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EDUCATION AND FARM PRODUCTIVITY IN PAKISTAN

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While the positive relationship between the educational attainments of farm operators and farm productivity has long been established on both theoretical and empirical grounds, the relative effectiveness of primary and secondary education in raising farm productivity, in a country like Pakistan, is still an open question. The present study uses the Cobb-Douglas production function framework for analysing the 'worker-effect' of different levels of formal education by introducing the education of farmers as an explicit input into the production function. It has been argued that secondary level of education by broadening the information base of farmers, and thus inducing the greater use of yield-raising inputs, raises farm productivity more than does primary education.

I. Introduction

In the agricultural sector, farmers perform not only the entrepreneurial function of coordinating various factors of production but also provide their own labour input. This aspect of the agricultural sector is particularly pronounced in developing countries having a traditional structure. Entrepreneurial abilities of farmers are known to be directly correlated with their information base and the information base is mainly a function of education.[1] Thus, farmers with more education are likely to be more productive

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[1] It was Chaudhri (1968) and later Welch (1970) and Khaldi (1975) who, while studying the role of education in Indian and U.S. agricultures, had proposed that educational attainment of farmers contributes to production in two ways: as 'worker-effect' and as 'allocative-effect'. However, Nelson and Phelps (1966) had earlier contended that education enhances innovative ability which is one dimension of 'allocative-ability'. (i) According to them, 'worker-effect' can be decomposed

and adjust more rapidly to changing circumstances. This relationship has been empirically verified in a number of studies.[2] However, it can be argued, that in the long run the role of education alone is not likely to be very significant in a traditional agriculture, unless support facilities like metalled roads, access to markets, fertilizers, and better crop varieties are also provided.

A relevant issue in this regard is the relative effectiveness of primary and secondary levels of education. Some economists maintain that primary education has a positive and significant impact upon farmers' productivity [Lockheed et al., (1980)], while others emphasize that general education of five years or more plays an important role in the diffusion of technology and the improvement of agricultural productivity [Wu (1977), Chaudhri (1979), Moock (1981), Fane (1975)]. In a country like Pakistan, the contribution of farmers' education to farm productivity is still an open question. The present study is an attempt to provide an answer to this question through an enquiry into the contribution of farm operators' education to farm productivity; this is done by analysing the "worker-effect"[3] of education, using educational level of farm operators as an explicit input in the agricultural production function. In this formulation the marginal product of education captures the "worker-effect" of education.

For the present analysis, Cobb-Douglas (C-D) production function was assumed and fitted over a country-wide data base, spread over the entire Indus Basin. Regression (log-linear) techniques were utilized in order to find out the relationship between yield per acre, labour productivity, input use, and different levels of formal education of farm operators.

Educational attainments of farm operators, especially secondary level schooling (5 years or more), were found to be significantly correlated with higher farm and labour productivity and with lower level of labour use. It was further observed that greater use of yield-augmenting inputs, like chemical fertilizers, has a significant relationship with operators' education, particularly with the secondary level of education.

This study has been divided into five sections. Section two discusses the data base of the present study. Production function analysis is pre-

into two parts: (a) A "pure worker-effect" which can be defined as the increased level of output per unit change in education, holding other factor quantities constant. (b) 'Worker-ability' refers to education's effect on technical efficiency, i.e., a more educated worker's ability to produce more output from a given bundle of inputs. (ii) An 'allocative-effect', that is, the increased level of formal education enhances the farmer's ability to acquire and decode information about production characteristics, as well as about the cost of other factor inputs.

2 See, Griliches (1963, 1964 and 1970), Gisser (1965), Kislev (1965), Fane (1975), Huffman (1972), Welch (1970), Khaldi (1975), Muller (1974), Wu (1977), Haller (1972), Harker (1971), Herdt (1971), Chaudhri (1968, 1969, 1972, 1974 and 1979), Lockheed et al. (1980), Ram (1976) and Moock (1981), Sidhu (1976, 1979), Pudasaini (1983), Ram (1980).

3 See No. 1.

sented in section three. Land utilization, labour productivity and input use on farms associated with different educational attainments of farm operators are discussed in the subsequent sections. The last section ties up the findings.

II. Source of Data

The data is taken from farm level cross-sectional survey, jointly conducted by the World Bank and Water and Power Development Authority (WAPDA) of Pakistan, across the entire Indus Basin for 2002 farms. This survey is called the "1977 Agricultural Economics Survey of the Indus Basin". Five hundred watercourses (clusters) were selected using the Cluster Sampling Technique. From each watercourse four farm operators were interviewed and stratified according to their farm size and tenurial arrangement. This survey provides information on farm output (crops and non-crops), input use, level of mechanization, farm operator's demographic characteristics, and other related information.

The present data have been extensively used both by WAPDA and Stanford University for in-house research and for several Ph.d. theses, respectively. It has also been used by the World Bank for an extensive agricultural study of Pakistan. After the editing and cleaning of data for the present study only 1787 cases were finally selected for analysis.

III. Production Function Analysis

The Cobb-Douglas (C-D) production function is widely used in agricultural economics to identify the contribution and importance of various factor inputs, including formal education, in the production of agricultural output.[4] There are two important considerations which explain this choice: first, it reasonably reflects the process of production and, secondly, it is computationally efficient, permitting estimation of coefficients by Ordinary Least Squares (OLS) Method. Griliches (1970) mentioned that statistical results obtained with C-D specification are reasonably efficient and can be interpreted in the framework of economic theory more easily; this point has also been made by Sidhu (1974).[5]

[4] See, e.g., Griliches (1963, 1964, 1970), Kislev (1967), Chaudhri (1968, 1974), Bardhan (1973), Huffman (1974), Sidhu (1974), Khaldi (1975), Fane (1975), Salam (1976), Aslam (1978), Khan (1979), Moock (1981), Bagi (1981), Wu (1977), Sidhu (1979), Pudasaini (1983) and Ram (1980).

[5] The use of single equation models for agricultural production function has been justified by Griliches (1957), Mundlak and Hock (1965), and Zellner, Kementa and Dreeze (1966), who argue that inputs in agriculture are largely predetermined because of a considerable lag in production; and because the error is largely weather-determined, simultaneous equation bias will be small for a well specified production function.

In view of the above evidence, C-D function was selected for our empirical estimation. Two different methods have been suggested in the literature for incorporating formal education explicitly in the C-D production function analysis. First, education may enter the production function in a neutral fashion, that is, without altering the 'output elasticities' of any other factor input. Second, it may enter the production function as an interacting factor so as to make different factor elasticities dependent on the level of farmer's education.

Two separate specifications of C-D production function were estimated by OLS method:

$$\begin{aligned}\ell n(GVP) = {} & \alpha \ell n(A) + \beta_1 \ell n(TL/A) + \beta_2 \ell n(FEXP/A) + \beta_3 \ell n(MC/A) \\ & + \beta_4 \ell n(AL/A) + \beta_5 \ell n(IRRI/A) + \beta_6 \ell n(AGE) \\ & + \beta_7 \ell n(F) + \gamma_1 P + \gamma_2 S + \gamma_3 H + \gamma_4 M + \gamma_5 TE.\end{aligned} \tag{1}$$

$$\begin{aligned}\ell n(GVP) = {} & \alpha \ell n(A) + \beta_1 \ell n(TL/A) + \beta_2 \ell n(FEXP/A) + \beta_3 \ell n(MC/A) \\ & + \beta_4 \ell n(AL/A) + \beta_5 \ell n(IRRI/A) + \beta_6 \ell n(AGE) + \beta_7 \ell n(F) \\ & + \rho_1 P \cdot \ell n(TL/A) + \rho_2 P \cdot \ell n(FEXP/A) + \rho_3 P \cdot \ell n(MC/A) \\ & + \rho_4 S \cdot \ell n(TL/A) + \rho_5 S \cdot \ell n(FEXP/A) + \rho_6 S \cdot \ell n(MC/A) \\ & + \gamma_1 P + \gamma_2 S + \gamma_3 H + \gamma_4 M + \gamma_5 TE.\end{aligned} \tag{2}$$

In equations (1) and (2) GVP is gross value of production in rupees; A is total cropped acreage on farm; TL/A is total amount of human labour in terms of mandays per acre used for all crops raised on farm; FEXP/A is per acre expenditure on chemical fertilizers, for all crops; MC/A is per acre maintenance expenditure for farm machinery used for crop operation only; AL/A is total number of working animals per acre; IRRI/A is total number of irrigations per acre for all crops; AGE is farm-operator's age in years; F is number of fragments of land per acre; P is one if farm-operator has 1–4 years of formal schooling, otherwise zero; S is one if farm-operator has 5 or more years of schooling, otherwise zero; H is one if farm is located on the head of the watercourse, otherwise zero; M is one if farm is located on the middle of the watercourse, zero otherwise; and TE is one if farm-operator is an owner, zero otherwise. The remaining terms denote interaction between primary and secondary education with human labour, fertilizers and machines. The choice of these variables is justified in Annexure 1.

Since the other variable factors of production in equations (1) and (2) have been defined per acre, $\hat{\alpha}$, the coefficient for land, is obviously the sum

of the factor elasticities in the C-D production function. In other words, the deviation of this coefficient from unity can be tested to yield a measure of the returns to scale. If this coefficient is not significantly different from unity, returns to scale are constant; if it is significantly below (above unity) they are decreasing (increasing).[6]

1. Empirical Evidence

The estimated regression coefficients of equations (1) and (2) are presented in the first and second columns respectively of Table 1. In general, the results are quite encouraging: in most cases, the variables have the expected signs, even though they do not display the expected significance. Given the estimation in natural logarithm of our variables, it may be noted that our estimated coefficients represent output elasticities with respect to different factors. The R^2 values are fairly high suggesting that our specification explains more than fifty per cent of the variation in total production across farms.

The relatively high value of the coefficient for total cropped acreage (A) suggests that this variable on its own explains most of the variation in farm output. Also, since the value of this coefficient is significantly less than unity, it may be concluded that our production functions display decreasing returns to scale. On the other hand, while the coefficients of human and animal labour carry the expected positive sign, they are not statistically significant even at the 10 per cent level. This unexpected result may be attributed to the presence of collinearity between these variables and total cropped acreage, and $\hat{\alpha}$ may have captured the effects of these variables also. However, this may also be due to the 'aggregation bias' that results from our treatment of different types of labour as a single input; in the presence of such a bias no firm inference can be drawn about the estimated coefficients. The expenditure on fertilizer per acre (FEXP/A) and the use of farm machinery per acre (MC/A) both turn out to be positive and significant explanatory variables in both our estimating equations. Similar results were obtained for our irrigation variable. Such a pronounced effect of irrigation suggests that proper and efficient water management leading to an increase in the number of water applications per acre, may be recommended as an important measure for improving productivity on our farms. The estimated coefficient for work experience as measured by AGE of farm operators is positive but not significant. This suggests that in an environment where technology flows are being accelerated, the farmer's ability to absorb and apply the relevant information does not significantly depend on his age. Similarly, the fragmentation of land has the expected negative sign, but it is not statistically significant.

[6] For details, see Bardhan (1973).

TABLE 1

OLS estimates of Cobb-Douglas co-efficients for the measures gross value products
(t-ratio in parentheses)

Estimates		ℓnGVP	ℓnlGVP
ℓn(A)	$\hat{\alpha}$	0.8494	0.8488
		(33.342)***[a]	(33.121)***[a]
ℓn(TL/A)	$\hat{\beta}_1$	0.0190	0.0270
		(0.936)	(1.095)
ℓn(FEXP/A)	$\hat{\beta}_2$	0.0920	0.0840
		(16.637)***	(13.397)***
ℓn(MC/A)	$\hat{\beta}_3$	0.0280	0.0240
		(3.761)***	(2.359)**
ℓn(AL/A)	$\hat{\beta}_4$	0.0150	0.0130
		(0.912)	(0.781)
ℓn(IRRI/A)	$\hat{\beta}_5$	0.1550	0.1570
		(5.681)***	(5.753)***
ℓn(AGE)	$\hat{\beta}_6$	0.0270	0.0210
		(0.464)	(0.368)
ℓn(F)	$\hat{\beta}_7$	−0.0050	−0.0060
		(0.451)	(0.485)
PRIMARY	$\hat{\gamma}_1$	0.0700	0.1710
		(1.071)	(0.605)
SECONDARY	$\hat{\gamma}_2$	0.1070	0.0610
		(2.434)**	(0.366)
P•ℓn(TL/A)	$\hat{\rho}_1$	–	−0.0520
			(0.791)
P•ℓn(FEXP/A)	$\hat{\rho}_2$	–	0.0260
			(1.241)
P•ℓn(MC/A)	$\hat{\rho}_3$	–	−0.0050
			(0.164)
S•ℓn(TL/A)	$\hat{\rho}_4$	–	−0.0140
			(0.330)
S•ℓn(FEXP/A)	$\hat{\rho}_5$	–	0.0380
			(2.477)**
S•ℓ(MC/A)	$\hat{\rho}_6$	–	0.0070
			(0.452)
HEAD	$\hat{\gamma}_3$	0.0230	0.0220
		(0.568)	(0.534)
MIDDLE	$\hat{\gamma}_4$	0.0740	0.0720
		(1.733)	(1.679)*
TE	$\hat{\gamma}_5$	−0.1180	−0.1160
		(3.297)***	(3.265)***
CONSTANT		5.714	5.700
R^2		0.573	0.575
$\bar{R}^2$		0.569	0.570
F		182.618***	125.559***
N		1787	1787

* Significant at 10 per cent, ** Significant at 5 per cent, *** Significant at 1 per cent.

[a] DRTS (Decreasing returns-to-scale).

The educational attainment variables have the expected positive sign, but primary level education (1–4 years of schooling) turns out not to be statistically significant in both the equations. The dummy for secondary level education (5 or more years of education) is statistically significant in one of the equations. The results on the interaction dummies are quite mixed. It appears that primary level education has a negative, though statistically insignificant, impact on labour use and expenditure on maintenance of machinery; though expenditure on fertilizer increases with the presence of primary education. Secondary level education improves, to a statistically significant degree, the application of fertilizers; however the impact on the use of machinery is only negligible, though positive, and not significant.

We also regressed the yields per acre for four different crops, viz., wheat, sugarcane, cotton, and rice, against crop acreage and three dummies for primary schooling, secondary schooling and tenurial arrangements: all these independent variables were specified as before. The results of this exercise are presented in Table 2. Except for sugarcane, the yield is nega-

TABLE 2

Regression estimates of yield per acre for four major crops

Estimates[1]	Wheat (Q/A)	Sugarcane (Q/A)	Cotton (Q/A)	Rice (Q/A)
Cropped acreage	–0.052	0.071	–0.010	–0.097
	(2.224)**	(1.888)	(0.279)	(3.921)***
Primary schooling	0.037	0.0001	0.0121	0,132
Dummy (1–4 Yrs)	(0.539)	(0.000)	(1.054)	(1.141)
Secondary schooling	0.186	0.022	0.202	0.212
Dummy (5+ Yrs)	(4.133)***	(0.256)	(2.588)**	(2.917)**
Tenurial arrangements	0.033	–0.171	–0.130	–0.040
(1, 0)	(0.892)	(2.358)**	(1.999)**	(0.679)
CONSTANT	2.580	0.767	1.617	2.848
R^2	0.018	0.027	0.014	0.036
$\bar{R}^2$	0.014	0.017	0.008	0.029
F	5.215**	2.678*	2.479*	5.643**
N	1156	394	704	604

[1] Estimated in natural logarithm.

* Significant at 90 per cent, ** Significant at 95 per cent, and *** Significant at 99 per cent. t-ratio in parenthesis.

[2] Low $\bar{R}^2$ is not an uncommon feature, particularly in cross-section data, because some other important factors which influences yield per acre are excluded from the present equations.

tively related to cropped acreage, and in two cases the relationship is significant. The coefficient for primary schooling though positive is not significant. However, the coefficients for secondary school dummy are significant in three out of four cases. Owner-operated farms have a lower yield than tenant farms. It may be noted that these results generally corroborate our earlier results.

IV. Effects of Education on Selected Variables

The present section describes the results of regression analyses undertaken to examine the effects of education and some other independent variables, e.g., tenurial arrangements and farm size, on selected dependent variables, viz., cropping intensity, labour productivity, labour use and fertilizer use. These dependent and independent variables, are defined as follows:

a) Dependent Variables

Cropping intensity (ℓnCI) was defined as the number of times an acre of land was cropped in a single year and measured as a ratio of cropped area to cultivated area. Output of different crops per manday (ℓnQ/MD) was taken as a measure for labour productivity, while in the case of total farm produce gross value-product per manday (ℓnGVP/MD) was incorporated. Labour use was measured by three types of variables i.e., total (ℓnTMD/A), hired (ℓnHMD/A), and family (ℓnFMD/A) labour mandays per acre used for all crops. Finally, use of fertilizers was measured in terms of per acre expenses on chemical fertilizers (ℓnFEXP/A) used for all crops.

b) Independent Variables

Primary education (P), secondary education (S), and tenurial arrangement (TE) dummies were entered as in section II. LF was the dummy for large farm sizes, having value equal to one if the farm size was greater than or equal to 50 acres of cultivated land, otherwise zero; SF was the dummy for small farm sizes, having value equal to one if the farm size was less than or equal to 12.5 acres of cultivated land, otherwise zero; (ℓnCA) was cropped acreage for individual crops and total cropped area for aggregate production; finally, (ℓnE) was the total number of schooling years attained by farm operator.

1. Cropping Intensity and Education

Multiple cropping, as indicated by higher cropping intensity, can be enhanced, among other things, by using land and other farm inputs more

effectively. Such effective use may depend on the cultivator's information base, which is directly related to the attainment of formal education. Thus it seems reasonable to expect that farmers with relatively higher formal education will increase their land use, i.e., education will be positively associated with cropping intensity.

Estimated coefficients, as shown in Table 3, confirm that cropping intensity is significantly higher on those farms where the farm operators have attained 5 or more years of formal schooling. These results also support the frequent observation that cropping intensity is lower on relatively large and owner-operated farms, particularly in developing agricultures.

2. *Education and Labour Productivity*

In view of the preceding discussion, it can be hypothesized that differences in farm labour productivity are likely to be directly influenced by the educational level of the farm operator.

The results of the estimation exercise, as presented in Table 3, indicate that there seems to be a significant relationship between labour productivity and farmer's education on the sample farms. Again, secondary level of education (5 or more years of schooling) has shown relatively more pronounced effect than primary education upon farm labour productivity both at crop and farm level. Higher labour productivity seems to have been associated with relatively large farms. Ownership of land has a significant but negative impact on labour productivity on the farm under consideration.

3. *Input use and Education*

Regression results, as presented in Table 4, examine the pattern of relationship between the use of two main farm inputs, namely farm labour and chemical fertilizer, and the educational attainment of the farmers. These results clearly suggest that inter-farm variations in the use of different types of farm labour are significantly correlated with the level of formal schooling of the farmers under consideration, although the directions are different, i.e., total farm labour use decreases as the educational attainment of farmers increases, while the use of hired labour per acre increases. The coefficient of education in family labour equation suggests that the decrease in the use of total labour per acre may be due to relatively greater reduction in the use of family labour resulting from formal schooling of farm operator. The coefficients of the dummy for large farms exhibit the same pattern as those for education, while small farms use relatively less hired labour though total labour use is higher. Owner operators use relatively less family labour on their farms. These results are quite consistent with generally observed

TABLE 3

Differences in cropping intensity, labour productivity and farmer education

Estimates	Cropping intensity ℓn(CI)	Labour productivity for				
		Wheat ℓn(Q/MD)	Rice ℓn(Q/MD)	Sugarcane ℓn(Q/MD)	Cotton ℓn(Q/MD)	Farm ℓn(GVP/MD)
ℓn(CA)	—	0.363 (9.465)***	0.268 (7.338)***	0.298 (4.101)***	0.307 (6.488)***	0.369 (10.653)***
P	0.009 (0.201)	0.117 (1.022)	0.050 (0.293)	0.386 (1.584)	0.310 (1.983)**	0.231 (2.210)**
S	0.074 (3.422)***	0.324 (4.332)***	0.372 (3.488)***	0.518 (3.159)***	0.359 (3.666)***	0.288 (5.445)***
TE	−0.069 (3.904)***	−0.151 (2.448)**	−0.186 (2.131)**	−0.407 (2.915)**	−0.343 (3.822)***	−0.259 (4.674)***
LF	−0.245 (6.197)***	—	—	—	—	—
SF	0.146 (8.101)***	—	—	—	—	—
CONSTANT	0.148	−1.735	−1.246	−4.276	−2.547	1.282
R^2	0.079	0.107	0.118	0.102	0.104	0.103
$\bar{R}^2$	0.077	0.103	0.112	0.093	0.099	0.101
F	35.431***	34.255***	20.055***	11.028***	20.313**	51.211***
N	1787	1156	604	394	704	1787

ℓn = Natural logarithm.

*Significant at 10 per cent, **Significant at 5 per cent, and ***Significant at 1 per cent.

t-ratios in parenthesis.

relationship in other studies.

Per acre expenses on chemical fertilizer seem to be significantly and positively influenced by the educational attainment of farm operators. These results further indicate that average expenditure on chemical fertilizer increases as farm size increases, while owner-operated farms spend relatively less on chemical fertilizer than non-owner farms located in sample areas.

TABLE 4

Differences in human labour and fertilizer use and farmer's education

Estimates	Labour use			Fertiliser use
	Total Labour ℓn (TMD/A)	Hired Labour ℓn (HMD/A)	Family Labour ℓn (FMD/A)	ℓn (FEXP/A)
ℓn (E)	−0.041 (5.489)***	0.168 (8.610)***	−0.205 (8.852)***	0.112 (4.364)***
LF	−0.395 (4.04)***	2.127 (8.332)***	−1.524 (5.029)***	1.036 (3.094)***
SF	0.391 (8.816)***	−0.918 (7.903)***	0.002 (0.000)	0.072 (0.470)
TE	0.209 (4.815)***	0.778 (6.854)***	−0.0335 (2.482)**	−0.281 (1.889)*
CONSTANT	3.314	−3.209	2.326	3.069
R^2	0.095	0.169	0.072	0.019
$\bar{R}^2$	0.093	0.167	0.669	0.017
F	47.018***	90.407***	34.546***	8.927**
N	1787	1787	1787	1787

ℓn = National logarithm.
* Significant at 90 per cent, ** Significant at 95 per cent, and *** Significant at 99 per cent.

V. Conclusion

One may conclude from the discussion of preceding sections that educational attainment of farm operators, particularly of non-owners with secondary level of education, is in all probability an important factor in determining farm productivity and the use of yield-raising inputs, like chemical fertilizers. Higher expenses on chemical fertilizers seem to be translated in higher farm productivity (section III). It can be further observed that relatively more educated farmers are able to achieve higher level of farm labour productivity. More specifically, secondary level of education (5 years or

more) turns out to be a better source for widening the information base of farm operators and thus increasing farm productivity. But still farm productivity differences depend upon land, irrigation and fertilizer.

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Annexure 1

Justification of variables used in the production function analysis is as follows:

A) Dependent Variable

Value of total production of crops (in Rupees) on the farm (GVP), is selected as dependent variable on the implicit assumption that the crop composition of total production is similar across the sample farms.[7] According to Khan (1979) and Bardhan (1973), the choice of total crop function is justified on the following grounds: (a) there is no significant correlation of farm size with high-value or low-value crops; and (b) the allocation of given inputs to any single activity (crop) on a farm is not made in isolation from all other feasible or competitive crops. Such a choice could be further justified on the ground that the present study seeks to analyse "agricultural productivity" differences among farms with farmers of varying levels of education, and not inter-crop allocative efficiency of inputs. Moreover, one can only reduce the toll of "aggregation problems" but not completely eliminate it.

B) Independent Variables

i) Total cropped area (A) has been taken instead of other measures of land (e.g., sown area, harvested or cultivated area), due to two main reasons: (a) it can incorporate the effect of cropping intensity (in case it is greater than one) upon the 'returns-to-scale'; and (b) since GVP is the value of total farm output, 'A' should be the total cropped area.

ii) The money value of fertilizer per acre (FEXP/A) was used rather than their physical quantities because the latter acts as an endogenous variable and may create simultaneity bias in single equation (OLS) estimation. The same logic could be applied to the (MC/A) variable, the money value of running expenditure per acre on all types of agricultural machinery used only for farm operations. This variable can also be treated as the proxy for the level of mechanization of the farms located in sample areas.

[7] Since the output data was collected in terms of quantity and standardized price was not used to compute the value, GVP may capture the effect of the different prices received by different farm operators for the same marketed crops.

iii) The treatment of total number of (8-hour) mandays per acre (TL/A) used for all crops as a single input is justified on two assumptions; these are: (a) that all types of labour are sufficiently homogenous to be easily aggregated,[8] and (b) imputation of wages for family labour as distinct from ordinary labour creates bias in estimation.

iv) Age (AGE) of the farmer serves as a measure of experience (learning-by-doing) in agricultural production processes on the farm.

v) Number of irrigations per acre for all crops (IRRI/A) is presumably a relatively new explanatory variable in the present analysis. The main reason for including this variable in the present analysis is its availability across the farms in the country level data, though many agricultural economists agree that 'land' captures the impact of irrigation water.

vi) The number of fragments per acre on the farm (F) was taken as a proxy for inefficiency, because fragmentation of land is widely regarded as one of the sources of production inefficiency in the agriculture of developing countries.

vii) The formal education of the farmer (SH) was taken as the source of farmers' information and knowledge. Its marginal product estimates 'worker-effect' in the production of agricultural products on the farm, because the underlying assumption is that formal schooling directly augments the skill of farmers in gathering, processing and interpreting of information necessary for production. Education was incorporated as a binary variable (as shift parameters), i.e., illiterate (omitted category), primary education (1–4 years), and secondary level of education (5 or more years). The choice of 5 years as a cut-off point is based on the generally held view that at least five years of schooling is necessary for an average individual to achieve and retain functional literacy.

The interaction of each of the binary variables for education with land, labour, fertilizers, and mechanization provides an estimation of the relative abilities of workers in their use.

The location of the farm on the water course is indicated in terms of categorial variables viz., tail (omitted), head (H) and middle (M). It is a well-known proposition that the location of farm on the water courses affects the absolute availability of water due to the strength of the water flow which may be reduced at the end (tail). Finally, tenurial arrangement (TE) is included in order to capture the impact of ownership of land on farm productivity.

[8] Barnum (1976) performed some empirical tests in this regard and concluded that "the aggregate bias resulting from the failure to treat different types of labour as separate inputs was minimal in the sense that: (i) the coefficients of the non-labour variables were not markedly affected by the aggregation of labour, also (ii) the sum of all coefficients including those on the labour input(s) was not affected by aggregating the labour variables".

Annexure 2

Mean and standard deviation of variables used in the production function and regressions (N=1787)

Variables[a]	Mean	Standard Deviation
Gross value product	8.564	1.091
Cropped acreage	2.631	0.803
Human labour per acre	3.719	0.953
Fertilizer expenses per acre	2.707	3.139
Machinery expenses per acre	−3.794	2.548
Working animals per acre	−2.018	1.138
No. of irrigations per acre	2.059	0.627
Age of farmers	3.743	0.308
Primary schooling	0.075	0.263
Secondary schooling	0.226	0.418
Fragments per acre	−3.501	1.458
Farms on head	0.367	0.482
Farms in middle	0.309	0.462
Owner operators	0.558	0.497
P·ℓn(TL/A)	0.275	1.004
P·ℓn(FEXP/A)	0.226	1.156
P·ℓn(MC/A)	−0.283	1.200
S·ℓn(TL/A)	0.779	1.522
S·ℓn(FEXP/A)	0.749	1.856
S·ℓn(MC/A)	−0.653	2.054
Small farms	0.511	0.500
Large farms	0.056	0.229
Gross value product per manday	2.214	1.211
Cropping intensity	0.188	0.383
Total labour manday per acre	3.719	0.953
Total hired labour mandays per acre	−3.577	2.599
Total family labour mandays per acre	2.606	2.918

[a] Estimated in natural logarithm.

Annexure 3

Mean and standard deviation of variables
used in crop-wise regressions
(Standard deviation in parentheses)

Variables[a]	Wheat	Cotton	Rice	Sugarcane
Total output	4.197 (1.001)	2.954 (1.284)	3.855 (1.303)	5.984 (1.301)
Yield per acre	2.570 (0.627)	1.592 (0.861)	2.777 (0.726)	1.010 (0.688)
Harvested acreage	1.627 (0.808)	1.362 (0.949)	1.079 (1.193)	4.985 (0.939)
Output per unit of labour (Mandays)	−1.147 (1.089)	−2.203 (1.232)	−0.970 (−1.118)	−2.890 (1.382)
No. of years of formal schooling of farms' operators	−2.638 (2.962)	−2.482 (3.023)	−2.804 (2.874)	−2.589 (2.992)
Primary schooling	0.078 (0.268)	0.091 (0.288)	0.069 (0.255)	0.084 (0.277)
Secondary schooling	0.230 (0.421)	0.242 (0.428)	0.214 (0.411)	0.231 (0.422)
Owner operators	0.572 (0.495)	0.549 (0.498)	0.520 (0.500)	0.627 (0.484)
Large farms	0.068 (0.251)	0.084 (0.277)	0.058 (0.234)	0.091 (0.288)
Small farms	0.480 (0.499)	0.446 (0.497)	0.492 (0.500)	0.487 (0.501)
N	1156	704	604	394

[a]Estimated in Natural Logarithm.

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