals and wage rates, one cannot conclude that the small farms are allocatively more efficient." (Yotopoulos, et al, 1970). The authors argue that seasonal changes in demand for agricultural labour, may imply different wage rates for different types of farmers.

than the effect of size of farm. Further research may be done on this issue.

(2) Mechanized farms are using excessive amounts of chemical fertilizer while other farms are facing constraints in using optimal quantities of the input. Institutional support may need to be given to non-mechanized farms.

(3) Further research needs to be undertaken to study distribution of fertilizer between farm groups. If it is observed that most of the supplies go to the mechanized farms, the use of fertilizer can be rationalized by withdrawing the subsidy and ensuring that small/tenant farmers can get institutional credit to buy fertilizer.

(4) Livestock is a significant factor in the farm business. In general it seems that while small farms are keeping more livestock than the profit maximizing quantities, large farms are facing excessive supplies of animals. Due to the close relationship of livestock with the crop sector as well as being part of the social system, research should be undertaken to study livestock-farm-household relationships. Policies could, then, be made to integrate livestock policy in agricultural development policy.

CHAPTER 7

SUMMARY AND CONCLUSIONS

This study attempts to highlight and quantify the impact of tenure, farm size and mechanization on allocative efficiency in a sample of 54 farmers randomly selected for the Punjab Province of Pakistan. The study, based on 1978-79 farm accounts survey data, aims at identifying resource constraints on various types of farms by using the production function approach.

The literature review on Pakistan agriculture indicated that the existing socio-economic structure tends to increase constraints on tenant/small farmers by inhibiting their access to modern technology.

The observation that different types of farmers have differential access to production inputs must also highlight the "weakness" of our assumption that all types of farmers face the same factor prices.

The conceptual framework for model specification, described in Chapter 3, showed that, due to limited degrees of freedom, the Cobb-Douglas production function was assumed to be appropriate. However, limitations of the selected model were recognized.

Results of the estimated average production functions for the whole sample suggested that land, labour, non-draft animals and fertilizer are significant determinants of farm output. It was also concluded that constant returns to scale exist on an average sample farm.

Group comparisons of farmers, however, suggested that small, tenants, an non-mechanized farms face surplus labour, large farms have surplus animals and mechanized farms use excessive fertilizer. On the other hand, production elasticity of labour was highest on mechanized farms and that of fertilizer was highest on tenant farms.

Tests for allocative efficiency showed that, on an average farm, resources were not efficiently allocated to all inputs. Tenants and non-mechanized farms were restricted in achieving allocative efficiency in all inputs. They used labour excessively; their farms were overstocked with animals; and the use of fertilizer on their farms was less than the optimum amounts determined by their production functions.

Large farms were allocatively efficient in labour and fertilizer use, but for them the livestock variable was not significant.

On average, large farms and mechanized farms were both allocatively efficient in labour use.

On the basis of the small sample, no broad policy recommendations are intended. However, the study encourages research in the following areas:

(1) Excessive use of fertilizer on mechanized farms and sub-optimal use on other farms.

(2) Overstocking of animals on both tenant vs owner and non-mechanized vs mechanized farms.

(3) Potential for institutional support for the tenants and small farmer to get adequate supplies of modern inputs.

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