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The Productive Value of Education in Agricultural Development

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I. INTRODUCTION. Modernization of agriculture is a complex process. Traditional agriculture is backward because of the potentially low productivity of traditional factors of production.[1] The essence of agricultural modernization, thus, is the creation of science-based, new and superior sources of increased productivity and their successful introduction in backward, low-productivity agriculture. Emphasis here is on the generation and availability of new high-productivity factors of production, since investments in older forms of capital constitute only a minor source of growth. Modernization of agriculture thus can only be accomplished through application of advances in scientific knowledge.

This scientific knowledge comes to the farmer in the form of complex modern factors of production which are potentially superior in economic productivity compared to traditional factors.[2] These modern factors have potential for improving well being of farm people and constitute the source of economic growth from agriculture. Thus, the modernization of a low-productivity agriculture depends upon the ability of farm people to understand the complex nature of these new factors of production, and to learn to use them skillfully and efficiently once they become available. As this process of modernization proceeds, it increases in complexity; and gains in agricultural productivity become dependent upon the rate of assimilation of the new technical advances Accumulation of knowledge about scientific agriculture and application of this knowledge and not the accumulation or expansion of primitive forms of capital is what matters for a successful tranformation of traditional agriculture.

Success in the production of modern inputs appropriate to a particular ecology from the available scientific knowledge depends upon the state of agricultural research and obviously requires high-level manpower skills and related investments.[3] Successful application of these modern inputs, however, depends upon their availability and profitability, as well as the speed of the learning process of the farming community. That is, it depends upon abilities of farmers to decode and comprehend the complex nature of modern inputs, to make an efficient selection from them and to make appropriate reallocations of their existing resources in order to avail themselves of the new opportunities embodied in the new superior inputs[4] Herein then, lies the source of demand for education. Intuitively it seems quite reasonable to argue that education is the source of these useful abilities which are necessary for learning new farming skills.

The contribution of education to the attainment of useful productive abilities has, however, not been properly recognized in most developing countries. In general education has been viewed as a consumption good, the supply of which could be increased when a country could afford it. Investments in industrial activity are considered to be more productive than investments in rural education. There has been (perhaps as a consequence) a lack of studies of the economic value of education of the farm people in developing countries. That education of the farm people contributes to their productive abilities and that investments in rural primary level education are thus an important source of economic growth has not been sufficiently recognized.[5]

It must be stressed that this neglect of education of the farm people delays the process of modernization of agriculture. Low-cost availability of modern inputs of production and information, and effective economic incentives are the necessary economic requirements for starting the process of agricultural modernization. Presuming that modern inputs and relevant information are available, modernization is delayed by the low level of schooling of farm people who must learn the new farming skills. Gains in agricultural production which are crucial for general economic growth and development are thus delayed or indefinitely postponed.

Agriculture in most developing countries has already begun to modernize It is difficult today to find a country with a strictly traditional agriculture as defined by Schultz [6] Most countries are making serious efforts to improve the supply of modern inputs to their agricultural sectors The educational implication of this change is increased demand for schooling and education relevant for agricultural production. In general farmers begin facing this change with very little schooling Abilities acquired from schooling thus become valuable to cope efficiently with the new inputs of production and to sharpen the response of farm people to better economic opportunities embodied in these inputs.

The purpose of this paper is to present some empirical evidence from a developing agriculture in northwestern India, evidence which shows that schooling of the farm people contributes to their useful productive abilities. For this purpose one must determine the value in agricultural production of the services provided by education, and that precisely is the goal of the paper. In the second section of the paper the theoretical model developed by Finis Welch[7] to study the productive value of education is discussed and made operational for the purpose of present investigation. In the third section an empirical test is carried out to evaluate the contribution of education to agricultural production.

In the fourth section some broad implications of agricultural research and educational policies are discussed in relation to the agricultural modernization process.

II. EDUCATION AS A FACTOR OF PRODUCTION. A vast amount of literature has appeared indicating relatively high rates of return to primary education in general. Most such studies, however, do not deal directly with the economic value of education in farming as such Yotopoulos (1968),[8] Chaudhri (1969),[9] Hayami (1969),[10] Welch (1970),[11] Herdt (1971),[12] Huffman (1974),[13] and Khaldi (1975),[14] are some of the recent studies which have explicitly viewed education as a factor of production in agricultural production function analysis. In an inter-country analysis of sources of agricultural productivity gaps, Hayami introduced education as a separate variable. His results indicate that differences in education constitute an important source of differences in agricultural productivity among nations. Yotopoulos shows that a small amount of education (2.24 years per household member) is an important factor of production in Greek agriculture---an agriculture which has only recently begun to modernize. Chaudhri's results also seem to support the view that the level of agricultural productivity in Indian agriculture is significantly related to the level of education even though the estimated coefficient for education is small. He estimated a district-level aggregate production function of gross revenue and included education as one of the influencing variables.

Herdt also estimated an aggregate production function (at the state level) for Indian agriculture for 1965. His results are, however, not consistent with those of the above mentioned studies. He obtained negative or nonsignificant coefficient estimates for education. In part his problem seems to be statistical---few observations and high intercorrelations, and in one case an incorrect selection of the measure representing education which creates the problem of linear dependency. Herdt argues that lack of technological complexity in Indian agriculture and uniform nature of this technology across the country result in little direct effect of education on agricultural production. The implication, of course, is that, Indian agriculture is still close to an equalibrium of a traditional agriculture.[15] In view of the stationary nature of technology, the extensive and prolonged observations that farmers make of other farmers and their elders result in efficient judgments (education or no education) about selection of inputs and their optimal use. This in turn has the implication, that since education does not contribute very much to agricultural productivity, the claim on education by farm people can wait until agriculture becomes more complex and productive.

For purposes of this paper Welch's study seems to be directly relevant. Welch distinguishes three distinct kinds of effects which constitute the productive value of education. The first, the "worker effect", is the result of better job performance resulting from increased education; education may simply permit a worker to accomplish more with given resources. Then there are effects associated with an enhancement of a worker's allocative ability corresponding to increases in his education. The increased allocative ability enables the farmer to make better decisions regarding selection of inputs (including the new ones) and regarding their efficient allocation between competing uses. These two effects are grouped together as the "allocative effect". Welch argues that the "allocative effect" is more important in agriculture than the "worker effect" and states: "Agriculture is probably atypical in as much as a large share of the productive value of education may refer to allocative ability than in most industries."[16] Thus the key to the productive value of education in a technically advancing agriculture lies in the education-induced abilities of the farm people to evaluate and incorporate new and improved technical inputs more effectively.

In order to make Welch's[17] model operational by including education as a variable in production function estimates and to distinguish its role, consideration of three different agricultural production relations is necessary. This consideration will help us to understand how education contributes to agricultural productivity.

Consider three production functions for a simple farm

$$(1) \quad Q = q(X,E),$$

$$(2) \quad G = g(X,E) \text{ and}$$

$$(3) \quad V = v(Z,E),$$

where Q is the physical output of a single commodity, G is aggregate value of gross sales from all commodities produced by the farm, V is value-added by some subset of farm supplied inputs Z(Z is a subset of X), X is an input vector including Z, and E is an index of education.

In an engineering type function describing production of a single commodity there is no role for allocative ability to function. The effect of education is related only to the complexity of the physical production process. A more educated worker can simply produce a higher level of output from a given level of inputs In production function (1), therefore, the marginal product of education dq/dE is marginal product as normally defined holding other input quantities constant and is called the "worker effect". This is, however, as Welch argues, not all that education contributes to output. Education may add to the ability of a worker to better interpret economic and technical information pertaining to the new factors of production and thus enable him to make a more efficient selection and allocation of these factors.[18]

In case of production function (2), G is the gross sales value of all commodities produced by a multi-enterprise farm and commodities in turn are functions of input vector X. Maximization of G requires that the value of marginal product of X be equal in all its competing uses. If we suppose that allocation of X among competing uses is a function of education and that education also improves technical efficiency of various production relations, the marginal product of education from (2) would include returns to allocative ability as well as the "worker effect" from (1).

In case of a value-added production function (3), physical output of each commodity is a function of the purchased inputs M which is a subset of input vector X and the farm supplied inputs Z another subset of input vector X. Value added V is expressed as the difference between gross sales from all commodities G and the total cost of the purchased inputs M. But again suppose that the quantities of M purchased are functions of education and that education also improves the technical efficiency of various production processes and allocation of X among competing uses. if then, a value-added production function (3) is estimated which specifies only farm supplied inputs Z and education E, and from which purchased inputs M are excluded, the return to education would include the effects of selecting the right quantities of M in addition to the "worker effect" and the "allocative effect".

Thus if a value-added production function for multi-enterprise farms is estimated, the marginal product of education includes all three effects, that is, the worker effect, the effect of allocating inputs among competing uses, and the effect of selecting the right quantities of purchased inputs. A production function of gross sales of multi-enterprise farms includes the "worker effect" and the effect of input allocation. Single commodity engineering-type production functions include only the "worker effect".

Welch carries out an empirical test of his hypothesis for a technically advanced and highly dynamic agriculture. His results support the view that in a dynamic agriculture education-induced ability enables the farmer to make better allocation and selection of inputs and plays the dominant role in determining the productive value of education. Huffman and Khaldi's papers provide further empirical support for these results in the case of U.S. agriculture.

In this paper, this hypothesis is tested for an agriculture (in the Indian State of Punjab) which has only recently started to modernize and is less dynamic than agriculture in the United States. Results of this analysis presented subsequently seem to support the hypothesis in this less dynamic setting as well, in spite of only a meager amount of education of about 2.6 years of schooling per adult household member. It seems that education starts to make considerable impact on agricultural productivity as the process of modernization of agriculture starts and the supply of new and technically superior inputs and production processes starts to appear on the scene. This seems to have important implications for educational policies of the developing countries.

III. EMPIRICAL TEST. The investigation in this study is based on micro (farm level) cross-sectional data for the Indian Punjab for 1967/68, 1968/69 and 1970/71. During this period Punjab agriculture was undergoing a rapid transition. The introduction of Mexican varieties of wheat led to the use of modern inputs such as fertilizers, pesticides, and numerous types of machinery and equipment (for example, irrigation tubewells, diesel engines for pumps, electric motors, tractors, threshers and planters, etc) which increased rather phenomenally during this period. This was the beginning of the "green revolution"[19] which marked the start of the process of modernization. This rapid change added greatly to the complexity of Punjab agriculture,[20] an agriculture already complex because of its multi-enterprise nature. The stage thus seemed to have been set for education to play a more productive role in agriculture.

The Data Sources. The data used in this investigation came from two different samples. For the years 1967/68 and 1968/69, the data pertain to Ferozepur district of Punjab. These data were collected by the Directorate of Economics and Statistics (Ministry of Food and Agriculture, Government of India) on 150 farms spread over 15 villages in the district. For the year 1970/71, the data pertain only to wheat, and were collected over four different locations in Punjab under the supervision of this author. All data are micro (farm level) cross-sectional data.

Regression Estimates. Production functions (1), (2), and (3) are estimated by ordinary least squares regression techniques. The random disturbance term in each case is assumed to be independently distritued with zero mean and finite variance. Use of single equation models for estimating agricultural production functions has been justified by several important authors. For example, Griliches,[21] Mundlak and Hoch,[22] and Zellner, Kmenta and Dreze,[23] all argue that because inputs in agriculture are largely predetermined due to a considerable lag in production and because error is largely weather-determined, simultaneous equation bias will be small for well-specified production functions. The production environment in the present study seems to meet the specification requirements postulated by the above writers. Equations (1), (2) and (3) are thus estimated by the application of ordinary least squares.

In Tables 1a and 1b, regression estimates for a production function for a single commodity (wheat) represented by equation (1) are presented. Dependent variable is quantity of wheat produced per farm measured in physical units. In Table 1a all four regressions pertain to year 1967/68 and include both the old and Mexican varieties of wheat. In regressions I and III education is introduced as a separate variable compared to regressions II and IV from which education is excluded. In regressions I and II fertilizer is treated as a separate variable compared to regressions III and IV where it is included in capital. These different specifications were tried in order to test for any possible bias in the estimated coefficients. The estimated coefficient for education in regressions treating fertilizer as a separate variable or those including it in capital appears to be quite stable. Separate treatment of fertilizer, however, improves the estimated coefficient for labor considerably. In Table 1b all four regressions relate only to the Mexican varieties of wheat, and observations for two more years have been added. In the case of regressions I and II, in addition to treating fertilizer as a separate variable, animal power has also been separated from capital and treated as a separate variable. Again the estimated coefficient for education appears to be quite stable with slightly improved standard errors compared to those in Table 1a.

Table 1a

Estimates of Production Function for Wheat 1967/68, Ferozepur, Punjab, India, Including Education as a Separate Variable

(Dependent variable is wheat in physical units)

Number of observations = 236				
Independent Variables*	Regression Number			
	I	II	III	IV
1. Labor	0.163 (0.058)	0.163 (0.059)	0.102 (0.060)	0.099 (0.060)
2. Land	0.590 (0.050)	0.593 (0.060)	0.512 (0.061)	0.511 (0.061)
3. Capital	0.199 (0.071)	0.195 (0.071)		
4. Capital including fertilizer			0.444 (0.075)	0.449 (0.076)
5. Fertilizer	0.087 (0.016)	0.088 (0.016)		
6. Education	0.038 (0.020)		0.037 (0.020)	
7. Variety dummy variable (old wheat)	-0.185 (0 056)	-0.186 (0.056)	-0.218 (0.055)	-0.219 (0.056)
8. Intercept	0.639 (0.414)	0.698 (0.415)	-0.211 (0.441)	-0.195 (0.446)
R^2 (adj)	0.922	0.921	0.920	0.919

Note Standard errors of the coefficient estimates are in parentheses. Variables other than old wheat (a dummy variable) are in natural logarithms.

* See Appendix A for definition of variables.

Table 1b

Estimates of Production Function for Mexican Wheat 1967/68, 1968/69, and 1970/71, Punjab, India, Including Education as a Separate Variable

(Dependent variable is Mexican wheat in physical units)

Number of Observations = 369				
Independent Variables*	Regression Number			
	I	II	III	IV
1. Labor	0.245 (0.058)	0.237 (0.058)	0.207 (0.060)	0.199 (0.060)
2. Land	0.549 (0.059)	0.548 (0.059)	0.536 (0.059)	0.535 (0.059)
3. Capital			0.203 (0.059)	0.210 (0.060)
4. Capital excluding animal power	0.132 (0.045)	0.138 (0.045)		
5. Animal power	0.014 (0.014)	0.015 (0.014)		
6. Fertilizer	0.094 (0.021)	0.097 (0.021)	0.097 (0.021)	0.100 (0.021)
7. Education	0.036 (0.016)		0.035 (0.016)	
8. Year dummy variable, 1968/69	-0.292 (0.051)	-0.291 (0.051)	-0.299 (0.050)	-0.298 (0.050)
9. Year dummy variable, 1970/71	-0.142 (0.053)	-0.166 (0.052)	-0.162 (0.052)	-0.186 (0.051)
10. Intercept	0.005 (0.325)	0.045 (0.326)	-0.209 (0.344)	-0.174 (0.345)
R^2 (adj.)	0.924	0.923	0.925	0.924

Note: Standard errors of the coefficient estimates are in parentheses. Variables other than dummy variables are in natural logarithms. Animal power when not included in capital is also measured in value terms as a flow of bullock services used for wheat production

* See Appendix A for definition of variables

Table 2

Estimates of Productions Functions for Aggregate Output and Value Added, 1968/69, Ferozepur, Punjab, India, Including Education as a Separate Variable.

Independent Variables*	Number of Observations = 132					
	Dependent Variables				Means of Independent Variables	
	Aggregate output		Value-added			
	I	II	III	IV	Arithmetic	Geometric
1. Labor (Adult)			0.273 (0.179)	0.378 (0.188)	5.19	4.62
2. Labor bill	0.388 (0.067)	0.415 (0.068)			5787.86	5014.80
3. Land			0.035 (0 154)	0.854 (0 160)	12.60	10 17
4. Land rent	0.347 (0.048)	0.337 (0.048)			6338.87	4818 40
5. Capital	0.295 (0 065)	0 274 (0.066)			10658 00	9050.10
6. Fertilizer	0 036 (0.016)	0.036 (0.016)			1366.45	640 00
7. Irrigation	0.109 (0.078)	0.127 (0.079)			0.88	0.85
8. Education		0.028 (0.015)		0.125 (0.075)	2.60	1 54
9. Dummy variable (Tractor)	0.230 (0.055)	0.234 (0.055)	0.502 (0.248)	0.508 (0.246)		
10. Dummy variable (Zone 2)	0.305 (0.055)	0.311 (0.055)	0.640 (0.244)	0 691 (0.244)		
11. Dummy variable (Zone 3)	0.318 (0.257)	0.327 (0 257)	0.557 (0.247)	0.622 (0.249)		
12. Intercept	0.328 (0.396)	0.330 (0.393)	5.373 (0.384)	5.299 (0.384)		
R^2 (adj.)	0.907	0.909	0.422	0.431		

Note: Standard errors of the coefficient estimates are in parentheses. Variables other than dummy variables are in natural logarithms. Means of aggregate output and value-added are as follows·

	Arithmetic mean Rupees	Geometric mean Rupees
Aggregate output	22538.99	17496.00
Value-added	8905 .67	5150.80

* See Appendix B for definition of variables.

Regressions in Table 2 present estimates for equations (2) and (3). Regressions I and II are the estimates of production functions represented by equation (2) for multi-commodity farms with gross sales as the dependent variable. And regressions III and IV are the estimates of production functions represented by equation (3) for the same set of multi-commodity farms with value-added as the dependent variable. In all cases the estimated coefficients for education are significantly different from zero at the 95 percent level using one-tailed t test.

The estimated coefficients for education from these regressions are smaller than 0.4 estimated by Hayami in an intercountry study.[24] In part this could perhaps be because agriculture at the international level is much more diversified and complex compared to the sample studied in this paper. But the importance of a factor of production cannot be judged merely from the size of its estimated coefficient. One has to consider its marginal productivity.

Marginal value products for the three types of production functions (1), (2) and (3) are presented in Table 3. Since the average household has 2.60 years of education per adult household member, the yearly return to education per household member is 2.60 times the marginal value product of education — assuming that marginal and average products are equal. These yearly returns for all three types of production functions are also presented in Table 3.

Table 3

Marginal Value Products and Yearly Returns to Education, 1968/69, Ferozepur, Punjab, India

Production Function	Marginal value product of Education* (Calculated at geometric means) (Rupees)	Yearly Return** for an Average Household member with 2.60 years of education. (Rupees)
1-Single commodity[a] (Wheat)	66.50	172 90
2-Gross sales	323.60	841.40
3-Value-added	418.50[b]	1088.10

* Measured as average number of years of schooling per adult household member.

** Yearly return figures are computed with the assumption that average and marginal products of education are equal. Actually the average product should be higher than the marginal product. These figures thus may be underestimated.

a. Regression I, Table 1b

b. Marginal value products for family labor (adult man years) and land (hectares), the two farm supplied inputs are rupees 421.28 and rupees 432.55 respectively.

Three conclusions seem to emerge from these results. First, education of farm people in Punjab does contribute significantly to agricultural production. The small amount of average schooling per adult household member (2.60 years) appears to be an important factor of production. The estimate of rupees 418.50 as marginal value product is not small. It is almost as large as marginal value products for an hectare of farm-owned land and an adult man-year of family labor. Suppose that the productive value of education of the average adult household member remains constant over his working life (which we assume to be 50 years) such that the yearly earnings of rupees 1088.10 per adult household member will remain constant over his productive life of 50 years. With these assumptions and discount rates of 5 percent and 10 percent, the capitalized value of 2.60 years of education for an average household member are rupees 19,869 and rupees 10,772 respectively.

Second, the pattern of marginal value products for the three production functions seems to support the hypothesis that "In agriculture, differences in job complexity associated with differences in education are less noticeable, and the product of education is more likely to be associated with allocative efficiency."[25] The marginal value product from the value-added production function is about seven times the marginal value product from the single-commodity, engineering-type production function It should be pointed out, however, that the wheat production function (1) in this paper, should more appropriately be labelled as single enterprise function rather than engineering function. As such the marginal value product from this function cannot strictly be interpreted as "worker effect". There are allocative decisions involved in the production of wheat crop. The marginal product from (1) thus has broader implications than simply as a "worker effect". The true "worker effect" of education in agriculture may perhaps be much smaller than indicated in Table 3. Estimates for the value-added production function (3) are obtained with the assumption that profit maximizing conditions hold for the purchased inputs. Since purchased (new) inputs were being rapidly adopted during the period of this investigation, it is quite probable that the marginal value products for them were above their prices. The education variable may thus be picking up this "gap" from the value-added production function with the result that the estimated marginal value product may be somewhat overestimated.

Third, it seems that education as a factor of production starts contributing to agricultural production at a fairly early stage of the modernization process. The complexity of Punjab agriculture because of its diversified nature aside, the process of modernization started only recently.

IV. IMPLICATIONS FOR AGRICULTURAL DEVELOPMENT. In planning growth most developing countries are replacing the doctrine of "industrial development to precede agricultural development" with an increased realization of the importance of agricultural productivity growth for over-all economic growth. What is important for economic development is interaction and interdependence between agriculture and industry, rather than the question of the primacy of agriculture or industry. It cannot be emphasized too strongly that agriculture has a substantial potential for contributing to economic growth. Current world food shortages and prices of agricultural commodities are underscoring the importance of agriculture. Contribution of agriculture to economic growth, however, has not been the direct concern of this paper. Here, the major purpose is to understand better the process of agricultural development and the importance of education in this process.

One may ask: Why are agricultures in developing countries not modnizing more rapidly? Why do many of them remain backward? Is it due to the perverse behavior of farmers in poor countries? This seems to be the implicit view of those who use exhortations and threats to persuade farmers to produce more. The notion of perverse behavior of farmers, however, seems not to be substantiated by evidence. On the contrary considerable literature has appeared which supports the opposite notion. What, then, are the reasons for underdevelopment of agriculture in the less developed countries?

It could be argued that it is the lack of availability of cheaper and high-productivity modern factors of production which holds back the development of agriculture in the developing countries. Profitability and availability of these modern factors of production provides the key for the start of the modernization process and it is their continued supply which maintains its momentum. In the case of most developing countries, these superior factors of production, however, are not readily available.

Basically the supply of new inputs is the result of application of advances in sciences to their production through research and low cost industrial technology. This process of research and production, however, involves substantial costs. Hayami and Ruttan have argued that "Agricultural technology is highly 'location specific' and the techniques developed in advanced countries are not, in most cases, directly transferable to less developed countries with different climates and different resource endowments."[26] In an international perspective of agricultural development they also bring out the fact that in most economies which have achieved a high rate of growth in agricultural production and productivity, substantial volumes of resources were invested in public sector agricultural research, educational and infrastructural improvement supportive of technical change in agriculture.[27] Availability of new superior inputs evolved through adaptive research, is the first step in modernizing a traditional agriculture.

As the introduction of modern inputs proceeds, an agriculture which is otherwise static and characterized by low productivity becomes more dynamic and increases in its complexity. Farm people now become involved in acquiring, decoding information, and adopting and learning efficient ways of using modern inputs. Lack of schooling, in addition to poor economic incentives, may impose severe constraints on modernization.[28] Larger time lags are required in assimilating the new farming skills and inputs in their selection and allocation, as a consequence of low level of schooling.[29] Interactions among dynamic complexity of agriculture, economic growth and education, thus, increase demand for education in agriculture.[30]

Results of this investigation seem to support the view that when a low-productivity agriculture embarks upon the process of modernization, elementary education of farm people becomes an important factor of production. The main contribution of education in production is in the enhancement of the allocative ability of the farmer. Primary education in most developing countries could be managed at relatively low costs because of the low opportunity costs involved. Investments in this level of education should yield relatively high rates of return. Evidence from advanced agricultures indicates high rates of return to elementary education and thus supports this view.

In the case of sparsely populated countries like Tanzania (and several other African countries), however, where farm population in many cases lives scattered over vast distances, costs associated with primary education may be quite high. This would be even more true in farming situations where farm youth start working at an early age. For example, it is not uncommon that children of cattle-herding populations start working at an early age of seven - eight years, which is the age when they are supposed to enter school. Substantial earnings foregone during the period of schooling in such cases raise the costs of primary education. But it seems reasonable to argue that, in view of the substantial contribution of a small amount of education to agricultural production in the sample studied (almost as high as that of the raw labor and agricultural land), educational policy in the developing countries should consider investments in primary education as a priority item. The strategy would also have a built-in mechanism for a more egalitarian income distribution over time.

Appendix A

Definition of Variables in Tables 1a and 1b

Labor - labor is the total input of labor per farm used for wheat production measured in hours, and includes both family and hired labor. Child and female labor was converted into man equivalents by treating two children (or women) equal to one man.

Land - land is measured as acres of wheat grown per farm.

Capital - capital is a measure of the flow of capital services going into wheat production per farm. (An hourly flow of services is derived for each durable input including capital in the form of livestock that the farm uses in wheat production. It includes depreciation charges, interest charges, and operating expenses. Depreciation schedules are based on the specific life of each input, but interest costs are estimated at a uniform interest rate of 10 percent per annum. The actual number of hours of use times the hourly flow of services of each durable input gives its total service flow. Aggregation of these asset-specific service flows plus the seed costs yields a measure of the capital services.)

Fertilizer - fertilizer input is measured as the current value in rupees of artificial fertilizer and farm-produced manures per farm.

Education - education is the index of education per farm household. It is obtained by dividing the sum of years of schooling of adult members (older than 13 years) by their number. Managerial decisions on Punjab farms are made jointly by the family. In general all adult members of the family engage in some type of farm work and participate in the decision making process. Some members may influence the decision making process more heavily than others, but decisions are not made by a single individual For this reason an index of education measured as the average number of years of schooling per adult household member is considered a better measure of education compared to the number of years of schooling of the head of the household. Preliminary regression estimates also provided better coefficient estimates for education when it was measured as an average index of schooling per adult household member

Variety dummy variable - it is a dummy variable with value of one for old wheat and zero for Mexican wheat. It is intended to capture differences in technical efficiency parameter of the production function due to differences in old and Mexican varieties of wheat.

Year dummy variables for 1968/69 and 1970/71 - these are 0-1 variables intended to capture the weather related differences in the technical efficiency parameter of the production function.

Appendix B

Definition of Variables in Table 2

Labor (Adult) - labor is the farm-supplied input of labor measured as number of adults (older than 13 years) per farm.

Labor bill - labor bill measured as rupees per farm includes payments to labor hired on daily wage basis and annual contract basis as well as the imputed value of services of family labor

Land - land measured in hectares refers only to the owned land.

Land rent - land rent refers to the total rental value of land services in rupees per farm. It includes the actual rent paid in cash or share of the produce, imputed rental value of and tax of owned land.

Capital - capital is the flow of capital services in rupees per farm as defined in Appendix A.

Fertilizer - fertilizer refers to the current value in rupees of artificial fertilizer and farm-produced manure per farm.

Irrigation - irrigation is measured as percent of irrigated land per farm.

Education - as defined in Appendix A.

Dummy variable - these three 0-1 variables are intended to capture differences in the technical efficiency parameter of the production function. The variables are: (1) values of one for tractor-operated farms and zero elsewhere, (2) values of one for farms in zone 2 and zero elsewhere, (3) values of one for farms in zone 3 and zero elsewhere. The two zonal dummy variables were necessary because the sample was stratified into three zones based on soil and climatic differences.

Aggregate output - aggregate output is the total value in rupees per farm of all commodities produced during the year. It includes value of livestock products.

Value-added - value-added in rupees per farm is obtained by subtracting from aggregate output value all yearly expenses related to all variables other than family labor and owned land, the two farm-supplied inputs.

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1. For an economic perspective of traditional agriculture and its modernization process see Theodore W. Schultz, Transforming Traditional Agriculture, Yale University Press, New Haven 1964. Also see Theodore W. Schultz, "The Education of Farm People: An Economic Perspective," University of Chicago, Human Capital Paper 72 2 (March 15, 1972), which constitutes the basic source for the development of subsequent thought and discussion in the first section of this paper in relation to the role and importance of education of farm people in the agricultural transformation process. For this, I am indebted to Professor Schultz.

2. Schultz, "The Education of Farm People," p. 6, already cited.

3. See Yujiro Hayami and Vernon W. Ruttan, Agricultural Development An International Perspective (Baltimore: The John Hopkins Press, 1971) p. 54 for similar ideas. They stress the importance of efficient technological choices consistent with a country's resource endowments to guide its development path to achieve a rapid rate of growth in agricultural productivity and output.

4. Finis Welch, "Education in Production," Journal of Political Economy, 78, 1970, pp. 35-59.

5. In the advanced countries an awareness of insufficiency of the educational effort for farm people is increasing rapidly. It was during the early 1960's that agricultural economics professions began to show some consciousness for the need to investigate this area. See for example, Lee R Martin, "Research Needed on the Contribution of Human, Social and Community Capital to Economic Growth," Journal of Farm Economics, 45, February 1963. Here I do not, however wish to imply that the useful consumer abilities to which also, of course, education contributes abundantly, are not important for farm people. Education indeed has value for farm people in numerous other ways than increasing their productive abilities.

6. Schultz, Transforming Traditional Agriculture, already cited, pp. 29-54.

7. Welch, already cited.

8. Pan A. Yotopoulos, "On the Efficiency of Resource Utilization in Subsistance Agriculture," Food Research Institute Studies in Agricultural Economics, Trade and Development, Vol. VIII, No. 2, 1968, Stanford University, Stanford, California.

9. Dharam Pal Chaudhri, "Farmers Education and Productivity: Some Empirical Results from Indian Agriculture," Department of Economics, University of Chicago, Human Capital Paper, 69: 4, 1969.

10. Yujiro Hayami, "Sources of Agricultural Productivity Gap Among Selected Countries," Am. J. Agr. Econ., 51· 546-575, August 1969.

11. Welch, already cited.

12. Robert W. Herdt, "Resource Productivity in Indian Agriculture," Am. J. Agr. Econ., 53. 517-521, August 1971.

13. Wallace E. Huffman, "Decision Making· The Role of Education," Am. J. Agr. Econ., 56: 85-97, February 1974.

14. Nabil Khaldi, "Education and Allocative Efficiency in United States Agriculture," Am. J. Agr. Econ., 57 650-657, November 1975.

15. That is, a traditional agriculture defined by Schultz, Transforming Traditional Agriculture, already cited, pp. 29-54.

16. Welch, already cited.

17. Ibid.

18. Education may also enhance the effective participation of farm people in the continuing evolution of economic institutions and in the progress in production technology. This has implications for increasing the productivity in the overall agricultural system.

19. For a quantitative assesment of the "green revolution" see my papers, "Economics of Technical Change in Wheat Production in the Indian Punjab," Am. J. Agr. Econ., May 1974, pp. 217-226 and, "Relative Efficiency in Wheat Production in the Indian Punjab," Am. Econ. Rev., September 1974 742-751.

20. It would, however, be quite erroneous to think that Punjab agriculture prior to the introduction of Mexican varieties of wheat was completely static. On the contrary, a stream of improved crop varieties which continued to be provided to the peasantry started quite early during the twentieth century. An excellent discussion of the early pioneering efforts in this respect is provided by William Roberts and S.B.S Kartar Singh, A Text Book of Punjab Agriculture (Lahore: Civil Military Gazett, 1947). The point to be emphasised, however, is the low level of absolute profitability and the low rate

at which improved innovations were generated and supplied to the farmers. These innovations and the complementary supply of modern inputs were not crowding in on the farmers in the same sense as they were in the advanced agricultures particularly after the second world war. Punjab agriculture thus even during the late 1960's was technically much less dynamic and at a much lower level of productivity than many advance agricultures.

21. Zvi Griliches, "Specification Bias in Estimates of Production Functions," J. Farm Econ. 39: 8-20, February 1957.

22. Yair Mundlack and Irving Hoch, "Consequences of Alternative Specifications in Estimation of Cobb-Douglas Production Functions," Econometrica 3: 814-828, October 1965.

23. Arnold Zellner, J. Kmenta, and J. Dreze, "Specification and Estimation of Cobb-Douglas Production Function Models," Econometrica 34 784-795, October 1966.

24. Hayami, already cited.

25. Welch, already cited.

26 Hayami and Ruttan, already cited, p. 39.

27. Ibid.

28. Schultz, Ibid.

29. Huffman, already cited, concludes that the rate of adjustment of Midwestern U.S. farmers to the changing optimum quantity of nitrogen in corn production is positively related to education of farmers.

30. Schultz, Ibid.