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Farm Size and Productivity Revisited

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The negative relationship between farm size and output per acre has been tested for Pakistan and it is concluded that the observed negative or positive correlations between land productivity and the farm size in the case of Pakistan are the result of over-aggregation. Land productivity curve is U-shaped; the productivity is high on desperately small farms due to intensive labour and irrigation use and on largest farms due to capital-intensive inputs. The middle-level efficient entrepreneur farmer has so far failed to emerge.

INTRODUCTION

We are concerned with factor/farmer relationships. In the rural production nexus, land is the primary factor of production which determines access to other factors. This bias is reflected in the varying use and combinations of inputs across farm size – that is differing technology. Debate focusses around the question: does productivity then vary in accordance with the pre-eminent factor, farm size.

The question acquires importance for underdeveloped countries especially, (as seen by the considerable literature on the topic) since most empirical studies began showing that smaller farms using their greater availability of family labour were more productive. Since a critical demand for food necessitates a rational re-allocation of factor resources in this dominant sector so as to maximise output, the argument for land reforms then becomes obvious. Further, the hold of large landowners on the factor markets must also be broken, not only to rationalize output, but also to rationalize inputs.

Significantly, very little work has been done in Pakistan on this issue, and the major work (to our knowledge) by Khan shows a positive correlation between land productivity and farm size [9]. In this paper, using a larger data-base, we obtain a very different set of results for the 19 districts of the Punjab. In doing this, we also try to explain the speciousness of Khan's tests.

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SURVEY OF LITERATURE: THEORETICAL CONSTRUCTS AND EMPIRICAL STUDIES

Farm Size

The inverse relationship between farm size and land productivity was first brought out by a number of farm-management studies carried out in India in the mid –'50s. Small farms appeared to be using more intensive inputs per acre and had a higher output per acre. This ran contrary to the expectation that differential access to inputs and information should result in a lower output per acre for the smaller farms.

The *ex-post* rationale provided for this was that farmers were maximising their use of those inputs with which they were better endowed [11]. For smaller farms, this means more intensive labour inputs per acre. Secondly, Srinivasan [12] pointed out that smaller farmers maximizing the expected utility of income, and averse to risk (given their marginal subsistence conditions), would tend to use more intensive inputs per acre regardless of labour market assumptions. Further, the level of use of capital inputs, like seeds, fertilizer, pesticides, and tractors is very largely contingent upon irrigation [10]. The causal relationship in effect depends upon three major factors:

(i) The use of labour;
(ii) Historically available irrigation; and
(iii) Cropping intensity.

Use of Labour

The marginal productivity of labour in general was found to be higher than the wage rate [2; 9]. Further, the rural labour market is divided between family labour and hired labour. The implicit wage rates of the former are found to be lower than the wage rates of the latter [2; 3; 11 and 12].

This duality is preserved by institutional restrictions (like the reluctance of women and children to join the labour market) and, more importantly, by the indivisibility of labour demand, especially at harvesting and sowing, when full time hired labour can be controlled better than part-time hired labour, since part-time labour has its own cultivation demands. So small farmers have a cheaper input whose use they can maximise. Figure 1 illustrates the compulsion of small farmers (with extremely low levels of income) to increase their use of family labour till its marginal productivity falls well below the market wage rate, in order to maximise output. Moreover, intensive labour use by smaller farmers would also facilitate higher cropping intensities.

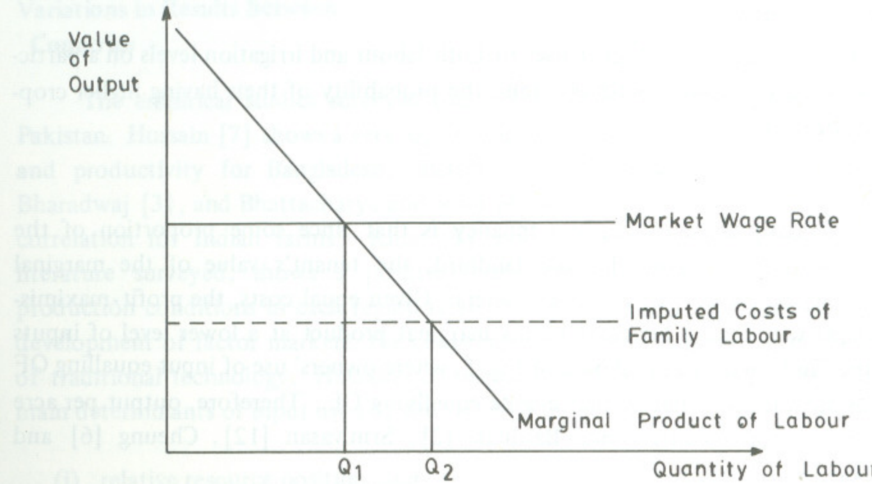

Fig.1

Irrigation

Most authors find larger proportions of the area irrigated on smaller farms, which may be explained by a number of factors. Theories about historically available irrigation suggest population dynamics and viability of relatively smaller farm sizes in irrigated regions as two such possible factors [11]. Immediate production rationales, contend that small farmers' aversion to risk would drive them to

(a) pay an increment in rent for irrigated land equal to, or greater than, productivity differentials, to avoid an even more expensive crop failure; and
(b) maintain better irrigation facilities, Bharadwaj, for example, found the ratio of differences in output between irrigated and unirrigated farms and the differences in costs between irrigated and unirrigated farms to be less than 1; i.e.

$$\frac{\Delta \text{ Output}}{\Delta \text{ Costs}} < 1 \ .$$

This is especially true for the smaller farms.

Landlords on the other hand, would prefer to parcel out irrigated land to tenants in small fragments, thus forcing the latter to cultivate intensively and maximise returns and, hence, the landlords' share.

Cropping Intensity

The coincidence of higher uses of both labour and irrigation levels on a particular set of farms would definitely raise the probability of their having higher cropping intensities.

Tenancy

The main argument against tenancy is that since some proportion of the tenant's output is 'taxed' by the landlord, the tenant's value of the marginal product lies below that of the land-owners. Given equal costs, the profit-maximising tenant will equate his costs to his marginal product at a lower level of inputs than the land-owners as is shown in Fig. 2, where owners' use of input equalling OF exceeds significantly that of the tenants equallying OE. Therefore, output per acre will be less for tenants. See Bardhan [2], Srinivasan [12], Cheung [6] and Junankar [8].

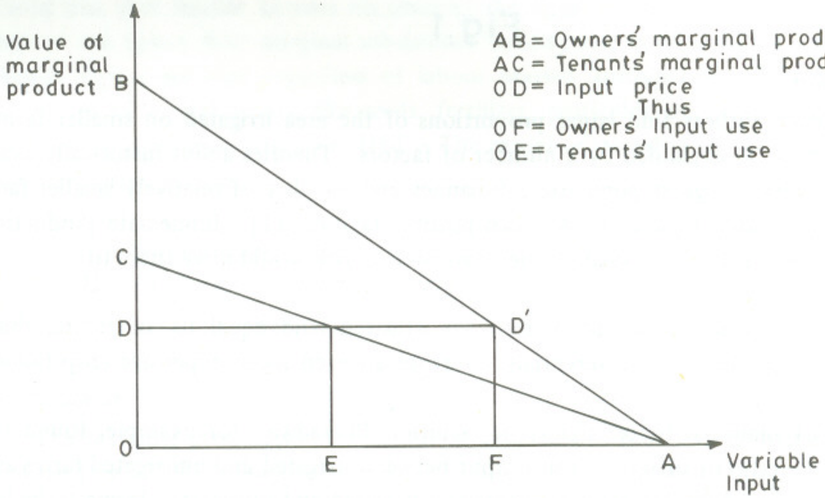

Fig. 2

The insecurity of tenure is likely to reduce the incentives for a tenant to make important labour increments such as improving drainage etc. which complement other inputs. So, despite a similar level of the use of inputs, productivity per acre might still differ.

Junankar [8], using a Cobb-Douglas production function, finds support for the hypothesis that tenants use less inputs but with one reservation. He finds that output per acre is negatively correlated to the proportion of the area leased in, but only on the larger farms, i.e. those greater than 10 acres. Chakravarty and Rudra [5], in contrast, found this hypothesis relevant only to smaller farms.

Variations in Results Between Countries

The empirical studies surveyed relate to three regions: Bangladesh, India and Pakistan. Hussain [7] shows a very significant negative correlation between farm size and productivity for Bangladesh. Bardhan [2], Bhagwati and Chakravarti [1], Bharadwaj [3], and Bhattacharya and Saini [4] show a weaker, though still negative, correlation for Indian farms. Khan [9] alone, from amongst the sample of the literature surveyed, shows a positive relationship for Pakistan. The differing production conditions in each region relate to the different forms and stages of the development of factor markets, the obtaining geographical conditions, and the levels of traditional technology. Hussain's conceptual framework [7] aptly identifies the main determinants of input use and the effect of input use on the output as

(i) relative resource position; and
(ii) allowable substitution.

It is, in fact, the second factor, viz substitutability, which seems to explain the variation in the results for the three different regions. The case of Bangladesh is an extreme example where the use of labour can be varied, primarily through more intensive cultivation and choice of labour-intensive crops, while the use of capital is low, since the seed/land ratio is fixed, tubewells are rendered useless in monsoons, and fertilizer becomes ineffective without controlled water. Therefore, total resource use per unit of land would be higher on the smaller and better labour-endowed farms, and consequently productivity will be higher.

For India and Pakistan, capital technology appears better adapted to the geographical environment, i.e. substitution possibilities between capital and labour are higher. Given the initial resource advantage of larger farmers, their total resource use and, so, productivity would be higher compared to those of the small farmers.

Evidence for Pakistan

Khan [9], contrary to all other area studies, finds that large farms (over 25 acres) are 9 percent more productive than smaller farms. His explanation is that while the smaller farms use more household labour and farm power, this might be less efficient than the greater use of hired labour and tractors on the larger farms. The Pakistani agricultural sector then appears to have the highest capital/labour substitution possibilities so that a positive productivity effect is being evidenced across farm size.

But we maintain that the primary dichotomy between the results for India and Pakistan still remains to be explained and we will present somewhat different results for the West Punjab. However, a bias must be noted in Khan's data set: all the 732 farms were irrigated. This implies a bias towards intensive use of capital like seeds, and fertilizer, since water facilitates this, and the initial resource position of the larger farmers would ensure their input advantage. Because Khan does not do an input variation test, it becomes difficult to prove that due to capital/labour substitution possibility, a positive productivity effect is being evidenced across farm size.

THE DATA AND THE VARIABLES

For this study, we rely primarily on two of the largest available sources of agricultural data in Pakistan, viz. the Agricultural Census for the year 1972 and the Rural Credit Survey for the same year. The former is the only organised institutional attempt at gathering information on the rural sector decennially. Although extensive information indexed by farm size and by district is available for inputs of all kinds, the major flaw in the data set is the total absence of output figures. The Rural Credit Survey allowed us to circumvent this problem. This survey was conducted in the same year as the census on an almost similar scale. Further, the data were amplified to a census level, making the two sources complementary.

Unfortunately, we have only aggregate information for 19 districts of the Punjab and for five farm sizes within these districts. So, for each farm size we have district aggregates. The loss of disaggregation therefore is a drawback. Ideally, one would have wanted to pull out a sample of individual observations from these large data sources, and subjected that to a closer examination.

For the present exercise, however, we have enough information from the two data sources, which are comparable in terms of both size and timing of data collection. The productivity figures from the Rural Credit Survey for all the farm sizes and the districts enabled us to get output figures for the Agricultural Census input figures.

List of Variables

Variables	*Description*
Output*	Market value of physical annual output.
Land Productivity	(a) Output/Total Cropped Area
	(b) Output/Total Cultivated Area
Cultivated Acreage	
Irrigation	Various definitional forms were tried, including
	(a) Irrigated Area as a proportion of total Cultivated Area.
	(b) Canal + Tubewell irrigated area as a proportion of total irrigated area – and as a proportion of total cultivated area.
	(c) Number of tubewells per 1000 cultivated acres.
	(d) Canal irrigated area as a proportion of total cropped area.
Fertilizer*	(a) Amount per cultivated acre.
	(b) Area fertilized as a proportion of total cropped area.
Labour	Two definitions of labour were used:
	(a) As a simple aggregate of the number of family workers over 10 years and permanently hired workers, per cultivated acre.
	(b) Total number of full time family workers, plus the number of part-time family workers deflated by an index of 0.5, plus the total number of casual family workers deflated by an index of 0.2.
Tractors	Number of tractors per cultivated acre
Bullocks	Number of bullocks per cultivated acre
Seed*	Seeds per cultivated acre.
Current Expenditure	Total expenditure on current farm inputs in one year, per cultivated acre.
Cropping Intensity	Total area cropped in the year, divided by total cultivated area
Farm Sizes	1. < 5 acres
	2. 5 – 12.5 acres
	3. 12.5 – 25 acres

4. 25 – 50 acres

5. > 50 acres

District Dummies — Regional variation was allowed for by grouping the 19 districts into three categories on the basis of canal irrigated area as a proportion of total irrigated area.

(a) < 30% – Rawalpindi, Campbellpur (now Attock), Jhelum, Mianwali.

(b) 30% to 60% Multan, Dera Ghazi Khan, Bahawalpur, Bahawalnagar, Rahim Yar Khan.

(c) > 60 % – Gujrat, Sargodha, Jhang, Lyallpur, Lahore, Sheikhupura, Gujranwala, Sialkot, Sahiwal, Muzaffargarh.

*Variables drawn from the Rural Credit Survey were taken per acre and standardized for the appropriate acreage in the Agricultural Census.

METHODOLOGY

An analysis of the determinants of productivity has important policy implications. The correlation of farm size to productivity points to an optimum size of the farm towards which policy should be directed. Land reform policies are thus not only desirable for their distributive objectives, but also for the increase in output that such a redistribution is likely to result in. Reasons for such increases in output have already been outlined above.

The given price incentives determine the cropping pattern on the farm, yields being then determined by individual production functions. From the social point of view, the maximisation of the value of total output on each farm is the objective. Obviously, market imperfections can distort both the price incentives and the technological parameters, the consequence being a social loss in the form of less than optimal out put. For our study we have allowed for variations in prices according to the farm size. Thus, given any market distortions that might exist in the output market, we can look at the optimisation process of the farmer.

We will be using a two-stage argument to determine the causality of productivity differentials. Firstly, we will use production functions to estimate the importance or priority that different variables have in determining output for each farm size. Secondly, we will try to determine exact input use across farm size through simple log-linear regressions. Complementarity between impact and usage should provide some explanation for differences in output per acre between farm sizes.

We will be using a variant of the standard Cobb-Douglas production function, where the value of total output is regressed on the per acre usage of inputs and the cultivated acreage.

$$\ln Y = a_o + a_1 \ln X_1 + \sum_{i=2}^{n} a_i \ln \frac{X_i}{X_1} + U_i$$

where

Y = Value of total output

X_1 = land

$X_2 \ldots X_n$ are all other inputs

$a_o \ldots a_n$ are regression parameters to be estimated, and

U_i are random errors which are expected to be independently distributed with a zero expectation and constant variance.

The land variable (X_1) is used to capture the scale effects. The value of the coefficient of the land variable therefore measures the returns to scale.

Often, in the measure of productivity, cropped acreage is used in the denominator. If small farms, as generally observed, tend to crop more intensively, then such a measure is likely to understate the inverse relationship between productivity and farm size. Cultivated acreage is therefore the more appropriate variable to use.

Institutional variables which are liable to explain or affect the production of agricultural output are also used. These are cropping intensity, the number of fragments per cultivated acre and the percentage of the area tenanted. The expected signs of the coefficients of these variables in the production function are positive for the first and negative for the remaining two.

Ideally, within a region farmers should have the same production function. However, as pointed out in the section above, owing to resource constraints, differences in the levels of education and knowledge, etc., different farm sizes may be operating on different production functions. The frontiers may differ either because of the shift in the production function or because of the differences in slope. We may write the two relationships for small and large farms as

$$Y_s = C_s + I_s X_s$$

$$Y_1 = C_1 + I_1 X_1$$

where Y_s and Y_1 are the outputs of small and large farms respectively, and X_s and X_1 are the vectors of inputs used at small and large farms. The farms will differ in their production techniques if $C_s \neq C_1$, and/or $I_s \neq I_1$.

The principal flaw in Khan's analysis [9] is that he introduces a dummy variable for farm size in his Cobb-Douglas production function to conclude a positive relationship between farm size and productivity. This methodology is inappropriate for deriving the stated conclusion because, as shown later, the result obtained is not a productivity differential but an output differential between large and small farms. What is relevant and needs to be stressed is the simple correlation between farm size and productivity. This correlation exercise assumes that all individual optimisation decisions have been made. For policy purposes also, this simple correlation is what is important. There is no way of holding the inputs and the market structure constant across farm size. Hence, to attempt to measure productivity differentials, holding all other inputs constant, is, firstly, not desirable and, secondly, not feasible.

Limitations of the Analysis

As is obvious by now, our analysis suffers from its being in grouped form. The problem at hand is likely to be handled best with individual data. If anything, our study can only underline the need for a deeper analysis based on individual data.

Census data in the country are normally not the best in quality. Thus any doubts on the quality of the data are also likely to reflect on the results of our analysis. Because of this doubt about the quality of the data, we have tried not to push the data too hard. No elaborate estimations are being indulged in. Again, not much analysis of the input markets is being attempted.

RESULTS

This section has been divided into three parts. In the first part we will discuss the evidence for land productivity in the Punjab, and its components. In the second part, we will analyze input/output relationships, estimating production functions, both for individual farm sizes and in an aggregated form. And in the third part we will examine the negative relationship between farm size and output per acre to establish some kind of causality.

I

We have calculated the value of annual aggregate output per cultivated acre for five farm sizes across the 19 districts of the Punjab. As Table 1 shows, the productivity curve has a definite U shape across farm size. That is, with the possible exception of one district, viz. Sialkot, nowhere do the middle farm sizes (i.e. sizes Nos. 3 and 4) have a higher productivity than either the smallest or the largest farm sizes.

Table 1

Value of Aggregate Output per Cultivated Acre

	Districts	Value of Output per cultivated Acre on Farms Sizes*				
		(1)	(2)	(3)	(4)	(5)
1.	Rawalpindi	137.18	103.97	62.55	93.18	490.53
2.	Campbellpur	139.22	99.40	43.03	65.23	45.67
3.	Jhelum	44.60	61.85	33.18	60.76	91.13
4.	Gujrat	218.17	239.87	197.07	179.18	289.32
5.	Sargodha	191.22	293.86	130.64	126.08	116.78
6.	Mianwali	81.18	130.32	97.91	75.98	36.39
7.	Jhang	240.97	312.95	81.82	150.45	351.12
8.	Lyallpur	848.37	745.21	221.39	520.00	792.38
9.	Lahore	232.21	323.48	141.04	235.67	290.95
10.	Sheikhupura	449.03	404.73	195.24	243.88	290.54
11.	Gujranwala	418.32	360.65	193.30	299.56	466.49
12.	Sialkot	225.20	267.01	211.04	264.29	266.95
13.	Multan	620.03	609.18	211.92	357.45	394.60
14.	Sahiwal	393.97	541.91	157.77	424.96	3058.32
15.	Muzaffargarh	166.55	215.68	78.26	105.73	151.00
16.	Dera Ghazi Khan	92.99	208.57	108.46	173.44	212.06
17.	Bahawalpur	351.78	541.32	190.25	199.79	311.42
18.	Bahawalnagar	294.88	341.57	127.21	196.49	125.25
19.	Rahim Yar Khan	282.20	470.24	213.07	351.69	309.97

Source: The Rural Credit Survey carried out by the State Bank of Pakistan in 1973, currently being prepared for publication with the collaboration of the Pakistan Institute of Development Economics, Islamabad.

*The Farm sizes given in this table represent the following areas :
(1) = 1.0 – 5.0 acres,
(2) = 5.0 – 12.5 acres,
(3) = 12.5 – 25.0 acres,
(4) = 25.0 – 50.0 acres, and
(5) = > 50.0 acres

As a preliminary test, the 95 observations (19 for each of the 5 farm sizes) for productivity were cross-tabulated according to farm-size category and level of productivity (Table 2).

Table 2

Number of Farms Corresponding to the Level of Productivity and Farm Size

Value of Output per acre	Productivity Category	Farm Sizes (1)	(2)	(3)	(4)	(5)	All Farms
Less than Rs. 200	Low	7	4	15	11	6	43
Rs. 200 to Rs. 400	Medium	8	9	4	6	9	36
Rs. 400 and above	High	4	6	0	2	4	16
Total		*19*	*19*	*19*	*19*	*19*	*95*

The values in each box represent the number of observations. A χ^2 (chi-squared) value of 18.09 shows the significance of the observed pattern at a 0.975-level of probability.

Finally, to confirm the U shape of the productivity curve, we decreased the number of farm-size categories to three: small farms (less than 12.5 acres) medium farms (between 12.5 and 50.0 acres), and the large farms (over 50.0 acres) (Table 3). Since we wish to show that

1. output/cultivated acre on medium farms is significantly lower than on small farms and large farms, and
2. differentials might also exist between small and large farms, in favour of the smaller farms,

we ran paired t-test, and obtained the following results.

	Small and Medium Farms	Medium and Large Farms	Small and Large Farms
t-value	4.92	– 1.72	– 0.84
Level of Significance	(.001)	(.05)	(0.5)

Table 3

A. *Value of Aggregate Output per Cultivated Acre*

	Districts	Value of Output per Acre on Small Farms	Medium Farms	Large Farms
1.	Rawalpindi	120.58	77.87	490.53
2.	Campbellpur	119.31	54.13	45.67
3.	Jhelum	53.23	46.97	91.13
4.	Gujrat	229.02	188.13	289.32
5.	Sargodha	242.54	128.36	116.78
6.	Mianwali	105.75	86.95	36.39
7.	Jhang	276.96	116.14	351.12
8.	Lyallpur	796.79	370.70	792.38
9.	Lahore	277.85	188.36	290.95
10.	Sheikhupura	426.88	219.56	290.54
11.	Gujranwala	389.49	246.43	466.49
12.	Sialkot	246.11	237.67	266.95
13.	Multan	614.61	284.69	394.06
14.	Sahiwal	467.94	291.37	3058.32
15.	Muzaffargarh	191.12	92.00	151.00
16.	Dera Ghazi Khan	150.78	140.95	212.06
17.	Bahawalpur	446.55	195.02	311.42
18.	Bahawalnagar	318.23	161.85	125.25
19.	Rahim Yar Khan	376.22	282.38	309.97

B. *Differences of Means Test across Farm Size*

Statistics relating to Farm Output	Small & Medium	Small & Large	Medium & Large
Mean of the output	128.44	– 118.31	– 246.39
Standard Deviation	113.81	612.7	624.59
t - Ratios	4.92	– 0.84	– 1.72
Significance level	(.001)	(.5)	(.05)
Degrees of Freedom	18	18	18

Source: The Rural Credit Survey carried out by the State Bank of Pakistan in 1973, currently being prepared for publication with the collaboration of the Pakistan Institute of Development Economics, Islamabad.

Both small and large farms were found to have significantly higher productivity levels than medium farms. But productivity differential were not found to be significant between small and large farms. That is, the U curve holds.

So, in the Punjab, the middle-range farmers are not the most productive, and the Green Revolution, even where it has been most pervasive in the central canal-colony districts, has not produced the alleged efficient middle-class farmer. In comparing the two ends of the U, representing the small and large farmers, we will report further tests ahead. Here we will just note the inconclusive result of the test. We also note that in 11 out of 19 districts small farms have a higher productivity level.

We also performed t-tests using a different measure of productivity this time, that is Output/Cropped Acre. The productivity per cropped acre is reported in Tables 4 and 5. The pair-wise difference of the means test is reported below:

	Small and Medium Farms	Small and Large Farms	Medium and Large Farms
t-Ratios	4.39	– 1.13	– 1.83
Significance	(.001)	(.5)	(.05)

The difference between the productivities of small and medium farms and those of medium and large farms remains, but the t-ratio for small and large farms increases. The U-shaped curve still persists and there is a dampening out of any negative relationship between farm size and productivity that may have existed, because smaller farms tend to have higher cropping intensities.

In comparing productivity differentials, land productivity can be broken down into several components as under[1]:

$$\Sigma \frac{\text{Physical Output} \times \text{Price}}{\text{Cultivated Area} \times \text{Cropping Intensity}}$$

Of these components, we will assume cultivated area to be exogenously determined. Physical output is contingent upon the level and combination of the inputs used. Price here reflects the differences in values of different crops, i.e. value differentials in the cropping pattern which might be found to vary across farm size and tenurial status. It can be argued that in comparing productivity differentials, the cropping pattern should not be controlled, since it reflects the social choice/compulsion to grow a particular crop. However, in view of its importance as an explanatory variable, we will first of all briefly test for variations in the cropping patterns across farm size, and in the next two sections analyze the determinants of output and cropping intensity.

Table 6 shows that the proportion of area under wheat and rice tends to fall slightly as the farm size increases. Conversely, the proportion of area under the major crop, cotton, on the largest farms is almost double that on the smallest farms. To test whether small farms tend to grow a larger proportion of food crops, out of necessity as well as a disinclination to enter a market which is biased against peasants who have a weaker economic position [3], we tried and analysis of variance of the

[1] Strictly speaking, this is $\sum_i \frac{Q_i \cdot P_i}{C_i}$

where

Q_i is output of the ith crop
P_i is price of the ith crop, and
C_i is cropped area under the ith crop.

Table 4

Value of Aggregate-Output/Cropped Acre

	Districts	Value of output per acre on Farms Sizes*				
		(1)	(2)	(3)	(4)	(5)
1.	Rawalpindi	105.64	96.12	60.00	96.45	620.19
2.	Campbellpur	113.71	94.05	44.31	69.58	48.24
3.	Jhelum	44.57	61.83	35.41	66.97	97.27
4.	Gujrat	177.77	210.00	179.36	168.11	279.47
5.	Sargodha	154.72	256.05	117.91	117.24	112.39
6.	Mianwali	76.12	125.03	95.04	76.82	37.17
7.	Jhang	194.22	278.32	77.78	148.43	339.74
8.	Lyallpur	668.53	613.53	188.40	446.70	689.21
9.	Lahore	156.16	242.27	110.65	191.55	226.04
10.	Sheikhupura	290.68	280.90	146.15	185.05	243.20
11.	Gujranwala	274.35	247.22	139.59	227.18	361.98
12.	Sialkot	157.59	202.17	160.08	212.08	202.04
13.	Multan	491.87	526.22	192.35	326.92	374.32
14.	Sahiwal	298.86	444.29	137.16	380.00	2695.27
15.	Muzaffargarh	139.07	194.12	72.68	102.28	156.21
16.	Dera Ghazi Khan	88.28	208.76	116.76	197.42	248.46
17.	Bahawalpur	292.06	492.07	175.24	196.96	308.17
18.	Bahawalnagar	261.09	324.08	125.11	203.31	127.32
19.	Rahim Yar Khan	242.06	429.49	203.40	337.47	309.70

Note: For source of this table and explanation of the farm sizes, see footnotes to Table 1, *supra*.

Table 5

A. *Value of Aggregate-Output/Cropped Acre*

Districts	Output per Cropped acre on Small Farms	Medium Farms	Large Farms
1. Rawalpindi	100.88	78.45	620.19
2. Campbellpur	103.88	56.95	48.24
3. Jhelum	53.02	51.19	97.27
4. Gujrat	193.89	173.74	279.47
5. Sargodha	205.39	117.58	112.39
6. Mianwali	100.71	86.11	37.17
7. Jhang	236.27	113.11	339.74
8. Lyallpur	641.03	317.55	689.21
9. Lahore	199.22	151.01	226.04
10. Sheikhupura	285.79	165.06	243.20
11. Gujranwala	260.79	183.39	361.98
12. Sialkot	179.88	186.44	202.04
13. Multan	509.05	258.14	374.32
14. Sahiwal	371.58	258.58	2695.27
15. Muzaffargarh	166.91	87.48	156.21
16. Dera Ghazi Khan	148.52	157.09	248.46
17. Bahawalpur	392.07	186.01	303.17
18. Bahawalnagar	293.35	164.21	127.32
19. Rahim Yar Khan	335.78	270.44	309.70

B. *Differences of Means Test across Farm Size*

Statistics relating to Farm Output	Small & Medium Farms	Small & Large Farms	Medium & Large Farms
Mean of the output	90.26	– 141.77	– 232.03
Standard Deviation	89.54	547.88	552.79
t- Ratios	4.39	– 1.13	– 1.83
Significance level	(.001)	(.5)	(.05)
Degrees of Freedom	18	18	18

Source: The Rural Credit Survey carried out by the State Bank of Pakistan, 1973, currently being prepared for publication with the collaboration of the Pakistan Institute of Development Economics, Islamabad.

Table 6

Cropping Pattern in the Punjab : Mean Area Under Each Crop as Percentage of Total Cropped Area[a] in the Farm Size Category

Farm Size[b]	Percentage of Total Cropped Area under Wheat	Cotton	Rice	Maize	Tobacco	Oilseeds	Sugar-cane	Total
1	62.5	18.5	8.0	5.0	0.4	1.0	4.5	= 100
2	60.6	22.8	8.1	2.4	0.3	1.7	4.1	= 100
3	62.0	22.2	8.2	1.5	0.2	2.4	3.5	= 100
4	61.4	23.5	7.2	1.4	0.2	3.1	3.2	= 100
5	54.8	33.7	6.2	1.0	0.1	2.2	2.0	= 100

Source: Same as for Table 1.
[a]The total cropped area used for this table is net of pulses, fodder crops, and orchards, resulting in the high crop proportions.
[b]Farm Sizes are the same as given in Table 1.

proportion of food crops grown across farm size for the full sample of 19 districts, but the differences turn out to be insignificant.

We then performed a chi-square test, based on the sample means of 19 districts shown in Table 6, for the area proportions of all the seven crops. The χ^2 value of 13.52 with 24 degrees of freedom was also found to be totally insignificant; i.e. the proportion of area under each crop did not seem to vary with the farm size. What these two tests show, however, is that no simple bias exists in the cropping pattern that can be picked up by using such aggregative and incomplete data. There are two aspects to this pricing component of productivity; viz. more lucrative crops and differentials in prices for the same crop.

We have not been able to adequately test the first aspect. The bias might well involve food-cum-cash crops like pulses, whose incidence is higher on small farms, and for which we have no data. Moreover, the bias definitely involves tenurial status with its host of clauses and conditions varying across regions; typically, sharecropping might inhibit the growing of cash crops by blunting incentives, while a fixed-rent lease might facilitate it.

Secondly, intra-crop price differentials across farm size or tenancy status would tend to affect output decisions, i.e. smaller farmers or share-croppers with a weaker bargaining position might choose to minimise market involvement by growing less cash crops. But, as pointed out earlier, price differences also reflect the social return to each group of farmers. So, for the purpose of this analysis, we will assume that our limited tests hold, and that it is possible to compare the aggregate value of productivity across farm size without a price bias affecting our analysis.

II

We will now use aggregate and individual farm size production functions to investigate

(i) the varying impact of input use on output across farm size;
(ii) returns-to-scale effects; and
(iii) whether different farm sizes have separate production functions.

Inputs, like current expenditure, and institutional variables, like the tenancy proxy and fragments per acre, were introduced successively into the equations to estimate their impact not only on output, but also on the resultant change in the elasticities of the other independent variables.

Table 7 shows the estimates of the full sample aggregate production function. Tables 8 and 9 present the results of the separate production functions corresponding to each farm size.

We began by running Equation 1 in Table 7 and Equations 1–5 from Table 8. For the full sample, only the cultivated area and fertilizer proved to be highly significant and had the expected signs. The irrigation proxy was obviously misspecified, but labour emerges as marginally significant and with the right sign. More important is the fact that between tractors and bullocks, bullocks appear to have a greater impact on output.

A similar trend was obtained for the five farm sizes for the land, irrigation, and fertilizer variables. Canals plus tubewells are only significant for the second farm size and no pattern can be seen. Labour remains totally insignificant throughout, as do seeds. Tractors, however, do follow the expected pattern. They are insignificant and negative for the smaller three farm sizes. For Farm Size 4, they become positive and strongly significant, and for Farm Size 5, the significance dwindles but the coefficient remains positive. In other words, tractors appear to affect output only on the larger farms, to supplement labour. The use of bullocks becomes relatively significant for the second and fourth farm sizes.

Seemingly, this combination of variables does not provide a very adequate explanation of production behaviour across farm size.

For Equation 2 in Table 7 and Equations 6–10 in Table 8, we used an alternative proxy for irrigation, the proportion of cultivated area irrigated, and dropped tractors, bullocks and seeds for an aggregate annual expenditure variable. Two district dummies were also added to test whether we could usefully differentiate between the input output/relationship of the canal colony districts, the arid/*barani* districts of the Northern Punjab, and the southern belt of semi-*barani* districts. Dummies 1 and 2 represent the North and South peripheral districts respectively, based on a criteria of the proportion of canal irrigation to the irrigated area. Finally, an alternative proxy was used for fertilizer.

Table 7

Aggregate Production Functions (Full Sample)[a]

(Dependent Variable is Value of Output)

Equation No.	Constant	Cultivated Area	Irrigated Area/ Cult. Area	Canal + Tubewell Area/ Cult. Area	Fertilizer Amount	Fertilized Area	Labour	Tractor	Bullocks	Seed	Current Expenditure	Area Leased In	Fragments	Cropping Intensity	Average Farm Size	R^2	F
1.	2.89^b	0.93^b		– 0.006	0.94^b		0.32	0.03	0.24	0.03						0.87	53.39
	(2.24)	(11.1)		(–0.0007)	(5.08)		(1.08)	(0.68)	(1.4)	(0.71)							
2.	4.86^b	0.88^b	0.06			0.11	0.2				0.44^b					0.92	103.62
	(4.94)	(12.99)	(0.83)			(1.13)	(0.84)				(6.74)						
3.	1.27	0.98^b	0.22^b		0.33^b		0.56					– 0.15	0.009	0.68	0.38	0.83	54.00
	(0.47)	(11.6)	(2.95)		(4.23)		(1.31)					(– 0.87)	(0.07)	(1.31)	(0.47)		
4.	2.26	0.97^b	0.17^b		-0.42^b		0.48^b				0.82^b	0.07	0.03	0.54	0.38^b	0.93	117.99
	(1.25)	(17.1)	(3.5)		(– 4.6)		(1.68)				(10.3)	(0.65)	(0.35)	(1.53)	(1.69)		

[a]Number of observations for the full sample is 95.
[b]Significant at the 10-percent level.

Table 8

Farm-Size Production Functions[a]

(Dependent Variable is Value of Output)

Equation No.	Sample Farm Size	Constant	Cultivated Area	Irrigated Area/Cultivated Area	Canal + Tubewell Area/Cultivated Area	Fertilizer Amount	Fertilized Area	Labour	Tractors	Bullocks	Seed	Current Expenditure	Regional Dummy 1	Regional Dummy 2	R^2	F
1	1	1.02	1.22[b]		0.07	0.35[b]		0.31	– 0.03	– 0.064	– 0.05				0.84	8.31
		(0.28)	(3.17)		(0.69)	(1.86)		(0.26)	(– 0.35)	(– 1.01)	(– 0.1)					
2	2	1.89	1.28[b]		0.16[b]	0.40[b]		–0.96	– 0.008	0.93	– 0.11				0.92	17.299
		(0.44)	(3.9)		(2.38)	(2.45)		(– 0.09)	(– 0.12)	(1.07)	(– 1.35)					
3	3	6.89[b]	0.62[b]		0.02	0.43[b]		0.05	– 0.02	0.74	– 0.08				0.89	13.36
		(1.97)	(1.92)		(0.293)	(3.01)		(0.06)	(– 0.18)	(– 0.73)	(– 0.74)					
4	4	7.47[b]	1.17[b]		0.09	0.19		0.22	0.34[b]	0.85	–0.01				0.91	16.571
		(3.76)	(5.95)		(1.39)	(1.27)		(0.25)	(2.3)	(1.1)	(–0.16)					
5	5	4.39	0.87[b]		– 0.04	0.81[b]		– 0.06	0.003	– 0.02	– 0.07				0.82	7.57
		(1.08)	(3.61)		(– 0.17)	(2.35)		(– 0.06)	(0.008)	(– 0.04)	(– 0.31)					
6	1	1.6	0.88[b]	– 0.68[b]			0.55[b]	– 0.44				0.2	– 1.18[b]	0.34	0.93	21.589
		(0.53)	(3.35)	(– 2.17)			(2.02)	(– 0.63)				(0.96)	(– 2.35)	(1.59)		
7	2	1.33	1.13[b]	– 0.005			0.32[b]	0.32				0.15[b]	–0.31	0.31[b]	0.97	49.296
		(0.47)	(5.23)	(– 0.38)			(3.03)	(0.8)				(1.72)	(– 1.06)	(2.42)		
8	3	5.66	0.64[b]	– 0.16			0.36[b]	– 2.55				0.25	0.004	0.2	0.93	20.851
		(1.65)	(2.95)	(– 0.83)			(1.78)	(– 0.5)				(1.0)	(0.999)	(1.25)		
9	4	2.38	0.91[b]	– 0.19			0.44[b]	0.16				0.23	0.1	0.3[b]	0.95	29.433
		(1.03)	(7.21)	(– 0.86)			(2.1)	(0.3)				(1.65)	(0.24)	(1.79)		
10	5	9.5[b]	0.89[b]	0.56[b]			– 0.56[b]	0.02				0.87[b]	– 0.02	– 0.14	0.96	37.41
		(3.24)	(7.79)	(2.14)			(– 2.11)	(0.05)				(7.86)	(– 0.06)	(– 0.75)		

Continued –

Table 8 – *Continued*

[a]The number of observations for each equation is 19.
[b]Significant at the 10-percent level.

The aggregate production function behaves very well. The sign of the new irrigation variable becomes positive, though still not significant. Fertilizer and labour drop in significance, while the expenditure variable proves to be highly significant. Multicollinearity between fertilizer and expenditure, which shall be discussed later, probably accounts for the drop in the former's significance. The farm size production functions present certain problems. Irrigation is negative for the first four farm sizes and insignificant for the middle three. For the largest farm size (> 50 acres) irrigation is both positive and significant which means that both the availability of water and its use have a considerable impact on output. Since in further specifications this irrigation variable stabilizes, to a positive and significant form for all farm sizes, we can only deduce that the equation in its present form is inadequately specified resulting in the erratic behaviour of a major variable like irrigation (Table 9). Fertilized area remains positive and significant for the first four farm sizes, and for the fifth farm size it becomes significantly negative. Labour remains consistently insignificant for all five farm-size categories. Current expenditure per acre becomes highly significant for the larger farm sizes, and its effect on output appears to be much greater. (Comparing, say, the second farm size with the fourth and fifth, the B coefficients for the latter two are higher.) Dummy 1 appears to be significantly negative only for the smaller farm sizes – i.e. in these arid districts the smaller farms' productivity per unit of resource use is lower than that of their counterpart farm sizes in the canal-colony districts. So, it would seem that the larger farms make up for their spatial disadvantage with the higher level of expenditure which we have just seen.

In summary, we have so far tested for the standard input variables and found some indications of input variations across farm size in tractors and investment.

Our data on labour, as experienced in further analysis also, are extremely inadequate, and indications of their variation have been sketchy. What can be seen, however, is that larger farms are relying heavily on capital inputs as the significance of labour use dwindles. We will now add three new variables to our analysis, the two institutional variables of tenure and fragmentation, and cropping intensity. *A priori*, tenurial status and the number of fragments per acre are expected to have a negative impact on output, and cropping intensity a positive one.

Equations 3 and 4 in Table 7 and Equations 1–10 in Table 9 show the results of the new specifications. Looking at Equation 3, first of all, we note that the standard inputs are all significant and have the expected signs. The proportion of the area leased in to the total farm area is negative but not significant. Fragments per acre appear positive and insignificant. So, these two variables do not appear to have any appreciable impact on output, at least in the aggregate production function. Cropping intensity, on the other hand, is marginally significant and has a positive sign. We have also added one more variable, the average farm size, which appears positive but not significant. It must be noted however that, unlike Khan [9], we are evaluating the impact of increasing the average farm size on *output* here, and not an averred estimate of land productivity.

Table 9

Farm Size Production Functions[a]

(Dependent Variable is Value of Output)

Equation No.	Sample Farm Size	Constant	Cultivated area	Irrigated Area/Cult. Area	Area Leased in	Fragments	Fertilizer Amount	Labour	Cropping Intensity	Current Expenditure	R^2	F
1	1	-5.53^b	1.11^b	0.08	-1.34^b	-0.76^b	0.22^b	−0.3	1.49^b		0.94	24.105
		(−1.4)	(4.66)	(0.48)	(−3.01)	(−3.57)	(1.8)	(−0.44)	(1.83)			
2	2	−0.83	1.06^b	0.3^b	-1.36^b	-0.63^b	0.12	0.28	0.87		0.95	30.5
		(−0.19)	(4.16)	(3.0)	(−2.34)	(−2.7)	(1.0)	(0.43)	(1.04)			
3	3	−1.9	0.96^b	0.19	0.13	0.73	0.28	−0.68	1.49		0.83	7.85
		(−0.16)	(2.6)	(1.39)	(0.31)	(1.52)	(1.39)	(−1.01)	(0.49)			
4	4	3.32	0.83^b	0.14	0.05	−0.25	0.13	1.04	1.11		0.91	15.0
		(0.5)	(2.8)	(1.2)	(0.09)	(−0.53)	(0.87)	(1.49)	(0.94)			
5	5	−7.38	1.6^{bc}	0.14	−0.17	1.25^b	1.14^b	−0.55	0.89		0.9	14.9
		(−0.99)	(5.41)	(0.76)	(−0.42)	(2.62)	(4.1)	(−0.66)	(0.76)			

Continued –

Table 9 – *Continued*

Equation No.	Sample Farm Size	Constant	Cultivated area	Irrigated Area/Cult. Area	Area Leased in	Fragments	Fertilizer Amount	Labour	Cropping Intensity	Current Expenditure	R^2	F
6	1	−1.21 (−0.32)	1.12^{b} (5.6)	0.11 (0.83)	−0.77^{b} (−1.74)	−0.45^{b} (−2.04)	−0.78^{b} (−1.83)	−0.75 (−1.24)	0.76 (1.03)	1.05^{b} (2.4)	0.96	31.034
7	2	0.81^{b} (1.88)	1.12^{b} (4.82)	0.29^{b} (3.26)	−1.05^{b} (−1.93)	−0.42^{b} (−1.78)	−0.68 (−1.54)	0.13 (0.22)	0.81 (1.07)	0.81^{b} (1.88)	0.96	33.259
8	3	−13.0^{b} (−1.84)	0.48^{bc} (2.07)	0.37^{b} (4.37)	0.87^{b} (3.08)	0.08 (0.29)	−1.52^{b} (−3.96)	−0.88^{b} (−2.28)	5.44^{b} (2.85)	1.45^{b} (4.91)	0.95	24.208
9	4	2.99 (0.48)	0.91^{b} (3.29)	0.15 (1.37)	−0.03 (−0.05)	−0.07 (−0.15)	−0.04 (−0.24)	0.41 (0.53)	−0.61 (−0.53)	0.36 (1.57)	0.92	15.209
10	5	2.38^{b} (3.52)	1.1^{b} (4.42)	0.16 (1.17)	−0.09 (−0.31)	0.29 (0.68)	−0.04 (−0.1)	−0.27 (−0.46)	−0.08 (−0.1)	0.87^{b} (3.52)	0.96	28.11

[a]The number of observations for each equation is 19.
[b]Significant at the 10-percent level.
[c]Significantly different from 1.

Equation 4 in Table 7 is similar to Equation 3, with the addition of current expenditure. This variable, again, is highly significant, and renders the fertilizer variable negative. The tenurial proxy now also becomes positive, but remains insignificant. For additional information, we can now turn to the farm size production functions in Table 9.

The coefficients of cultivated area are all positive and highly significant for both sets of Equations 1–5 and Equations 6–10 (Here, also, the only difference between the two sets is the addition of the expenditure variable in Equations 6–10.) We have so far refrained from commenting on the land variable as a value of returns to scale, because the earlier specifications were incomplete. The test of the land coefficient for a significant difference from 1 shows that for Equations 1–5, only farms over 50 acres are experiencing increasing returns to scale, and for Equations 6–10, only Size 3 (i.e. 12.5–25 acres) is experiencing decreasing returns to scale. The remaining farm sizes are operating on constant returns to scale. This apparent instability in the results is due to the expenditure variable. Prior to its inclusion, for Equations 1–5, its impact on output is affected through other inputs, and results in the increased efficiency for the largest farmers. Moreover, the middle-farm size, i.e. No. 3, with the help of current expenditure, also shows constant returns to scale. After adding the expenditure variable, and thus controlling for it, Farm Size 5 loses its advantage and drops back to constant returns, while Farm Size 3 drops further down to significantly decreasing returns to scale. It must also be noted that significance levels for current expenditure are the highest for precisely those two sets of farms whose land elasticities change so radically.

Therefore, using the more appropriately defined set of equations (Nos. 6–10), the enigmatic production behaviour of Farm Size 3 poses itself. In Equation 8, all the explanatory variables, besides fertilizer and labour, have positive and significant elasticities and there are decreasing returns to scale. Since fertilizer is rendered negative for all farm sizes, the explanation must lie in either the impact of labour, as measured here, or in the form of some kind of labour-utilization factor which constrains efficient input utilization, e.g. maintenance and improvement of land and water courses, or labour management. But what emerges most importantly is that the middle farm sizes are seen to be inefficient now on two counts:

(i) Productivity, i.e. output/acre.
(ii) Returns to scale,[2] i.e. output/unit of the vector of inputs.

To complete our analysis of the remaining inputs, the irrigation variable is now positive for both sets of regressions, viz. Nos. 1–5 and Nos. 6–10, for all

[2]While returns to scale is merely a necessary criteria for determining efficiency, but taken in conjunction with 1-productivity inefficiency, this becomes a sufficient condition.

farm sizes. However, it is not significant for the first set where current expenditure is not included (except for Farm Size 2). In the second set, its significance increases considerably for all farm sizes except the first.[3]

Tenure in Table 6 for both sets of equations is negative at a significant level for farm sizes 1 and 2; i.e. tenure does act as a definite constraint on increasing output for the smaller subsistence-level farmers. For the third farm size, tenure becomes positive at a significant level; i.e. farms with a larger proportion of area leased in have a higher output. What seems to be happening is that larger farmers are able to use the advantages that accrue to larger farm size, like easier access to capital and a better bargaining position on the market,[4] to outweigh the cost of producing on rented land. Similarly, for Farm Sizes 4 and 5, the fact that the disincentive is not significant means that it is economic for them to produce on rented land. Fragmentation again yields very clear results. Labour time, lost in commuting and carrying equipment, seems to be a problem faced only by the smallest two farm sizes in both Tables 6 and 7. So, the larger farms manage to overcome the disutility of lost labour time through the greater use of capital equipment. Secondly, the productive value of the soil, i.e., inferior or better fragments, must also affect output. So, the second aspect of this result is that larger farmers must manage to acquire better fragments on a market where acquisition of land is biased against the smaller farmers.[5]

For Equations 1–5 in Table 9, the use of fertilizer is significant only for the smallest and largest farm sizes, i.e. their use of fertilizers is more efficient in combination with the use of other inputs, as compared to the middle range of farmers whose coefficients are positive but not significant. For Equations 6–10, a high correlation of –0.97 with current expenditure makes the fertilizer coefficients negative.

The labour coefficients remain insignificant and erratic.

Cropping intensity is relatively stable and marginally significant for Farm Sizes 1 and 2 in both sets of equations. The aberrant behaviour of Farm Size 3, despite its highly significant cropping intensity, was noted earlier. And Farm Sizes 4 and 5 get negative and insignificant coefficients in Equations 9 and 10. So, there appears to be a dichotomy between small and large farms in the causal factors for higher output, with the latter groups clearly not relying on cropping intensity.

[3]In order to explain this further, we ran one more set of regressions in which the aggregate irrigation variable was dropped for two separate variables of tubewells irrigated area and canal irrigated area proportions. (See Appendix Table 7).

[4]If nothing else, just storage and transport problems, the urgent need for liquidity, or previously mortgaged crops compell smaller farmers to sell their crop at once, at the going, depressed harvest time rates.

[5]Table 7 shows similar results for both tenure and fragmentation.

In effect, what we have determined through the use of production functions is that

(i) Farm Size 3 operates on decreasing returns to scale, while the smaller and larger farmers obtain constant returns to scale;

(ii) Smaller farmers rely on both cropping intensity and effective use of current expenditure;

(iii) The largest farmers use capital inputs to compensate for not only cropping intensities but also the institutional problems of tenure and fragmentation;

(iv) Tenancy and fragmentation are strong disincentives to increasing output for the two smallest farm sizes; and

(v) The use of irrigation on smaller farms and of fertilizer on the largest farms is more effective relative to the middle farm sizes.

To determine whether the five farm sizes operate on separate production functions, we carried out a covariance-of-coefficients analysis. Additive farm size dummies were used to pick up those structural differences between production functions which were not caused by any of the input variables included in the analysis. And multiplicative farm size dummies were used to isolate the causal inputs responsible for differing factor elasticities as well as intercepts.

$$Y = a_o + a_i'D + \Phi' X + \gamma' DX + U$$

where

Y is the vector of farm size outputs, and a_o is the constant term (and so the intercept of the first farm size);

a_i (4 X 1) = the vector of the coefficients of the four additive dummies representing Farm Sizes 2, 3, 4 and 5;

D (4 X 1) = the vector of the four additive dummies,

Φ (J X 1) = the vector of the coefficients of J inputs;

X (J X 1) = the vector of the J inputs;

γ (4J X 1) = the vector of the coefficients of (4JX1) multiplicative dummies (i.e. each of the 4 dummies multiplied by each of the J inputs); and

DX (4J X 1) = the vector of (4JX1) multiplicative dummies.

Table 10 gives the coefficient vectors. Since a_o and Φ represent the constant and slope of the first farm size, the productivity of that farm size is being compared with those of four larger farm sizes (Nos. 2, 3, 4 and 5). As can be seen, none of the additive dummies proved significant. So, there appears to be no structural difference between the production functions.

Table 10

Coefficient Vectors[a]

(Dependent Variable is Value of Output)

Constant and Variables	Farm Size	Value of the Coefficients	t-ratios
α 0		1.34	
α 2		– 1.69	0.29
α 3		3.42	0.46
α 4		1.48	0.24
α 5		4.85	1.02
Φ : Cultivated Area		1.16	5.92[b]
Irrigated Area		0.22	1.93[b]
Fertilizer Amount		– 1.35	3.77[b]
Labour		– 0.84	1.3
Current Expenditure		1.62	4.41[b]
Cropping Intensity		0.4	0.5
γ : Cultivated Area	2	0.03	0.1
	3	– 0.36	1.08
	4	– 0.2	0.78
	5	– 0.23	1.04
: Irrigated Area	2	0.06	0.41
	3	– 0.09	0.57
	4	– 0.06	0.43
	5	– 0.05	0.33
: Fertilizer Amount	2	0.35	0.56
	3	0.45	0.67
	4	1.31	3.35[b]
	5	1.07	2.59[b]
: Labour	2	1.25	1.42
	3	1.46	1.6
	4	1.25	1.41
	5	0.75	0.96

Continued –

Table 10 – *Continued*

Constant and Variables	Farm Size	Value of the Coefficients	t-ratios
: Current Expenditure	2	– 0.43	0.72
	3	– 0.24	0.33
	4	– 1.25	3.09[b]
	5	– 0.63	1.54
: Cropping Intensity	2	0.3	0.27
	3	0.31	0.25
	4	0.21	0.18
	5	– 0.82	0.82

[a]The number of observations is 95.
[b]Significant at the 10-percent level.

For the multiplicative dummies, the land variable did not seem to account for any difference in production functions. Even though the coefficients of the three larger farm sizes were negative, the difference in slope (and so the difference in impact on output) from the land variable of the first farm size was negligible. Similarly, irrigation appeared insignificant though negative for the three larger farm sizes. Fertilizer, in fact, is the only significant variable in this exercise that puts Farm Sizes 4 and 5 on to higher production functions. Use of labour is marginally significant for farms less than 50.0 acres. Cropping intensity is totally insignificant but negative for farms over 50.0 acres. The expenditure result is the most interesting in that its marginal productivity seems to decrease for the larger farms, and significantly so for the middle range of 25–50 acres.

Thus, inter-farm differentials in the marginal productivities of the main inputs seem to show that Farm Sizes 1, 2 and 3 operate on the same production function, while Farm Sizes 4 and 5 lie above them through their use of fertilizer. Since the marginal significance of some of the other variables cannot be ignored in explaining production differentials, we ran the same exercise with only two dummies to see if the trends persisted.

$$Y = a + C'D + \Phi' x + \gamma' D x + U$$

where

C (2 x 1) = the vector of the coefficients of the two additive dummies;
D (2 x 1) = the vector of the two additive dummies;

γ (2J x 1) = the vector of the coefficients of (2J x 1) multiplicative dummies; and

Dx (2J x 1) = the vector of (2J x 1) multiplicative dummies.

In Table 11, a and Φ now represent Farm Sizes 1 and 2. The productivity of the two smallest farm sizes is compared with that of Farm Sizes 3 and 4 (C_2) and Farm size 5 (C_3). The significant variables remain the same, and, more importantly, the same pattern persists. The middle farm sizes now emerge as the most inefficient in their use of land, irrigation, labour, and current expenditure. This provides some explanation of our earlier results which showed a U-shaped productivity curve as well as decreasing returns to scale. The use of these inputs by Farm Sizes 3 and 4 may be high, but their impact on output seems to be marginally lower than both the smallest and the largest farm sizes. Moreover, their productivity positions seem to be further exacerbated by the non-availability of complementary input, i.e. irrigation, with the high levels of fertilizer that they use. The largest farm size again has a definite advantage in the use of fertilizer, but is moderated by a much lower cropping intensity relative to the smallest farm sizes.

III

We have tried to identify, for each farm size, the relative priority that inputs and institutional constraints take, in determining their outputs. The assumption, *ceteris paribus,* must now be dropped to allow for interaction of all the variables, and productivity (as opposed to pure output) and input differentials must be seen as they exist across farm size. The input use so determined, taken in conjunction with the impact of inputs found above, will, we hope, help to establish some kind of causality.

The various measures of productivity and inputs were regressed on the average farm size in a log-linear form. Table 12 reports the results. In testing the standard hypotheses of a linearly negative relationship between farm size and output per cultivated acre, we found that a weak negative correlation does exist. This result is in keeping with the first part of our analysis where a U-shaped productivity curve emerged. Here, we have productivity decreasing somewhere after the smallest farm size ranges, but not continuously, which leaves room to imply an upward trend for the largest farm sizes.

To test this U-shaped productivity curve, we tried fitting a quadratic form to the data, with the following results:

$$\text{Output/cultivated acre} = 5.8 - \underset{(1.31)}{0.47}\ (\text{Farm size}) + \underset{(1.26)}{0.09}\ (\text{Farm size})^2$$

$$R^2 = 0.02$$

$$F = 0.86$$

Table 11

Coefficient Vectors[a]

(Dependent Variable is Value of Output)

Constant and Variables	Farm Size	Value of the Coefficients	t-ratios
α		0.91	
C 2		2.66	0.66
C 3		5.28	1.41
Φ : Cultivated Area		1.03	10.17[b]
Irrigated Area		0.26	4.09[b]
Fertilizer Amount		– 1.01	4.11[b]
Labour		0.2	1.15
Investment		1.28	5.1[b]
Cropping Intensity		0.8	1.64
γ : Cultivated Area	2	– 0.17	1.2
	3	– 0.1	0.92
: Irrigated Area	2	– 0.12	1.42
	3	– 0.09	0.73
: Fertilizer Amount	2	0.9	3.24[b]
	3	0.73	2.31[b]
: Labour	2	– 0.22	0.78
	3	– 0.3	0.64
: Current Expenditure	2	– 0.8	2.85[b]
	3	– 0.3	0.94
: Cropping Intensity	2	– 0.23	0.32
	3	– 1.22	1.85

[a]The number of observations is 95.
[b]Significant at the 10-percent level.

This functional form is an improvement over the simple linear form, since the significance of the variables improves considerably and the correct signs appear. However, the R^2 still remains very low. Our intuitive explanation is that regional variation within each farm-size range accounts for the loose fit. This result in any case is in contrast to that of Khan [9] who simply uses two farm size dummies (< 25 acres and > 25 acres) to show that large farms are 8 percent more productive than small farms.

We have two points of criticism of Khan's methodology, and, so, of the positive correlation result:

1. Additive dummies can be used to infer land productivity differentials only if equivalent units of land are assumed under the production

function. Theoretically, this seems feasible since, in the estimated form, all inputs including land are held constant. So, if a positive coefficient for the farm-size dummy is found at a significant level, this intercept difference *divided* by the common acreage will yield a land-productivity differential. However, this exercise is rendered invalid by the fact that land cannot be held constant if mutually exclusive land dummies are being used. That is, the line of least fit is being extrapolated for large farms into the small farm-size range where they do not exist. Similarly, the small-farms regression-line is being extended to the larger farm-size range where they do not exist, to plot an output differential for all acreages. So, the shape of the estimated production function is not like the one given in Fig. 3A, representing Khan's derivation, but like that shown in Fig. 3B.

The production function is rendered discontinuous by the farm-size dummy, and it is not possible to derive output differentials with respect to land using this technique.

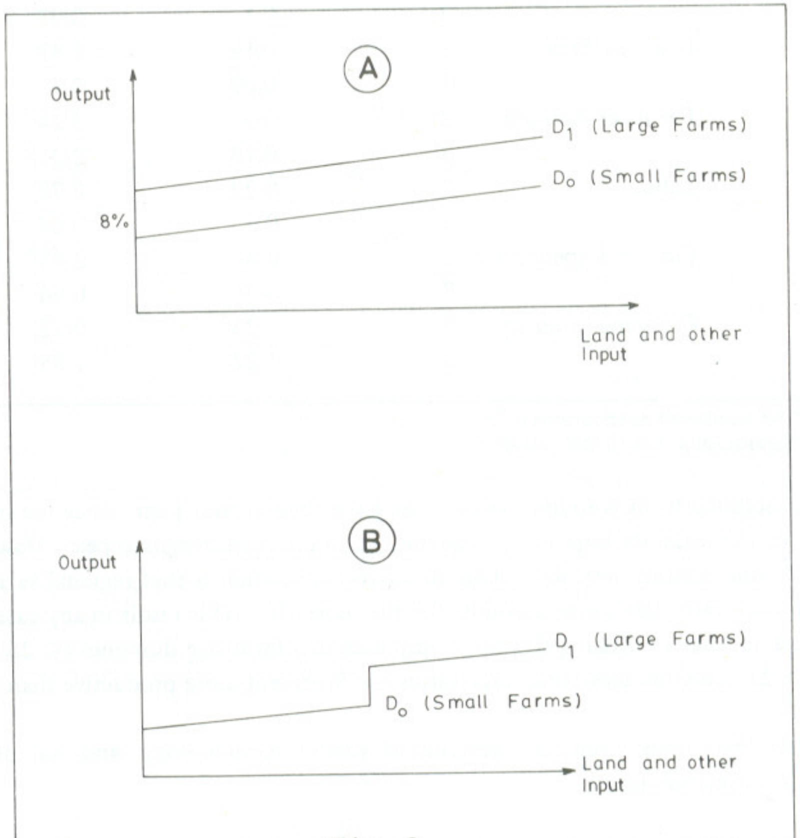

Fig. 3

2. The result of defining just two dummies (< 25 and > 25 acres) leads to an over-aggregation problem. The third farm size (12.5–25 acres) is incorrectly categorized with Farm Sizes 1 and 2, when the latter's productivity performance (according to our analysis and our data) is distinctly better. This aggregated and, so, considerably lowered productivity for farms less than 25 acres leads Khan's analysis a positive relationship with farm size. More importantly, it causes him to overlook the U-shaped curve which definitely warrants examination.

Table 12

Single Variable Regressions[a]

Equation No.	Dependent Variables	Constant	Farm Size	R^2	F
1.	Output/Cultivated Area	5.87	– 0.04 (– 0.58)	0.004	0.342
2.	Output/Cropped Area	5.61	0.02 (0.47)	0.002	0.221
3.	Irrigated Area/Cultivated Area	– 0.64[b] (– 2.08)	– 0.01 (– 0.1)	0.001	0.01
4.	Labour 1	0.54[b] (15.68)	– 0.73[b] (– 57.8)	0.97	3263.0
5.	Labour 2	0.56[b] (14.61)	– 0.82[b] (– 57.8)	0.97	3343.0
6.	Tractors	– 10.47[b] (26.26)	1.03[b] (6.98)	0.34	48.7
7.	Bullocks	– 0.16[b] (– 1.79)	– 0.73[b] (– 2.21)	0.84	489.0
8.	Seeds	– 9.21[b] (– 29.72)	1.59[b] (11.95)	0.61	142.9

[a]The No. of observations is 95.
[b]Significant at the 10-percent level.

To further test whether productivity differentials existed for individual crops, we regressed the outputs per cropped acre for each of the seven major crops on the average farm size. That the value of the output per cropped acre is the same, but the value of the output per cultivated acre varies, implies that cropping intensity must vary across farm size (Table 13).

Table 13

*Single Variable Regressions**

Equation No.	Dependent Variable	Constant	Farm Size	R^2	F
1.	Wheat Output/Cropped Acre	2.41[a] (18.53)	0.02 (0.32)	0.011	0.102
2.	Cotton Output/Cropped Acre	1.65[a] (12.74)	0.1[a] (2.15)	0.047	4.628
3.	Rice Output/Cropped Acre	2.33[a] (11.6)	–0.01 (– 0.14)	0.00	0.019
4.	Maize Output/Cropped Acre	1.45[a] (5.32)	0.22[a] (2.21)	0.05	4.905
5.	Tobacco Output/Cropped Acre	2.02[a] (7.51)	0.02 (0.19)	0.004	0.036
6.	Oilseed Output/Cropped Acre	1.67[a] (6.2)	– 0.03 (– 0.34)	0.001	0.118
7.	Sugarcane Output/Cropped Acre	4.52[a] (12.73)	0.24[a] (1.85)	0.04	3.42

*The number of observations is 95.
[a]Significant at the 10-percent level.

Table 14 shows the results of regressing cropping intensity on the various inputs. Farm size here shows a very strong negative correlation to cropping intensity, i.e. smaller farms do have a significantly higher cropping intensity which largely accounts for their higher output per cultivated acre. The other inputs are positive as expected, except labour and bullocks.

Table 14*

Determinants of Cropping Intensity

Independent Variables	Co-efficients	t-statistics
Constant	4.47	
Farm Size	0.17[a]	– 3.16
Canal + Tubewell Area/Cultivated Area	0.03[a]	2.89
Fertilized Area	0.09[a]	5.99
Labour	– 0.12[a]	– 1.85
Tractors	0.02[a]	2.9
Bullocks	– 0.05	– 1.39
Seeds	– 0.0005	– 0.07
Area Leased	0.07[a]	2.33
Fragments	0.06[a]	– 2.42
R^2	0.67	
F	18.85	

*Number of observations = 95.
[a]Significant at the 10-percent level.

Returning back to input use across farm size in Table 11, the irrigation variable is negative but insignificant. Most importantly, however, both the proxies for labour show a very strong negative correlation with farm size. Tractors, bullocks and seeds, too, carried the expected signs.

POLICY IMPLICATIONS

The most immediate implication of the analysis presented above is that since small farms manage to produce a very high output per acre without high levels of capital input use, their potential for improvement is the greatest. This is a strong economic argument both for land reforms and for directing more capital subsidies towards small farms.

Secondly, the nascent entrepreneurial class of farmers does not appear to be emerging from amongst the middle range of farm sizes since their production behaviour seems to be the least efficient. Moreover, it is the largest farm sizes that appear to have the highest capital use. However, this is not to infer that all or even a significant proportion of the large farms have been transformed into capitalist farms since such an analysis would require at least some computation of profit and investment functions. Here we can only point out that our results imply only the beginnings of the growth of a capitalist class of farmers from amongst the largest farm owners.

Thirdly, since the largest farms, with the aid of very high horsepower capital equipment, only manage to produce only as much as the smallest labour-intensive farms, the rationale for capital intensity loses ground. Farm-level decisions about optimum production techniques must be taken on the basis of inputs valued at their actual shadow costs, and not at their subsidised costs. Accordingly, subsidies and tax relief on the import of heavy agricultural capital equipment must be removed and restricted to lighter varieties. Then only will a lower capital/output ratio in the agrarian sector become more compatible with the exigencies of a capital-poor country like Pakistan.

CONCLUSIONS

We can now sum up the results of our tests. A negative but insignificant correlation was found between output per cultivated acre and farm size. However, a more significant quadratic form provided a better explanation of productivity phenomena. The derived U-shaped curve entails that the smallest and largest farm sizes have the highest land poductivities, while the middle farmers are relatively inefficient. The causality of this phenomenon, as determined by the production function exercise; seems to be that the middle farm sizes are using inefficient combinations of inputs that yield lower marginal productivities, specifically water management and current forms of expenditure in production.

The more interesting aspect of our results is that, given the constraints faced by the smallest subsistence-level farmers, these farmers manage to produce outputs per acre equivalent to, if not higher than, those obtained by the largest farmers. This is primarily due to the fact that the smaller farmers, out of a compulsion to maximise output per unit of land, maximise their use of the variable inputs in some cases up to and beyond the point where their marginal productivity becomes negative. Differentials in input use between the small and other farm sizes are more significant for land-capacity utilization, labour and bullock use. The largest farmers compensate for this primarily through the use of capital equipment and higher levels of current investment. Differences in the use of irrigation (except for the middle

farm sizes) and fertilizer are less significant and prone to regional variation. Institutional constraints, like tenancy and fragmentation, operate only against the smallest farmers, because larger farms are able to moderate the disincentives again through the more intensive use of capital.

So, a high level of input use per acre for both very small and very large farms, with their respective biases towards intensive labour and capital use, accounts for their higher output per acre relative to the middle range of farm sizes.

Appendix

For Equations 1–5 in Appendix Table 1, canals do not emerge as significant, probably because of the form in which this variable was obtained by us. For tubewells, our results are slightly better in that all the coefficients are positive. But the most interesting result is that tubewells emerge as significant only for the first farm size which we were querying earlier. What this simply means is that the smallest farm size is utilizing tubewell water to the best advantage.

Appendix

Table 1

Farm Size Production Functions[a]

(Dependent Variable is Value of Output)

No.	Sample Farm Size	Constant	Cultivated Area	Area Leased In	Fragments	Fertilizer Amount	Labour[1]	Cropping Intensity	Current Expenditure	Tubewells	Canals	Tractors	Bullocks	Seeds	R^2	F
1	1	– 1.62 (– 0.37)	1.05[b] (5.41)	– 0.74 (– 1.27)	– 0.79[b] (– 2.77)	– 0.8[b] (– 1.78)	– 0.96 (– 1.43)	1.16 (1.32)	1.04[b] (2.16)	0.13[b] (1.73)	– 0.04 (– 0.64)	– 0.03 (– 0.63)	0.7 (1.74)	– 0.04 (– 0.57)	0.98	25.191
2	2	1.49 (0.25)	1.09[b] (4.4)	– 1.04 (– 1.4)	– 0.07 (1.75)	0.001 (0.002)	– 0.18 (– 0.22)	0.64 (0.65)	0.19 (0.29)	0.08 (0.73)	0.09[b] (1.71)	0.02 (0.3)	1.17 (1.37)	– 0.07 (– 0.82)	0.98	20.593
3	3	–2.78 (– 0.28)	0.5 (1.41)	1.0 (1.55)	0.03 (0.06)	– 1.01 (1.7)	– 0.42 (– 0.64)	3.22 (1.17)	1.12[b] (2.49)	0.09 (0.41)	0.11 (0.92)	– 0.03 (– 0.25)	– 0.17 (– 0.64)	– 0.05 (– 0.26)	0.96	12.088
4	4	15.17 (1.43)	1.16[b] (3.17)	0.36 (0.51)	– 0.18 (– 0.28)	– 0.17 (– 0.57)	0.62 (0.55)	– 1.12 (– 0.65)	– 0.03 (– 0.08)	0.37 (1.27)	– 0.04 (– 0.33)	0.34 (1.15)	0.12 (0.1)	0.007 (0.07)	0.95	8.838
5	5	17.53 (1.51)	1.24[b] (3.26)	– 0.1 (– 0.42)	0.19 (0.32)	– 0.42 (– 0.91)	– 0.11 (– 0.2)	– 2.45 (–1.47)	0.97[b] (3.8)	0.24 (0.94)	– 0.12 (– 0.17)	– 0.68[b] (2.78)	– 0.21 (– 0.84)	0.003 (0. 02)	0.98	25.877

[a]The number of observations for each equation is 19.
[b]Significant at the 10-percent level.

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