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Input Use and Productivity across Farm Sizes: A Comparison of the Two Punjabs†

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Agricultural production depends upon certain crucial inputs e.g., water, fertilizer etc. In the less developed regions of South Asia in general, and the Indo-Pakistan sub-continent in particular, the use of these inputs depends not only upon the financial affordability but also upon the institutional accessibility of farmers to these inputs. Besides high economic costs, bureaucratic controls and corruption regarding the distribution of inputs have created problems of limited accessibility, especially to the small farmers. In the absence of any credit, information and/or input-distribution networks, the use of these inputs, and related productivity gains, become confined to that class of farmers which not only has better access to these inputs but is capable of using them in the best possible way e.g. use of water and fertilizer in the appropriate amount and at the appropriate time.

This paper[1] attempts to study how input use and input productivity vary across farm sizes, with some reference to the infrastructural and institutional factors, whose development play an important role in improving the distribution and productivity of inputs.

For such an analysis, a comparison of the two Punjabs i.e. Pakistani and Indian Punjabs, presents an ideal framework. Separated by a national boundary since 1947, the two Punjabs enjoy a common history and culture, similar agricultural practices and agroclimatic conditions. Government policies in the two Punjabs, however, have not only differed between the two provinces at the same time, but also over time in the same province. It may be noted that due to certain policy measures, land distribution, tenancy conditions, promotion of agricultural co-operatives and provision of infrastructural features, such as roads and electricity, are relatively more improved in Indian than Pakistani Punjab.[2]

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[2] For a detailed discussion, see Mujahid (1985).

In land distribution, Indian Punjab shows a dominance of medium-sized (5–25 acres) farms, which have occupied 60.3 percent and 69.2 percent of farm area in 1960 and 1972 respectively. Although Pakistani Punjab also has a major portion of area under medium-sized farms but the share of large landholdings is not only large, but unlike in India, has increased from 35.7 percent in 1960 to 41.8 percent in 1972.

With a greater degree of 'landlord absenteeism' among Pakistani farmers due to their other commitments in the cities, it is not surprising to observe a lower incidence of ownership in Pakistani than in Indian Punjab, where such commitments are much limited.[3]

As regards infrastructural provisions, the Indian Punjab has experienced an approximate ten-fold increase in mileage during 1950–1980, whereas Pakistani Punjab witnessed a mere doubling of its road length during these years. Regarding rural electrification, Pakistani Punjab, with only 23.1 percent of its villages electrified, compares poorly with Indian Punjab which had all its villages electrified by the mid-1970s. This has important consequences on the use of tubewells and not surprisingly, Indian Punjab has a greater number of electric tubewells than Pakistani Punjab.[4]

The network of co-operatives which play a vital role in the distribution of agricultural credit and inputs is better developed in Indian Punjab than in Pakistani Punjab. It may be mentioned that although credit availability as a percentage of gross value product in agriculture is negligible in both Punjabs, yet this proportion in Indian Punjab is thrice than that in Pakistani Punjab.

The methodology and empirical analyses which follow will assist in identifying variations in input use and input productivities across farm sizes in the two Punjabs.

METHODOLOGY AND DATA

Unlike some of the works related to this issue,[5] the present study is based on time-series analysis, not emphasising land productivity variations across farm sizes *per se*, rather it focuses on the differential access to inputs and their marginal productivities. These may result from policy differentials producing different levels of institutional and infrastructural developments.

The econometric exercise undertaken in this study can be discussed in two parts:

[3] For details, see Hamid (1981).

[4] According to Yasin (1975), electric tubewells incur less operational costs than diesel tubewells. The latter are more common in Pakistan due to a very low degree of rural electrification.

[5] Mazumdar (1965); Hosain (1974); Ghosh (1973); Roy (1981); Khan (1979) and Mahmood and Haque (1981).

1. Input use by Farm Size

To determine the levels of use of various inputs, such as labour, water and fertilizer across farm sizes, the following specification was estimated:

$$X_i = a_0 + a_1\, MED^{6} + a_2\, LRG \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

where:

X_i : use of input i i.e., amount of labour per unit of land, canal-tube-well and HYV intensities[7] and fertilizer use per unit of land;

MED : proportion of farm area under medium-sized (5–25 acres) farms; and

LRG : proportion of farm area under large-sized (> 25 acres) farms.

2. Input Productivity by Farm Size

The standard method to determine variations in productivity across farm sizes is to estimate a single production function for each farm-size category[8] and test the difference in the coefficients using *t* conventional techniques.[9]

As the present study is a time-series analysis, therefore it is based upon secondary data. Published data do not provide sufficient information as to enable the estimation of separate production functions for each farm-size category. Hence, this study relied on the following indirect technique of estimating productivity differentials:

$$\begin{aligned}\log\ (GVP) = {} & \beta_0 + \beta_1 \log(LAB) + \beta_2\, CAN + \beta_3\, TW + \beta_4\, FERT + \beta_5\, (FERT)^2 \\ & + \beta_6\, MED + \beta_7\, LRG + \beta_8\, (MED\ddagger LAB) + \beta_9\, (LRG\ddagger LAB) + \beta_{10}\, (MED\ddagger CAN) \\ & + \beta_{11}\, (LRG\ddagger CAN) + \beta_{12}\, (MED\ddagger TW) + \beta_{13}\, (LRG\ddagger TW) + \beta_{14}\, (MED\ddagger FERT) \\ & + \beta_{15}\, (LRG\ddagger FERT) + \beta_{16}\, (MED\ddagger (FERT)^2) + \beta_{17}\, (LRG\ddagger (FERT)^2) \quad \ldots \qquad (2)\end{aligned}$$

where:

GVP = gross value product per hectare for 8 major crops[10] in agriculture;

LAB = labour-use per hectare;

[6] Omitted category of farm size is 'small' farms i.e., proportion of total farm area in <5 acre farms.

[7] Canal-intensity: proportion of cropped area under canal irrigation tubewell-intensity: proportion of cropped area under tubewell irrigation. HYV-intensity: proportion of cropped area under high-yielding varieties.

[8] As estimated by Mahmood and Haque (1981).

[9] For example, Chow test.

[10] Wheat, rice, cotton, sugar-cane, maize, barley, bajra and gram.

CAN = canal-intensity;
TW = tubewell-intensity;
FERT = fertilizer use (in nutrient tons) per hectare;
MED = As defined for Equation (1);
LRG = As defined for Equation (1);
MED‡LAB, MED‡CAN, MED‡TW, MED‡FERT = interaction of medium-sized farm and input variables; and
LRG‡LAB, LRG‡CAN, LRG‡TW, LRG‡FERT = interaction of large-sized farm and input variables.

Given less than 100 percent area under any one size of farms, the coefficients for *MED* and *LRG* variables (and interaction variables) are to be interpreted in the standard manner. For example, $\beta_6/100$ shows a change in log (GVP) when there is a one percent switch from small to medium-sized farms, *ceteris paribus*. The coefficients for the interactive terms indicate the relative contribution of various farm sizes to output due to the use of an input. For example, the values obtained for β_8 reflect the percentage change in output (productivity) when labour[11] is applied on medium-sized, rather than on small (omitted category) farms. β_9 has a similar interpretation except that it reflects the difference in output when one unit of labour is shifted from small to large farms.

Specification (1) was estimated using the Ordinary Least Squares (OLS). Due to the strong correlation among variables, the OLS failed to yield satisfactory results for the productivity Equation (2), therefore this equation was estimated using Mixed Estimation Technique (MET).[12] Using the OLS, output (log (GVP)) was regressed separately on each input,[13] using a small part of the data set.[14] The estimate of the variance-covariance matrix was obtained by regressing the output on all possible pairs of explanatory variables.[15] With these estimated values of coefficients and variance-covariance matrix as 'priors', Equation (2) was estimated by applying MET to the remaining data set.

DATA

Depending upon the availability of data, the above specifications were estimated with the help of published time-series and cross-sectional data using the following:

(a) 19 districts data (1959-60 – 1980-81) for Pakistani Punjab; and
(b) 16 districts data (1959-60 – 1980-81) for Indian Punjab.

Data used can be classified in two categories:

(1) based on annual figures: for most of the variables, such as crop acreage and production, area under various sources of irrigation, and fertilizer use, annual data were available from government and private publications of the two provinces.
(2) based on census figures: for labour and for structural variables, such as area under various farm sizes, census figures were used. As rapid changes do not occur in the short-run, values for the missing years were interpolated using exponential trend for labour and linear trend for structural variables.[16]

RESULTS AND CONCLUSIONS

1. Input Use by Farm Size

The regression analysis relating input use and farm size provides some useful information (Table 1). A number of conclusions, important for efficiency and equity arguments on input use across farm sizes, can be drawn from these tables:

(i) As expected, labour intensity declines as area is switched from small to larger (medium-sized or large) farms. With an abundant supply of family help available, requiring virtually no supervision, the smallest farms use relatively more labour (per acre) than larger farms, on which hired labour and its supervision is a costly activity.
(ii) It is not surprising to note that in both regions canal water, due to its public management and accessibility only to the influential groups, is least used on small farms. In Pakistani Punjab, it is the medium-sized farms which are the highest users, whereas the large farms are the ones using most of this water (per acre of cropped area) in Indian Punjab.
(iii) For tubewell intensity, fertilizer intensity and intensity of use of high-yielding varieties (HYV) of seeds, empirical results indicate a uniform pattern in Pakistani Punjab. The small farms are using the lowest amount of these inputs (per acre), whereas in India, it is the small farms who have the highest intensities of these inputs.

It is interesting to note that in Pakistani Punjab medium-sized farms tend to

[11] As output and labour are expressed in log terms, the coefficient is the output elasticity of labour. For other variables, the coefficients are to be interpreted as semi-elasticities.

[12] This technique differs significantly from more conventional estimation techniques (such as Ridge Regression) used for correcting multicollinearity.

[13] Coefficients thus obtained were biased due to exclusion of relevant variables.

[14] Data for the first three years for all districts were used to obtain OLS estimates. These, however, were not significantly different from those obtained from similar regressions on the complete samples.

[15] The estimated variance-covariance matrix is also biased.

[16] For details see Mujahid (1985).

Table 1

Use of Labour, Irrigation, Fertilizer and HYV across Farm Sizes Pakistani and Indian Punjab

Dep. Vars	Labour Use per Hectare		Canal Intensity		Tubewell Intensity		Fertilizer Intensity		HYV* Intensity	
Fram Size	Pakistan	India	Pakistan	India	Pakistan	India	Pakistan	India	Pakistan	India
CONS.	1784.3	583.9	−3.42	0.006	−1.32	1.14	−0.19	0.20	−1.30	1.08
	(7.72)	(18.24)	(−9.92)	(0.08)	(−8.3)	(14.4)	(−8.7)	(25.80)	(−4.5)	(14.6)
MED.	−1173	−104.7	4.76	0.04	2.03	−1.14	0.26	−0.27	2.03	−1.24
	(−4.1)	(−2.21)	(11.24)	(0.42)	(10.4)	(−9.73)	(9.73)	(−23.2)	(5.9)	(−9.37)
LRG.	−1337	−356.0	3.52	0.76	1.03	−0.85	0.18	−0.13	1.12	−0.56
	(−6.3)	(−7.83)	(11.20)	(7.80)	(7.1)	(−7.59)	(8.83)	(−11.7)	(4.2)	(−6.11)
R^2	0.14	0.16	0.24	0.18	0.29	0.23	0.19	0.61	0.26	0.34

Notes: Terms in parantheses are the *t*-statistics.

Number of observations is 418 for Pakistan, 352 for India.

*Number of observation for HYV is 209 for Pakistan and 176 for India.

exhibit the highest use of canal and tubewell water (per acre), fertilizer and high-yielding varieties. This may be because larger farms suffer from neglect because of absentee landlords, also some large farms are large because they cultivate poor land or a large portion of farm area lies as wastelands.[17] For all these reasons, input intensities on large farms are lower relative to medium-sized farms, which are situated best with respect to access and use of inputs.

2. **Input-productivity by Farm-size**

Estimation of the productivity Equation (2), yielded the following relationships with respect to difference in input-productivity across farm sizes (Table 2).

Labour

PAK. $\partial \log(GVP)/\partial \log(LAB) = -0.17 + 0.48\ MED + 0.28\ LRG$

IND. $\partial \log(GVP)/\partial \log(LAB) = 0.13 + 0.31\ MED + 0.16\ LRG$

As in most developing countries which have an abundance of labour with a low shadow price, Pakistani and Indian Punjabs also show a low labour productivity (elasticity) on small farms which use a relatively higher amount of labour per unit of land. In both Punjabs, productivity (elasticity) of labour is highest on medium-sized farms as they most likely combine the best mixture of input accessibility, better supervision of labour and land quality.

Canal Irrigation

PAK. $\partial \log(GVP)/\partial CAN = 0.84 + 0.78\ MED - 1.04\ LRG$

IND. $\partial \log(GVP)/\partial CAN = 4.08 - 3.62\ MED - 5.58\ LRG$

In Pakistani Punjab, the lowest semi-elasticity (marginal productivity at a given level of output per acre) of water is on the large farms, which probably due to easy access either tend to over-use or waste this valuable input. Medium farms tend to be the relatively 'most efficient' users of water for the above-mentioned reasons. In Indian Punjab, productivity of canal water is inversely related to its use, i.e. small farms use the least amount but efficiently enough to have the highest water productivity.

Tubewell Irrigation

PAK. $\partial \log(GVP)/\partial TW = 1.26 + 0.75\ MED - 2.15\ LRG$

IND. $\partial \log(GVP)/\partial TW = 1.75 - 1.64\ MED - 0.22\ LRG$

[17] It has been a tendency of the non-farming moneyed classes to buy large farms, consisting mainly of poor quality land as they can declare a big portion of their income as farm income which is exempted from income tax.

Table 2

Estimate of Yield Equation: Pakistani and Indian Punjab

Independent Variables	Dependent Variable	Pakistan log (GVP/H)	India log (GVP/H)
CONSTANT		3.31	5.54
		(12.28)	(23.69)
log (LABOUR)		–0.17	0.13
		(–5.21)	(3.40)
CANAL		0.84	4.08
		(20.45)	(17.68)
TUBEWELL		1.26	1.75
		(29.11)	(14.03)
FERTILIZER		33.40	–13.64
		(15.18)	(–5.24)
FERT. SQUARED		–218.50	60.36
		(–6.45)	(3.03)
MEDIUM		0.61	–1.98
		(2.11)	(–16.29)
LARGE		2.50	–0.75
		(10.92)	(–5.55)
MED. ‡ log (LAB.)		0.48	0.31
		(16.17)	(31.71)
LRG. ‡ log (LAB.)		0.28	0.16
		(9.90)	(16.42)
MED. ‡ CANAL		0.78	–3.62
		(8.86)	(–10.54)
LRG. ‡ CANAL		–1.04	–5.58
		(–8.18)	(–13.26)
MED. ‡ TWELL		0.75	–1.64
		(24.01)	(–8.22)
LRG. ‡ TWELL		–2.15	–0.22
		(–9.35)	(–0.87)
MED. ‡ FERT.		7.80	35.99
		(1.89)	(7.42)
LRG. ‡ FERT.		–258.94	–191.30
		(–3.83)	(–4.01)
MED. ‡ FERTSQ.		–94.60	10.65
		(–16.14)	(2.36)
LRG. ‡ FERTSQ.		1040.40	–35.53
		(10.48)	(–0.95)

In both the regions the semi-elasticity of tubewell water follows exactly the same pattern as for canal water and for the same reasons.

Fertilizer

PAK. $\partial \log(GVP)/\partial FERT = 33.40 + 7.80\ MED - 258.94\ LRG - (417.00 + 189.20\ MED - 2080.80\ LRG)\ FERT$

IND. $\partial \log(GVP)/\partial FERT = -13.64 + 35.99\ MED - 191.30\ LRG + (120.72 + 21.30\ MED - 71.06\ LRG)\ FERT$

The results indicate that in Pakistan the semi-elasticity of fertilizer, and hence, fertilizer productivity (at a given level of output per acre) changes positively as more area is allocated from small to medium-sized farms, but at a higher level of fertilizer use this change tends to diminish and ultimately becomes negative. This indicates a relatively higher efficiency of input use for the medium-sized farms which have low levels of input use, while the small farms tend to be more efficient with higher levels of fertilizer use. The situation is completely reversed if the change in land allocation is from small to large farms.

In Indian Punjab, on the other hand, the marginal product (semi-elasticity) of fertilizer is highest for medium-sized farms and lowest for large farms for all levels of fertilizer use. With higher use of inputs the medium-sized farms tend to become more efficient while large farms become increasingly inefficient in the use of fertilizer.

SUMMARY

(i) Modern inputs, including fertilizer, canal and tubewell water and HYV seeds play a crucial role in agricultural output. As a consequence, the productivity gains corresponding to these become confined to that class of farmers which has better access (either politically or financially) to such inputs.

(ii) A comparative analysis of the Pakistani and Indian Punjabs reveals that due to policy, the Indian Punjab is better equipped than the Pakistani Punjab with respect to land distribution, owner operation of farms, infrastructural provision such as roads and electrification, and institutional credit.

(iii) Contrary to convention, this study attempts to estimate farm size-productivity relationships on the basis of time-series information. Econometric estimates reveal that generally, medium-sized farms (of 5–25 acres) in Pakistani Punjab and small-sized farms (of less than 5 acres) in Indian Punjab are the most efficient users of inputs relative to farms of other sizes in their respective provinces. This may be attributed to the fact that in Pakistani Punjab, due to an inequitable system of input distribution and lack of infrastructural facilities, the small farms represent a deprived lot. Large farms, on the other hand, suffer partly due to the neglect of the absent landlord and partly due to a high proportion of waste area in their holdings. Medium farms are operated by peasants who are not only able to afford the modern inputs but are also capable of efficient management of their farms.

In Indian Punjab, due to a well-developed network of co-operatives, input-distribution is widespread and better organized with the small farmers getting their due share. Further, infrastructural facilities are well-provided. Unlike the small farms in Pakistan, the small farms in Indian Punjab are at no relative disadvantage as compared to their larger counterparts.

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