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Dean T. Jamison and Peter R. Moock

Farmer Education and Farm Efficiency in Nepal

The Role of Schooling, Extension Services, and Cognitive Skills

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Farmer Education and Farm Efficiency in Nepal: The Role of Schooling, Extension Services, and Cognitive Skills

DEAN T. JAMISON and PETER R. MOOCK
The World Bank, Washington, D.C.

Summary. – This study uses data from Nepal to ascertain the relation between education and farmer efficiency. It finds a positive effect of education on efficiency for three major crops, but only with the recently introduced wheat crop is the effect statistically significant at standard levels. The data provide no evidence that education's effects should be attributed, even in part, to family background correlates or to a measure of ability. Among the cognitive outcomes of education, numeracy is found to affect productivity in wheat production (as well as the propensity to be growing wheat at all). Measures of farmer modernity and agricultural knowledge are not found to be correlated with farm efficiency. Calculations from the results suggest that a one-standard-deviation improvement in the numeracy test score has a present value that is high relative to the probable cost of effecting such an improvement.

1. INTRODUCTION

Our purpose in this paper is to examine the extent to which the cognitive outcomes of education mediate between the education that individuals receive and their subsequent efficiency as farm operators. The data for testing aspects of this causal association were obtained in the Terai region of Nepal as part of a larger study into the determinants and consequences of both formal education (schooling) and nonformal education (extension services) in rural, low-income settings.

Our paper on education and agricultural efficiency follows up a monograph on this subject that reviews the empirical literature in this area through 1978, develops a consistent and thorough theoretical framework for examining the role of education in production, and tests a number of major hypotheses concerning education's effects on agricultural efficiency using earlier data sets from Thailand, Korea and Malaysia (Jamison and Lau, 1982). Although the data set we collected for this paper lacks the inter-farm price variation that would have enabled us to investigate the impact of education on allocative efficiency,[1] the household-level data set was designed to include previously overlooked variables that can be used to extend our understanding of and increase our confidence in the relation between education and efficiency in production. In particular, the data set includes information both on the background of the farm operators and on several dimensions of their cognitive skill. This allows us to assess empirically the extent to which variables associated with education may be responsible for its apparent effect on efficiency and to assess (in a preliminary way) the extent to which specific outcomes of education are responsible for its effects.

The paper is organized into four principal

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sections. In the introduction we present an overview of the links between education and efficiency and indicate the gaps in the existing empirical literature. The second section describes our data set. In the third and fourth sections, we lay out the empirical analyses and discuss our substantive findings. The third section is an analysis of education and technical efficiency; the fourth is an analysis of the impact of education on the adoption of new crops and methods of production.

2. BACKGROUND

Education may have productive value both because it enables the manager of a firm to produce larger output quantities from the same measured quantities of inputs and because it helps the manager to allocate the firm's resources in a cost-efficient manner, choosing which outputs to produce, how much of each output to produce, and in what proportions to use inputs in the production of any output. In other words, education may enhance both technical efficiency and allocative efficiency in production. Welch (1970) labels these the 'worker' and 'allocative' effects of education. The first is simply 'the marginal product of education as marginal product is normally defined, that is, it is the increased output per change in education, holding other factor quantities constant'; the second has to do with the manager's 'ability to acquire and decode information about costs and productive characteristics of other inputs' (Welch, 1970, p. 342).

Economists often assess the economic benefits of education in wage employment by observing the correlation between education and the earnings that workers receive. The literature documenting and interpreting this correlation has proliferated over the two-decade period since T. W. Schultz, in his presidential address to the American Economics Association, reintroduced the concept of human capital and urged members of the profession to pursue this field of inquiry (Schultz, 1961).[2] Outside the wage sector, education's value in production becomes more difficult to assess. In a study of family consumption patterns, Michael (1972) has attempted to show that education raises an individual's 'full income' even when money income remains the same. It does so, he argues, by increasing the productivity of time spent in household production.[3] Recently, a few economists have turned their attention to the productive effects of education for the self-employed.

Since a self-employed individual receives no 'wage' as such, some of this research has sought to estimate education's marginal product (the 'worker effect') directly by means of a production function analysis. This procedure has an advantage over one that relies on market wages in that no assumption need be made about the equivalence of wages and the marginal product of labour. Though this procedure could, in principle, be used to estimate education's effect in any sector, most of the research to date has focused on agriculture and, within agriculture, especially on crop production.[4] Other economists have concentrated on the allocative effects of education. For reasons of data availability, most of this research has made use of aggregated information (at the district, state, or national level), and again, the preponderance of it has focused on agricultural production.[5] An aspect of allocative efficiency is the willingness of individuals to adopt profitable new technologies. A vast sociological literature exists on the diffusion of innovation.[6] Nearly all of the studies on this subject look at education as one factor determining or accelerating an individual's decision to adopt an innovation.

One interpretation, favoured by many economists (and most educators), of the correlation between education and *earnings* is that education functions to enhance the productive capacity of workers and allocative capacity of managers. An alternative interpretation, known as the 'screening hypothesis', says that education does not *make* workers more productive; it merely identifies those who were more productive to begin with. According to this hypothesis, education signals productive ability to employers without actually affecting it.[7]

In one sense, the screening hypothesis is not relevant to self-employment. In self-employment, by definition, there is no separation between employer and employee, and no need for signals concerning the employee's ability. For research purposes, however, the screening hypothesis is every bit as relevant to self-employment as it is to wage employment. In empirical studies that seek to estimate the *causal* impact of education on production, without direct measures of other background factors that shape productive capacity, education may serve as a proxy for these factors, and these studies may lead to erroneous conclusions.

Most of the previous studies on education in farm production have failed to include measures of family background. Hence, they are open to the interpretation that the reported results provide an upwardly biased estimate of education's impact. In this study, we try to control for family background by including measures of the farmer's childhood socioeconomic status. With these measures in the analysis, we can, with some confidence, claim that any statistical effects of education on productive efficiency are, indeed, causal effects.

Another question inadequately addressed in previous studies has to do with the intermediate outcomes between education and production. Through which of its outcomes does education have whatever effects it does, in fact, have on productive behaviour? Bowman (1976a) has argued that the effects of education relevant to the small farmer may be categorized under two major headings, 'formation of competences' and 'transmission of information'. The formation of basic competences (e.g. literacy, numeracy, abstract reasoning ability) is a primary responsibility of the school system. The transmission of information (on prices and technology), which may require frequent updating as old information becomes obsolete, can be accomplished through a variety of channels including the extension services. This study examines several cognitive achievement measures in an attempt to ascertain the important mediating variables between education and productive efficiency. Figure 1 illustrates the plan of the study, which essentially organizes the determinants of productive efficiency into four broad categories: (i) family background, (ii) education, (iii) the mediating achievement variables just referred to and (iv) current socioeconomic status.

3. THE DATA

The data for the analyses reported in this paper were obtained from a survey of rural households in two of Nepal's 75 administrative districts.[8] The districts, Bara and Rautahat, are located in the Nepal Terai. In simple terms, Nepal is divided into three ecological zones running in parallel strips from east to west. The northernmost zone, which straddles the border between Nepal and China (Tibet), consists of the Himalayan Range. The middle zone, which includes Kathmandu and the Kathmandu Valley, is known as the Hill Region. It ranges in altitude from 1000 to 4000 m. The Terai to the south is a flat, fertile area straddling the border between the hill regions of Nepal and the Indian States of Bihar and Uttar Pradesh. The inhabitants of the Terai on the two sides of the Indian–Nepalese border share many cultural and economic characteristics. The people are primarily agrarian. Although the Nepal Terai comprises less than a third of the country's land area and accounts for only about 40% of the population, it produces well over half the country's agricultural output, exporting surplus rice and other cash crops both internally within Nepal and internationally, primarily to India.

Our sample is a two-stage random sample of households in six panchayats of Bara (out of 109 panchayats in the district) and six panchayats of Rautahat (out of 132). Lists of owners of all dwellings in the twelve panchayats were obtained from the local rural health workers.[9] Then, using a three-digit random number table obtained from the

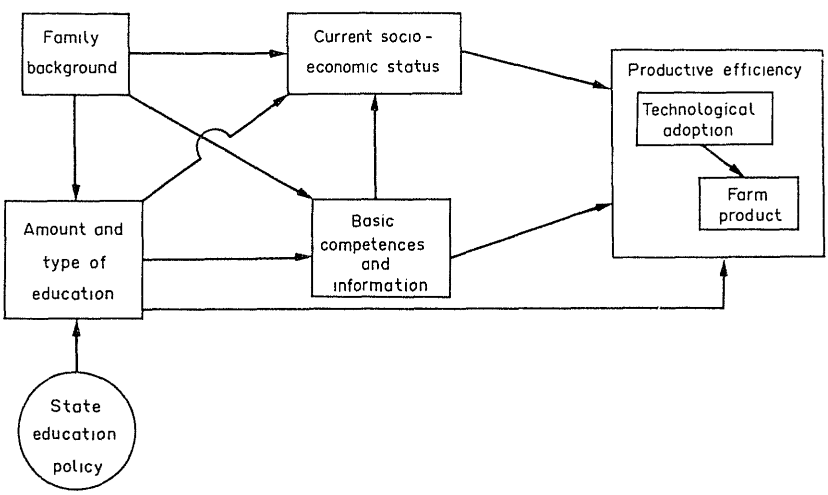

Figure 1. *Schematic model of education's impact on productive efficiency.*

Nepal Central Bureau of Statistics, households to be interviewed were selected randomly within panchayats until a 15% sample of households had been chosen in each of the twelve panchayats. (Ten extra households per panchayat were selected for replacement of households lost through sample attrition.)[10]

The survey instruments included questions on household production, family health and fertility, farmer education and competences, and general household characteristics. In this paper, we do not address the health and fertility variables.[11] We restrict our attention to agricultural production and more especially to the impact of education on technical efficiency and adoptive behaviour. The production data cover the 1977–78 agricultural year (from monsoon to monsoon) and relate to the three principal crops of the sample area – early paddy, late paddy, and wheat. The study households were visited three times, first in October–November 1977, next in January–February 1978 and finally in April–May 1978. Field workers for the interviewing were recruited in the field, at Birgunj (zonal headquarters of Narayani Zone) and Guar (district headquarters of Rautahat). The final field team comprised seven males and seven females, who worked in pairs. All the field workers had graduated from secondary school and spoke both Nepali (the language in which the instruments were written) and Bhojpuri (the language of most of the respondents). Nepali and Bhojpuri are closely related languages of the Indo-Aryan group, and the questions were translated from Nepali to Bhojpuri in the field.

The initial sample consisted of 792 households. However, after eliminating landless households, landed households that grew none of the three major crops in 1977–78 and households missed in any of the three rounds of data collection, we are left with a maximal sample size of 683. All of the household heads in this sample are male and live at home. Table 1 describes the variables used in the empirical analyses and presents their means and standard deviations.

(a) *Agricultural data*

Most (659) of the 683 households grew early paddy in 1977–78, whereas only 397 and 484 grew late paddy and wheat respectively. A smaller number of cases for any particular variable in Table 1 reflects missing information in the data set.[12] So that the reader may assess the extent of any selection bias induced by these missing data, descriptive statistics for each of the analytic subsamples will be presented in the analysis sections of the paper.

Of the 683 households in our sample, 22% cultivated just one of the three major crops in 1977–78; 35% just two; and 43% all three. Table 1 indicates that the average paddy crop, early or late, was larger (in hectares planted) than the average wheat crop. It is worth noting at this point that paddy tends to be the more labour-intensive and wheat the more capital-intensive of the two crops. Whereas the average labour input per hectare cultivated was smaller for wheat than for paddy, the rates of animal use and chemical fertilizer use were both higher. The paddy yields in our sample was 654 kg/ha for early paddy and 817 kg/ha for late paddy. A farmer double-cropping with these yields would have obtained an annual output of 1471 kg/ha, which compares quite unfavourably both with the national average yield in the preceding (1976–77) crop year of 1890 kg/ha and with the 1977–79 average for all developing countries of 2102 kg/ha. The lower yields for our sample may be explained by a drought that afflicted this area in the year of the survey. The drought ended with the onset of the 1978 monsoon. Wheat yields in our sample (at 995 kg/ha) were essentially the same as the national average of 1004 kg/ha, but far below the average for all developing countries of 1443 kg/ha.

(b) *Amount and type of education*

The educational indicators of primary interest for policy purposes are formal educational attainment and exposure to the government-provided extension services. The average school attainment of the farm heads in our sample is 1.19 yr (variable 11 in Table 1). School attainment will be handled here both as a quasi-continuous variable and, in collapsed form, as three indicator variables – never went to school (the omitted category), completed one-to-six years (variable 12), and completed seven or more years (variable 13). At one extreme, nearly 30% (544) of the 683 farm decision-makers never went to school; at the other, only 50 individuals (8%) have completed seven or more years of school. Of these 50 farmers, only 10 continued beyond the tenth year. Our choice of six years as a point at which to break the educational continuum reflects the structure of the educational system in Nepal, where the first-level of education, as defined by UNESCO, now comprises the first seven years of school.[13]

Table 1. *Variable definitions, means and standard deviations, all farms*

Variable		Mean	SD	Number
Early paddy (N = 659)				
EP 1	Output (kg)	517.17	632.48	638
EP 2	Area cultivated (ha)	0.92	2.07	656
EP 3	Labour input (person-days)	199.10	264.87	659
EP 4	Female labour (proportion)	0.29	0.12	659
EP 5	Hired labour (proportion)	0.55	0.32	659
EP 6	Animal input (ox-days)	30.96	51.88	654
EP 7	Chemical fertilizer (0,1)	0.09	0.28	638
Late paddy (N = 397)				
LP 1	Output (kg)	719.09	1275.69	384
LP 2	Area cultivated (ha)	1.00	1.40	397
LP 3	Labour input (person-days)	210.67	332.96	397
LP 4	Female labour (proportion)	0.31	0.11	397
LP 5	Hired labour (proportion)	0.53	0.30	397
LP 6	Animal input (ox-days)	33.25	45.47	395
LP 7	Chemical fertilizer (0,1)	0.09	0.28	384
Wheat (N = 484)				
W 1	Output (kg)	303.77	382.73	675
W 2	Area cultivated (ha)	0.32	0.34	484
W 3	Labour input (person-days)	51.35	39.56	484
W 4	Female labour (proportion)	0.09	0.10	484
W 5	Hired labour (proportion)	0.30	0.27	484
W 6	Animal input (ox-days)	13.21	12.47	483
W 7	Chemical fertilizer (0,1)	0.52	0.50	475
Technological adoption (N = 683)				
8	Chemical fertilizer (1 if used, 0 if not)	0.38	0.49	683
9	Wheat crop (1 if cultivated, 0 if not)	0.71	0.46	683
Other variables (N = 683)				
10	District (Bara = 1, Rautahat = 0)	0.48	0.50	683
11	School attainment (yr)*	1.19	2.74	683
12	1–6 yr of school completed (0,1)	0.13	0.34	683
13	7+ yr of school completed (0,1)	0.07	0.26	683
14	Recent contract with extension agent (0,1)	0.30	0.46	661
15	Households in panchayat with recent extension contact (proportion)	0.29	0.23	683
16	Age (yr/10)	4.37	1.37	683
17	Numeracy (0–14)	7.24	4.40	683
18	Literacy (0,1)	0.20	0.40	683
19	Raven's Progressive Matrices (RPM) score (0–36)	12.88	4.46	576
20	Agricultural knowledge test score (0–12)	6.64	2.37	579
21	'Modernity' index (1–7)	4.45	1.71	553
22	Father's landholding (ha/10)	0.30	0.56	608
23	Father's literacy (0,1)	0.11	0.31	681
24	Current landholding (ha)	1.39	2.42	682
25	Market value of house (Rs./1,000)	3.53	6.12	682
26	Grain storage facility on farm (0,1)	0.08	0.27	683
27	Occupation (farmer only = 0, other = 1)	0.12	0.33	683
28	Households in panchayat growing wheat (proportion)	0.70	0.10	683
29	Households in panchayat using chemical fertilizer (proportion)	0.24	0.11	683

*This and all subsequent individual-level variables refer to the household head.

Moreover, at an early stage in the data analysis, we ran simple breakdowns of crop yields by educational attainment, and these tended to support our decision to break the attainment variable at this point.

Of the 661 farmers answering the question, 30% report having been in recent contact with the government-run agricultural extension programme (variable 14). Other, more detailed indicators of extension contact are available in the data set, but these will not be discussed since, unfortunately, our analysis showed none to be any more successful in explaining either crop outputs or the adoption of new inputs than is the crude, contact/no-contact dichotomy. A second measure of extension exposure, this one of indirect exposure, is the proportion of households in the farmer's panchayat reporting contact with the extension services (variable 15). This is to say, a value for variable 15 equals the panchayat-wide average of values for variable 14, but any particular farmer's answer to the question underlying variable 14 (coded either '1' or '0') is necessarily either above or below the value for variable 15.

The sample households are divided almost evenly between Bara and Rautahat districts (variable 10). Households in the two districts differ significantly with respect to certain key variables. Bara holdings are, on average, smaller than Rautahat holdings, but Bara farmers report a much higher incidence of extension contact. The higher incidence of extension contact in Bara probably reflects the introduction there of the training-and-visit (T & V) system, which stresses message saturation and the communication of *appropriate* recommendations via specifically trained, single-purpose extension agents and carefully selected contact farmers.[14] To the extent that yields are higher in Bara than in Rautahat – other variables (including the incidence of extension contact) held constant – the difference may be due, at least in part, to the qualitative improvement in extension resulting from the introduction of T & V. The coefficient on variable 10 is, thus, also an indicator of extension impact.

A final educational characteristic that may be expected to affect productive efficiency is the farmer's work experience. One finds two experience indicators in Table 1, age (variable 16), a crude indicator of the *amount* of experience, and occupational status (variable 27), an indicator of the *type* of experience. The average age of the household heads in our sample is just under 44 yr. The ages range from 14 to 87. Most (88%) of the farmers in our sample have no employment other than work on the family farm. The remainder, in addition to farming, also have employment in the wage sector or run a nonfarm business.

(c) *Basic competences and information*

Variables 17 through 20 in Table 1 measure the farmer's numeracy, literacy, abstract reasoning ability and knowledge of the agricultural extension service's recommendations on cropping practices. These skills we view as the immediate outcomes of the farmer's family background and educational background, and as intermediate between these background variables and economic behaviour (see Figure 1).

A farmer's numeracy score (variable 17) is based on the answers he gave to 14 arithmetic problems posed by a member of the interview team during the course of the survey.[15] A farmer was rated as literate (variable 18) if he could write his own name and read aloud a simple sentence in Bhojpuri or Nepali. One farm head in five passed this literacy test, the same as the ratio of farmers who report having attended school. The zero-order correlation coefficient between variable 18 and a variable indicating whether or not the farmer ever went to school[16] is 0.96. The Raven's Progressive Matrices Test, an instrument containing 36 abstract reasoning problems and intended to be relatively language and culture independent (Raven, 1974), was used to measure reasoning ability (variable 19). [There is some evidence (e.g. Welland, 1981) that there are a number of dimensions of 'ability' that one should attempt to control for in estimating the impact of education and its outcomes on productivity; the Raven's score, however, is all that we have available.]

The survey team asked each farmer a number of questions relating to agriculture and agricultural practices. These were intended to reflect the individual's knowledge of the agricultural extension department and of its current recommendations to farmers in the area. The responses to the questions were rated as 'correct' or 'incorrect' and a selection of questions used to form an index of agricultural knowledge (variable 20).

Many researchers, in analysing observable differences in socioeconomic behaviour in developing areas, have considered the role of the individual's 'attitude towards change'. The hypothesis has been that an individual's psychological outlook can be measured along a continuum the poles of which may be labeled 'modern' and 'traditional' outlooks, and that observable behaviour is systematically related to this construct. In the design of the research project of which this study forms a part, it was decided to test this hypothesis in a rural sample. An index of modernity (variable 21) was derived from the farmer's responses to nine attitudinal questions adapted to Nepal from the short version (OM-12) of the Inkeles modernity instrument (Inkeles and Smith, 1974).

Certainly, attitudes may function as determinants of behaviour, but we must confess to some discomfort with the modernity concept. Nonetheless, we did try using variable 21 (the modernity index) in our analyses of crop production and technological adoption. Yet whenever this variable was found to have an effect, the effect was opposite in sign to what we *think* should have been predicted; that is, the effect was always negative. We are at a loss as to how to interpret this perverse finding. Given our discomfort over the construct itself and over the finding that 'modernity' is related negatively to productive efficiency, we have dropped this variable from the final analyses.

4. EDUCATION AND TECHNICAL EFFICIENCY

Technical efficiency refers to a firm's ability to produce on the industry's production frontier – to achieve the maximum output from a given bundle of physical inputs (land, labour and capital). Technical efficiency is an engineering concept rather than an economic one. In discussing technical efficiency, one does not consider the impact of prices on a firm's behaviour. A firm is more technically efficient than another firm whenever its production frontier is higher than the other's. Presumably, a firm that is more technically efficient than another possesses more information about the production process. For example, a technically efficient crop farmer possesses the best available information on the timing of inputs, handling of tools, spacing of plants – on all of the *techniques* of production not reflected in the metrics used to quantify physical inputs. To take into account differences in technical efficiency across firms (or over time), we can specify the production function so that it includes on the right hand side, in addition to measured physical inputs, if not measures of the techniques themselves, then measures of characteristics presumed to be linked to the use of these techniques. In this study, the proxies used include education and the cognitive outcomes of education. The production function reads

$$Y = f(X,E)$$

where Y is the quantity of output, X is a vector of physical inputs, and E is a vector of variables that characterize the particular firm. The parameters of f apply to all firms in the industry. Assuming a stochastic disturbance term uncorrelated with X and E permits us to estimate f (and hence the effects of E) by ordinary least squares. The regression equation is an estimate of the 'average' production function for the industry.

This section begins with a discussion of the functional form we use to model production and of the specific data available for this aspect of our analysis. It then reports our basic results and discusses their implications for calculating the economic benefits of improving school quality. The section concludes with results from exploration of alternative specifications of education's effect on efficiency.

(a) *Functional forms and data*

The functional form chosen for the production functions estimated here is a modification of the Cobb–Douglas production function:

$$Y = \alpha \prod_{i=1}^{m} X_i^{\beta_i} \prod_{i=1}^{n} e^{\gamma_i E_i}$$

or, in linear form,

$$\ln Y = \ln\alpha + \sum_{i=1}^{m} \beta_i \ln X_i + \sum_{i=1}^{n} \gamma_i E_i$$

in which α is an efficiency parameter and β_i the elasticity of output with respect to input X_i. The parameter γ_i ($= \partial \ln Y / \partial E_i$) may be interpreted as indicating the proportionate change in output that results when characteristic E_i (say, age) increases by one unit (a year).[17] If E_i is a 0–1 indicator variable rather than a continuous variable, then γ_i indicates the approximate proportionate difference between the output produced by a firm demonstrating this particular characteristic (say, contact with the extension services) and that produced by a firm not demonstrating this characteristic (no contact with the extension services). Specifications involving indicator variables and other nonlinear specifications are discussed at the end of this section. The restrictive implication of this specification is that the effect of any characteristic (E_i) on the production function is neutral, i.e. the effect is to shift the entire function. Alternative specifications whereby characteristics are permitted to augment the effects of physical inputs differentially have not yet been fully explored with this data set.[18]

The variables to be used in the production function analyses are listed in Table 2. The variable list is a subset of the variables in Table 1, and the descriptive statistics in any column are based on one of three subsamples of households. The number of households that grew early paddy and for which we have information on *all* of the variables in the variable list is 443 (out of 659 early paddy growers) or 67% of early paddy growers. The number in the case of late paddy is 284 (out of 397) or 72%; in the case of wheat, 343 (out of 484) or 71%. A comparison of Tables 1 and 2 shows that most variables differ little between the full sample and the three crop subsamples except for the fact that the farmers in the crop subsamples are, on average, somewhat more schooled than other farmers in this part of the Terai and somewhat more likely to have been in contact with the extension services.

(b) *Basic results*

The least-squares regression results are presented in Table 3.[19] For each crop, the variables are entered in three steps.[20] The physical inputs and educational background characteristics are entered first. Then, to distinguish the direct and indirect effects of education on crop outputs, we enter the farmer's competences and information in a second step. Although literacy belongs conceptually in this second block of variables, in practice we were forced to exclude it from all of our analyses. The correlation between educational attainment and this crudely measured, 0–1 indicator of reading and writing ability is so high (cf. p. 6) that, when both were included, the regression coefficients for variables 12, 13, and 18 were altogether unstable, fluctuating meaninglessly from equation to equation. The third block of variables consists of the two family background measures. The purpose of this final step is to assess the extent to which the regression coefficients for education and cognitive skills measure the

Table 2. *Means and standard deviations, crop subsamples*

Variable	Early paddy (N = 443)		Late paddy (N = 284)		Wheat (N = 343)	
	Mean	SD	Mean	SD	Mean	SD
1 Output (kg)	538.70	646.50	688.47	1,061.50	311.30	414.51
2 Area cultivated (ha)	1.02	2.45	0.96	1.23	0.33	0.36
3 Labour input (person-days)	210.54	254.30	210.11	319.19	52.97	41.51
4 Female labour (proportion)	0.29	0.12	0.31	0.11	0.09	0.10
5 Hired labour (proportion)	0.55	0.32	0.52	0.30	0.31	0.28
6 Animal input (ox-days)	33.27	55.79	32.58	42.43	13.53	12.72
7 Chemical fertilizer (0,1)	0.11	0.31	0.10	0.30	0.54	0.50
10 District (Bara = 1, Rautahat = 0)	0.49	0.50	0.49	0.50	0.52	0.50
11 School attainment (yr)	1.37	2.91	1.84	3.35	1.57	3.14
12 1–6 yr of school completed (0,1)	0.15	0.36	0.17	0.38	0.15	0.36
13 7+ yr of school completed (0,1)	0.08	0.28	0.12	0.33	0.11	0.31
14 Recent contact with extension agent (0,1)	0.33	0.47	0.33	0.47	0.34	0.47
15 Households in panchayat with recent extension contact (proportion)	0.30	0.23	0.30	0.23	0.31	0.23
16 Age (yr/10)	4.31	1.34	4.39	1.36	4.31	1.35
17 Numeracy (0–14)	8.62	3.36	8.96	3.46	8.91	3.28
18 Literacy (0,1)	0.23	0.42	0.30	0.46	0.26	0.44
19 Raven's Progressive Matrices (RPM) Score (0–36)	12.98	4.67	13.45	5.04	13.12	4.88
20 Agricultural knowledge test score (0–12)	6.60	2.34	6.67	2.44	6.74	2.33
22 Father's landholding (ha/10)	0.31	0.56	0.37	0.55	0.34	0.61
23 Father's literacy (0,1)	0.13	0.33	0.15	0.36	0.13	0.33
27 Occupation (farmer only = 0, other = 1)	0.12	0.32	0.07	0.26	0.12	0.32

Table 3. *Cobb–Douglas production function recessions*

Variable	Early paddy (N = 443) (EP1)	(EP2)	(EP3)	Late paddy (N = 284) (LP1)	(LP2)	(LP3)	Wheat (N = 343) (W1)	(W2)	(W3)
Constant	5.013	4.790	4.887	4.256	4.296	4.231	4.073	3.994	3.961
2 Area cultivated (ln-ha)	0.662	0.648	0.665	0.493	0.483	0.475	0.502	0.495	0.492
	(8.85)	(8.68)	(8.94)	(7.78)	(7.62)	(7.52)	(7.19)	(7.12)	(7.05)
3 Labour input (ln-person-days)	0.116	0.115	0.114	0.221	0.239	0.233	0.318	0.320	0.321
	(1.58)	(1.56)	(1.55)	(3.58)	(3.90)	(3.75)	(3.56)	(3.65)	(3.66)
4 Female labour (proportion)	0.425	0.416	0.410	−0.226		–	0.259	0.347	0.360
	(1.76)	(1.74)	(1.72)	(−0.77)	–		(0.93)	(1.22)	(1.27)
5 Hired labour (proportion)	−0.212	−0.228	−0.212	−0.009	–	–	−0.136	−0.145	−0.145
	(−2.17)	(−2.38)	(−2.21)	(−0.06)		–	(−1.27)	(−1.35)	(−1.33)
6 Animal input (ln-ox-days)	0.112	0.122	0.115	0.245	0.236	0.245	0.164	0.172	0.176
	(2.39)	(2.60)	(2.47)	(3.91)	(3.79)	(3.97)	(2.13)	(2.24)	(2.28)
7 Chemical fertilizer (0,1)	0.200	0.199	0.195	0.231	0.220	0.218	0.305	0.301	0.301
	(2.16)	(2.18)	(2.15)	(2.12)	(2.05)	(2.02)	(5.29)	(5.20)	(5.21)
10 District (Bara = 1, Rautahat = 0)	0.201	0.198	0.197	0.114	0.158	0.155	0.071	0.059	0.057
	(2.63)	(3.37)	(3.42)	(1.30)	(2.31)	(2.23)	(1.00)	(0.84)	(0.79)
12 1–6 yr of school completed (0,1)	0.043	0.002	0.050	−0.030	−0.411	−0.048	−0.067	−0.116	−0.108
	(0.55)	(0.00)	(0.63)	(−0.33)	(−0.44)	(−0.52)	(−0.86)	(−1.44)	(−1.32)
13 7+ yr of school completed (0,1)	0.133	0.050	0.152	0.135	0.128	0.131	0.311	0.244	0.271
	(1.21)	(0.43)	(1.25)	(1.20)	(1.09)	(1.08)	(3.18)	(2.35)	(2.30)
14 Recent contact with extension agent (0,1)	0.007	–	–	0.084	0.130	0.114	0.074	0.083	0.083
	(0.11)		–	(1.01)	(1.71)	(1.50)	(1.13)	(1.27)	(1.26)
15 Households in panchayat with recent	0.202	–	–	0.122	–	–	0.414	0.473	0.472
extension contact (proportion)	(0.12)	–	–	(0.59)	–	–	(2.51)	(2.84)	(2.85)
16 Age (yr/10)	0.019	0.024	0.023	0.012	–	–	0.006	–	–
	(0.89)	(1.15)	(1.08)	(0.48)	–	–	(0.30)	–	–
27 Occupation (farmer only = 0, other = 1)	−0.010	–	–	0.055	–	–	−0.034	–	–
	(−0.12)			(0.44)	–	–	(−0.42)	–	–
17 Numeracy (0–14)		0.009	–		0.015	0.013		0.022	0.022
		(0.88)	–		(1.20)	(1.07)		(2.26)	(2.30)
19 Raven's Progressive Matrices (RPM)		0.008	0.012		−0.006	–		−0.001	–
score (0–36)		(1.25)	(1.84)		(−0.81)	–		(−0.21)	–
20 Agricultural knowledge test		0.003	–		−0.025	−0.024		−0.019	−0.018
score (0–12)		(0.26)	–		(−1.61)	(−1.51)		(−1.45)	(−1.40)
22 Father's landholding (ha/10)			−0.034			0.048			0.004
			(−0.61)			(0.69)			(0.08)
23 Father's literacy (0,1)			−0.145			−0.125			−0.076
			(−1.58)			(−1.27)			(−0.84)
R^2	0.696	0.698	0.700	0.811	0.812	0.813	0.761	0.765	0.765
Adjusted R^2*	0.686	0.689	0.691	0.802	0.805	0.805	0.751	0.754	0.754

Note: Numbers in parentheses are t values. Dashes indicate a variable removed from the equation based on a null result in an earlier step.
*R^2 adjusted for degrees of freedom (Nie *et al*., 1975, p. 358, footnote).

causal effects of these variables on production, and not the direct effects of family background on production.[21]

The land, labour and animal (variables 2, 3 and 5) elasticity estimates are all significantly greater than zero and their values remain remarkably stable across different specifications of the same production function. The regression coefficients for variables 4 and 5, wherever statistically significant, suggest that female labour is more productive than male labour, and hired labour less productive than family labour. The use of chemical fertilizer (variable 7) – which, on those farms that used it, averaged 48 kg/ha on early paddy, 77 kg/ha on late paddy, and 127 kg/ha on wheat – added between 22 and 35% to crop outputs.[22] Table 4 gives computed marginal value products of land, labour and animal power for all three crops, valuing paddy and wheat respectively at Rs. 1.25 and Rs. 3.00 per kg.

cally different from zero in a one-tailed test. Apparently, the completion of seven or more years of school has a positive effect on the technical efficiency of farmers in the Nepal Terai, increasing crop outputs by as much as 31%, whereas the completion of fewer than seven years has no effect; there is even, in the case of wheat, the suggestion of a *negative* effect of the one-to-six-year category of school attainment.

The results pertaining to the efficacy of nonformal, adult education (i.e. direct and indirect exposure to the government-run extension programme for farmers – variables 14 and 15) are encouraging in that the signs of the regression coefficients are, in all cases, positive as predicted. The influence of indirect extension contact on wheat yields appears especially powerful. The regression coefficient for this variable (the proportion of households in the farmer's panchayat reporting recent

Table 4. *Average marginal value products, in rupees*

Input (unit)	Early paddy	Late paddy	Wheat
Land (ha)	436	430	1401
Labour (person-day)	0.4	0.9	5.6
Animal (ox-day)	2.3	6.3	11.8

Note: The approximate farmgate prices of paddy and wheat in 1977–78 were Rs. 1.25 and Rs. 3.00 per kg respectively.

Turning to variable 10 in Table 3, we find that farms in Bara obtained crop outputs from 6 to 22% higher than farms in Rautahat, other factors held constant. This difference can be interpreted to reflect, at least in part, the quality of the extension programme in Bara, where the training-and-visit extension system had recently been introduced. By this indicator, the effect of extension *quality* is strongest for early paddy and weakest for wheat. In no case does off-farm employment (variable 27) show a significant effect on output in the first step of the regression sequence, and this variable has been excluded from all subsequent steps.

The estimated effects of the variables of central interest in this paper are summarized in Table 5. The effects of education (schooling and extension contact) on crop outputs are seen to be greater in the case of wheat, a recently introduced crop, than in the case of paddy, an established crop. With school attainment, the regression coefficient for variable 13 is, in every case, larger than the coefficient for variable 12, and the latter is never statisti-

extension contact) is 0.472 in the final equation for wheat. The interpretation of this variable is that a 10 percentage-point increase in extension coverage in a farmer's panchayat is associated with a 5% increase in the farmer's wheat output, other factors held constant including the farmer's own personal contact with the extension programme. The implication here is that a farmer can acquire technical information relevant to the production of a new crop either directly, from an extension agent, or indirectly, from other farmers who have themselves been in contact with extension agents.

A question sometimes raised in connection with an observed correlation between past education and current productivity concerns the extent to which education serves as a proxy for unobserved family background variables, thereby rendering the observed correlation spurious. Figure 2 is a simplified version of Figure 1, showing the causal chain linking family background, education, and production (output quantity). The paths a, b, and c represent, respectively, the causal effect of family

Table 5. *Summary of effects of education and competences in production function regressions*

Variable	Early paddy (EP1)	Early paddy (EP2)	Early paddy (EP3)	Late paddy (LP1)	Late paddy (LP2)	Late paddy (LP3)	Wheat (W1)	Wheat (W2)	Wheat (W3)
Educational background									
10 District (Bara = 1, Rautahat = 0)	++	++	++	+	++	++	0	0	0
11 1–6 yr of school completed (0,1)	0	0	0	0	0	0	0	0*	0*
13 7+ yr of school completed (0,1)	(+)	0	(+)	(+)	(+)	(+)	++	++	++
14 Recent contact with extension agent (0,1)	0	0	0	(+)	++	+	(+)	(+)	(+)
15 Households in panchayat with recent extension contact (proportion)	0	0	0	0	0	0	++	++	++
Competences and information									
17 Numeracy (0–14)		0	0		(+)	(+)		++	++
19 Raven's Progressive Matrices (RPM) score (0–36)		(+)	++		0	0		0	0
20 Agricultural knowledge test score (0–12)		0	0		0*	0*		0*	0*
Family background									
22 Father's landholding (ha/10)			0			0			0
23 Father's literacy (0,1)			0*			0*			0

Note: The symbols in this table may be interpreted as follows: ++ = b (regression coefficient) positive and significant at 0.05 level in a one-tailed test; + = b positive and significant at 0.10 level in a one-tailed test; (+) = b positive and significant at 0.15 level in a one-tailed test; 0 = null hypothesis could not be rejected at 0.15 level in a one-tailed test (either in this equation, or in some prior equation in which case variable was excluded from this equation); 0* = though not predicted, a negative effect is suggested by size and sign of t-value.

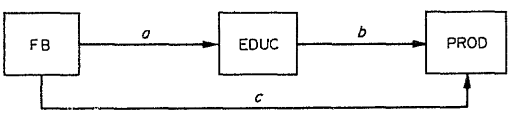

Figure 2. *Simplified causal diagram relating family background, education and production.*

background on education, that of education on production, and that of family background on production:

$$\frac{\partial \mathrm{EDUC}}{\partial \mathrm{FB}},$$

$$\frac{\partial \mathrm{PROD}}{\partial \mathrm{EDUC}} \text{ and}$$

$$\frac{\partial \mathrm{PROD}}{\partial \mathrm{FB}}$$

If, in the absence of information on family background, a researcher were to regress PROD on EDUC for a sample of producers, the resulting regression coefficient would tend to overestimate b, the *causal* effect of education on production. The bias would be greater, the greater is c (the causal effect on production of family background, the variable omitted from the regression equation).

To determine the extent to which education, in steps (1) and (2) of the production function regressions, serves as a proxy for unobserved family background characteristics, we enter in step (3) two measures of family background – father's landholding and father's literacy (variables 22 and 23). In general, the regression coefficients for these variables are statistically nonsignificant, and the coefficients for the variables already in the equations are unaffected by the entering of family background. It would seem that the causal effect of a farmer's family background on technical efficiency in agriculture is, to a large extent, mediated by education (which *is* affected by family background – see Jamison and Lockheed, 1982). The statistical effects of school attainment and exposure to the extension services in steps (1) and (2) of the regressions thus appear to be true causal effects.

The estimated effects of numeracy, reasoning ability (RPM score), and agricultural knowledge – the measured outcomes of education – are, for the most part, statistically nonsignificant. The regression coefficient for numeracy is positive in every case, but significant at the 0.05 level only in the case of wheat. At least for wheat, it appears that numeracy may be an important intervening variable between school attainment and technical efficiency (cf., in Table 3, the regression coefficients in equations (W1) and (W2) for variable 13). The regression coefficient for farmer's RPM score is statistically significant only in the case of early paddy. The results for the agricultural knowledge variable are puzzling; the regression coefficients are, in most cases, *negative*. One might choose to conclude that this variable does not measure what it was intended to measure.

Both for educational attainment and for numeracy, there are relatively weak effects on productivity for familiar, traditional crops (early and late paddy); for the recently introduced wheat crop, however, definite effects are evident. This is consistent with Schultz's (1975) hypothesis that education is of value only in a changing environment.

(c) *Economic benefits of school quality*

The inclusion of the numeracy test score in the production functions allows an estimation of the economic returns to *quality improvement* in education; this thereby extends previous work on the returns to education so as to include another important dimension of educational policy. In order to provide an approximation of the benefits of a policy to improve the quality of instruction in mathematics, we calculated the marginal value product of a one standard deviation (i.e. 4.4 point) increase in the numeracy test score in each of the three major crops. Using the production functions in Table 3 and the prices in Table 4, we find a marginal value product of Rs. 27 per year for early paddy, Rs. 49 for late paddy, and Rs. 90 for wheat. Projected over a 40-year working life and discounted at 10% per annum, these benefits amount to Rs. 264, Rs. 479 and Rs. 880, respectively. These total to Rs. 1623 or about U.S. $125,[24] a substantial multiple of the cost of a single year of schooling. On the one hand, this amount overestimates benefits because not all farmers grow wheat. On the other hand, since higher numeracy increases the probability of growing the profitable wheat crop, it underestimates total benefits. In any case, the figure should be regarded only as an approximation.

It is difficult to compare this estimated benefit of a one standard deviation improvement in numeracy with the costs that might be required to effect such an improvement. The reason is that, to the authors' knowledge, no studies exist relating achievement at some point in elementary school to adult achievement levels. It is, however, not unreasonable to suppose that a school intervention resulting in a one standard deviation score improvement over the typical school period (in our sample only 1.2 yr) would result ultimately in a one standard deviation improvement in adult scores. Effecting a one standard deviation improvement is, however, rather difficult; nonetheless, studies of improved textbook availability and of educational radio (Jamison *et al.*, 1981) demonstrate improvement of 0.2–1 standard deviations at per annum costs per subject far lower than $125. It seems likely, then, on the basis of this admittedly preliminary analysis, that economic benefits are likely to exceed, perhaps substantially, the cost of at least some approaches to school quality improvement.

(d) *Nonlinear effects of education*

As indicated above, the effect of school attainment in the Cobb–Douglas production functions appears to have a distinct threshold. Farmers who have completed one-to-six years of school are no more productive than farmers who have never been to school, but farmers who have completed seven or more years of school are significantly more productive than farmers who have completed fewer than seven. Lockheed, Jamison, and Lau (in Jamison and Lau, 1982, Chapter 2) summarize the results of 37 earlier farm-level studies of education and crop production in low-income countries. Of the 37 studies, eight specified the relation between output (or the log of output) and education as a stepped function, breaking the educational attainment continuum either at three years or six years of school completed. All but one of the eight studies reported statistically significant regression coefficients for the indicator variables used. The clear suggestion in these studies, corroborated by the present study, is that an individual who completes just 'a few' years of school (fewer than four years, or fewer than seven years, depending on the study) does not retain enough learning to benefit from it later as a farmer.

We push the investigation of education's role in agricultural production further in Table 6, where we report the results of three new regressions for each of the three crops. The nonlinearity of the relation between school attainment and the natural log of output is borne out when we compare, for each crop, equation (3), carried over from the earlier tables, and equation (4) in which the quasi-continuous measure of school attainment (variable 11) is substituted for the two indicator variables (12 and 13); equation (3) is, in every case, a better fit, as indicated by the R^2 statistics. Still, the regression coefficient on years of school completed (variable 11) invites a comparison with the results of earlier research. According to the review article in Jamison and Lau (1982, Chapter 2), mean gain in output associated with one additional year of school completed, in the 31 studies for which this figure could be computed, is either 1.8% or 2.2% depending on how the studies are weighted. Our own results bracket the computed mean figures. The estimated gains in output associated with one additional year of schooling are smaller than 1% and statistically nonsignificant in the case of both paddy crops, and the gain equals 2.3% in the case of wheat.

Noting that the regression coefficients for one-to-six years of school completed in the step (3) equations are actually negative for two of the three crops, we decided to test a quadratic specification of the relation between each of the dependent variables and school attainment. These regression equations are labeled (EP5), (LP5), and (W5). This specification is an improvement over the log-linear specification (prior equation) only in the case of wheat. The results for wheat may be summarized:

$$\ln Y = (-0.027)S + (0.005)S^2 + \ldots$$

which implies that the marginal productivity of education changes from negative to positive at 2.7 yr of school completed.

The final equation in Table 6 for each of the three crops employs the two school attainment indicator variables, plus a variable which is the product of the second of the two indicators (variable 13) and the extension indicator (variable 14). The added term does not enhance the explanatory power of the equation either in the case of early paddy or in the case of wheat. In the case of late paddy, however, the negative interaction term suggests that, for this crop at least, schooling and extension contact serve as substitutes for one another in the production function. Of the 37 studies reviewed in Jamison and Lau (1982, Chapter 2), 16 provided information on nonformal education, and half of these tested for an interaction between nonformal education and schooling. The results of these studies are inconclusive, however, some authors reporting positive coefficients and others, negative coefficients. The question of whether formal education and nonformal education act as complements or substitutes, or whether the two are independent of one another, remains very much an open question.

5. EDUCATION AND TECHNOLOGICAL ADOPTION

T. W. Schultz and others have argued that allocative skills make a difference only in a changing environment. In a static, traditional farm community, wrote Schultz (1964), all farmers are 'poor but efficient'. In a dynamic setting, however, prices fluctuate and technology improves, forever creating opportunities for the efficient production manager to increase profits. The Nepal Terai is typical of most contemporary farm communities, where conditions change rapidly in large part owing to the ease of communication with the outside world. Two relatively new technologies were in evidence at the time of the data collection for this study. The first was the use of store-bought chemical fertilizer in crop production. This practice was seen in the previous section of the paper to have a consistently large and positive effect on output quantities. The second innovation was the growing of wheat, an increasingly popular food, which can supplement paddy in the farm family's diet and can also be sold as a cash crop.

In the analysis presented here, each of the two adoption decisions is treated as discrete and dichotomous. During the 1977–78 agricultural year, each of the farmers in the Terai sample did or did not apply chemical fertilizer and each did or did not cultivate wheat. Turning back to Table 1, we see that 38% of the 683 farmers applied at least some store-bought fertilizer, and 71% cultivated at least some wheat. The purpose of the analysis that follows is to see what, if anything, characterizes the 'early adopters', that is, those farm managers who had adopted the use of chemical fertilizer or the cultivation of wheat as of the 1977–78 season. In particular we are interested in ascertaining the extent to which the education levels and cognitive skills of farmers influence the

Table 6. *Effects of school attainment and extension contact in production function regressions*

Variable	Early paddy				Late paddy				Wheat			
	(EP3)	(EP4)	(EP5)	(EP6)	(LP3)	(LP4)	(LP5)	(LP6)	(W3)	(W4)	(W5)	(W6)
12 1–6 yr of school completed (0,1)	0.050			0.054	−0.048			−0.059	−0.108			−0.111
	(0.63)			(0.68)	(−0.52)			(−0.63)	(−1.32)			(−1.35)
13 7+ yr of school completed (0,1)	0.152			0.074	0.131			0.321	0.271			0.341
	(1.25)			(0.45)	(1.08)			(1.96)	(2.50)			(2.15)
11 School attainment (yr)		0.009	0.008			0.003	0.242			0.023	−0.027	
		(0.77)	(0.30)			(0.23)	(0.82)			(1.98)	(−1.01)	
Variable 11 (school attainment) squared			0.0001				−0.002				0.005	
			(0.04)				(−0.79)				(1.01)	
14 Recent contact with extension agent (0,1)	–	–	–	−0.009	0.114	0.119	0.119	0.163	0.083	0.078	0.076	0.097
	–	–	–	(−0.13)	(1.50)	(1.57)	(1.56)	(2.01)	(1.26)	(1.18)	(1.15)	(1.42)
Variable 13 (7+ yr of school) times variable 14 (extension contact)				0.144				−0.340				−0.124
				(0.71)				(−1.72)				(−0.72)
15 Households in panchayat with recent extension contact (proportion)	–	–	–	–	–	–	–	–	0.472	0.432	0.473	0.475
	–	–	–	–	–	–	–	–	(2.85)	(2.60)	(2.83)	(2.86)
Total number of independent variables in equation	13	12	13	15	12	11	12	13	15	14	15	16
R^2	0.700	0.699	0.699	0.700	0.813	0.812	0.812	0.815	0.765	0.759	0.762	0.765
Adjusted R^2*	0.691	0.690	0.690	0.689	0.805	0.804	0.804	0.806	0.754	0.749	0.751	0.754

Note: For each crop, equation (3) in this table is the same as equation (3) in Tables 3 and 5. Equations (4), (5) and (6) differ from equation (3) only as shown here; otherwise, the variables included in these equations are the same as those included in equation (3). The remaining regression coefficients, which tend to differ hardly at all from those in equation (3) are not reported in the paper. The numbers in parentheses are t-values. Dashes indicate a variable removed from the equation based on an earlier null result.

*R^2 adjusted for degrees of freedom (Nie *et al.*, 1975, p. 358, note).

adoption decision, controlling for economic status.

(e) *Data and methods*

Table 7 describes the variables to be used in the analyses of adoptive behaviour. The number of households for which we have information on all of the 17 listed variables is 458, or 67% of the 683 households in the full sample. Again, as we saw with the crop subsamples, we see here that the mean educational attainment is marginally higher in this subsample than in the full sample, and that a farmer in this subsample is moderately more likely to have been exposed to the agricultural extension programme (cf. Tables 1 and 7).

Variables 24 through 27 are four measures of what we have been referring to as farmer's socioeconomic status (see Figure 1). Under this rubric we can identify a number of economic factors expected to influence adoptive behaviour. Current landholding and house value are measures of household wealth and, indirectly, of the household's income-earning capacity. To the extent that nonadoption (of fertilizer or wheat) reflects either a capital constraint or an aversion to risk, we would predict positive effects of these variables on the likelihood of adoption. Occupation (i.e. off-farm employment) is also an indicator of income and, as such, it too should have a positive effect on adoptive behaviour. On the other hand, off-farm employment may impede the household head from learning about a new agricultural enterprise and thereby result in nonadoption (or in adoption later than would otherwise have been the case). Finally, the presence of a granary on the farm may be expected, *ceteris paribus*, to increase the profitability of both innovations and thereby to increase the probability of adoption.

By definition, the expected value of either of the dichotomous dependent variables (fertilizer use and wheat cultivation) must lie between 0 and 1 regardless of the values of the independent variables. The logit model is one appropriate tool for analysing determinants of a dichotomous dependent variable. The logit model assumes that there is an index, Z, which is a linear combination of the independent variables, X_i:

$$Z = a + \sum_{i=1}^{m} b_i X_i$$

The dependent variable, D (in this case, adoption), is expected to equal 0 or 1 depending on whether Z is greater than or smaller than some threshold value. Over the population of individual (potential adopters), the threshold values are assumed to be logistically distributed, reflecting random differences in 'tastes'. The estimated coefficients in the logit analysis, the b_i's, can be used to calculate changes in the probability of adoption as a function of changes in the values of the independent variables.

(f) *Results*

The logit results are presented in Table 8.[25] As with the production function regressions in the previous section, the independent variables are entered in a series of steps. The educational

Table 7. *Means and standard deviations, adoption subsample* (N = 458)

Variable	Mean	SD
8 Chemical fertilizer (1 if used, 0 if not)	0.41	0.49
9 Wheat crop (1 if cultivated, 0 if not)	0.71	0.46
12 1–6 years of school completed (0,1)	0.15	0.36
13 7+ years of school completed (0,1)	0.09	0.28
14 Recent contact with extension agent (0,1)	0.31	0.46
15 Households in panchayat with recent extension contact (proportion)	0.30	0.23
16 Age (years/10)	4.28	1.33
17 Numeracy (0–14)	8.74	3.29
19 Raven's Progressive Matrices (RPM) score (0–36)	13.16	4.39
20 Agricultural knowledge test score (0–12)	6.61	2.29
24 Current landholding (ha)	1.49	2.64
25 Market value of house (Rs./1000)	3.62	6.44
26 Grain storage facility on farm (0,1)	0.08	0.27
27 Occupation (farmer only = 0, other = 1)	0.12	0.32
28 Households in panchayat growing wheat (proportion)	0.70	0.10
29 Households in panchayat using chemical fertilizer (proportion)	0.30	0.23

Table 8. *Chemical fertilizer and wheat crop logit regressions*

Variable	Chemical fertilizer used (CF1)	(CF2)	(CF3)	(CF4)	Wheat crop cultivated (WC1)	(WC2)	(WC3)	(WC4)
Constant	–1.368	–1.784	–1.176	–1.641	0.451	0.936	0.632	–1.615
	(–2.50)	(–2.03)	(–2.03)	(–2.62)	(0.89)	(1.49)	(1.05)	(–1.40)
12 1–6 yr of school completed	0.727	0.598	0.580	0.578	–0.015	–0.088	–0.475	–0.538
(0,1)	(1.92)	(1.46)	(1.41)	(1.41)	(–0.04)	(–0.20)	(–0.98)	(–1.10)
13 7+ yr of school	0.939	0.733	0.472	0.347	0.633	0.689	0.060	–0.102
completed (0,1)	(2.09)	(1.36)	(0.88)	(0.66)	(1.04)	(1.03)	(0.80)	(–0.14)
14 Recent contact with extension	0.407	0.374	0.430	0.492	0.853	1.141	1.030	0.873
agent (0,1)	(1.01)	(0.90)	(1.03)	(1.19)	(1.62)	(2.19)	(1.84)	(1.57)
15 Households in panchayat with recent extension contact	1.007	1.191	1.356	–1.123	0.425	–	–	–
(proportion)	(1.06)	(1.18)	(1.35)	(–0.61)	(0.39)	–	–	–
16 Age (yr)	–0.112	–0.103	–0.171	–0.180	–0.005	–	–	–
	(–0.98)	(–0.89)	(–1.40)	(–1.47)	(–0.04)	–	–	–
17 Numeracy (0–14)		0.051	–	–		0.070	0.043	0.070
		(0.85)	–	–		(1.38)	(0.84)	(1.30)
19 Raven's Progressive Matrices		0.001	–	–		–0.063	–0.073	–0.077
(RPM) score (0–36)		(0.03)	–	–		(–1.55)	(–1.72)	(–1.81)
20 Agricultural knowledge		–0.010	–	–		–0.041	–	–
test score (0–12)		(–0.14)	–	–		(–0.60)	–	–
24 Current landholding (ha)			0.152	0.148			0.313	0.288
			(2.08)	(2.17)			(2.23)	(2.10)
25 Market value of			–0.055	–0.056			0.058	0.070
house (Rs./1000)			(–1.48)	(–1.53)			(0.89)	(1.04)
26 Grain storage facility			–0.272	–			–0.303	–
on farm (0,1)			(–0.42)	–			(–0.41)	–
27 Occupation (farmer only = 0,			–0.200	–			–0.037	–
other = 1)			(–0.373)	–			(–0.08)	–
28 Households in panchayat growing								0.033
wheat (proportion)								(2.26)
29 Households in panchayat using				0.049				
chemical fertilizer (proportion)				(1.62)				

Note: Numbers in parentheses are asymptotic *t*-values. Dashes indicate a variable removed from the equation based on a null result in an earlier step.

background characteristics are entered first, followed by the farmer's competences and information in a second step. The third block of variables comprises the four measures of current socioeconomic status. In a fourth and final step in the series for each dependent variable, a variable is entered that measures the extent of the adoption of this particular innovation in the farmer's own neighbourhood (his panchayat). This step tests the 'diffusion' or 'contagion' model of technological adoption. A positive coefficient for this variable, other factors held constant, suggests that a farmer's decision to adopt an innovation is influenced, in part, by the behaviour of his neighbours.

The results presented in Table 8 are summarized in Table 9. We see that having attended school is related to the adoption of chemical fertilizer. This link appears to be mediated, especially at a high level (7 or more years) of school completion, by the farmer's wealth, as measured by farm size (variable 24). It seems, however, that there is no parallel effect of school attainment on the decision to grow wheat. Turning to the effect of the government-run extension programme, a farmer who reports recent extension contact (variable 14) is somewhat more likely than a farmer who does not, to be an innovator, although this effect is statistically significant only for the decision to grow wheat. In the case of chemical fertilizer, it is not *direct* extension service contact (variable 14) but, rather, *indirect* contact (variable 15) that appears to make

Table 9. *Summary of effects in logit regressions*

Variable	Chemical fertilizers used (CF1)	(CF2)	(CF3)	(CF4)	Wheat crop cultivated (WC1)	(WC2)	(WC3)	(WC4)
Educational background								
12 1–6 yr of school completed (0,1)	++	+	+	+	0	0	0	0
13 7+ yr of school completed (0,1)	++	+	0	0	(+)	(+)	0	0
14 Recent contact with extension agent (0,1)	(+)	0	(+)	(+)	+	++	++	+
15 Households in panchayat with recent extension contact (proportion)	(+)	(+)	+	0	0	0	0	0
16 Age (yr)	0	0	0	0	0	0	0	0
Competences and information								
17 Numeracy (0–14)		0	0	0		+	0	+
19 Raven's Progressive Matrices (RPM) score (0–36)		0	0	0		0*	0*	0*
20 Agricultural knowledge test score (0–12)		0	0	0		0	0	0
Current socioeconomic status								
24 Current landholding (ha)			++	++			++	++
25 Market value of house (Rs./1000)			0*	0*			0	(+)
26 Grain storage facility on farm (0,1)			0	0			0	0
27 Occupation (farmer only = 0, other = 1)			0	0			0	0
Diffusion								
28 Households in panchayat growing wheat (proportion)								++
29 Households in panchayat using chemical fertilizer (proportion)				+				

Note: The symbols in this table may be interpreted as follows: ++ = *b* (regression coefficient) positive and significant at 0.05 level in a one-tailed test; + = *b* positive and significant at 0.10 level in a one-tailed test; (+) = *b* positive and significant at 0.15 level in a one-tailed test; 0 = null hypothesis could not be rejected at 0.15 level in a one-tailed test (either in this equation or in some prior equation in which case variable was excluded from this equation); 0* = though not predicted, a negative effect is suggested by size and sign of t-value.

a difference. In either case, however, the statistical effect of the agricultural extension programme on adoptive behaviour is somewhat diminished when, in step (4), a variable is added that measures the diffusion of this innovation in the farmer's own panchayat. A farmer is more likely to grow wheat or use chemical fertilizer the greater the proportion of other farmers who do so in this farmer's immediate area.

The extension programme may serve as a catalyst in the diffusion process. Extension agents preach the benefits of a new farm technology, and this promise is heard and acted upon by the most innovative of the area's farmers. Although the bulk of the area's farmers assume a more cautious, 'show-me' posture toward the new technology, nevertheless, as soon as the benefits of the innovation have been demonstrated in practice, some of these farmers will also adopt. As the evidence continues to accumulate, further adoption takes place, first at an increasing rate, and then, when some majority of farmers are already using the new technology, perhaps at a decreasing rate.[26]

In general, with one important exception, the measured cognitive outcomes of education (variables 17, 19 and 20) appear to have only weak effects on the decisions to adopt chemical fertilizer and wheat cultivation. The logit coefficient for the farmer's RPM score (variable 19), our measure of general reasoning ability, even displays the 'wrong' sign in the case of wheat cultivation. The exception is the coefficient for numeracy (variable 17). It always has a positive sign as predicted, but it is statistically significant only for wheat adoption.

NOTES

1. In a companion paper to this one Pudasaini (1982) does use data on interfarm price variation in Nepal to examine education's effects on allocative efficiency, i.e. on a farmer's capacity to adjust input and output levels to the prevailing prices, given his or her production function.

2. Although economists during the first half of the twentieth century tended to ignore investment in human beings, this subject had received considerable attention from earlier economists and political economists, from Sir William Petty down to John Stuart Mill. For an account of the classical roots of modern human capital theory, see Kiker (1968). For an excellent compendium of recent studies through mid-1975 on the contribution of education to earnings, at the micro level, and to economic growth, at the macro level, see Blaug (1978).

3. The outputs of 'household production' are entities that enter the utility function directly and are not generally available for purchase in the marketplace. These outputs or 'commodities' are produced with inputs of market purchases and household members' time (Becker, 1965). To take one class of examples, Cochrane, Leslie and O'Hara (1982) review a range of studies showing education's contribution to the household 'production' of the health and nutrition of its members.

4. This focus may be attributed to the relative homogeneity of agricultural products and to the fact that small, family farms survive today in many parts of the world, whereas comparable firms have tended to disappear in most other sectors. A number of microlevel studies of education and agricultural production in low-income countries have been summarized and their conclusions synthesized in Jamison and Lau (1982).

5. For a discussion and a review of such studies, see Schultz (1975).

6. This research is reviewed in Rogers (1971) and Villaume (1977).

7. A third interpretation, the 'credentialling hypothesis', says that education partitions workers into noncompeting groups. Bowles and Gintis (1976) provide a Marxian version of the credentialling hypothesis. Of course, the three interpretations of the education–earnings correlation are not mutually exclusive; it is quite possible for all three mechanisms described here to be operating at the same time. An extensive economic literature has developed on the screening hypothesis, and on the impact of education on earnings controlling for 'innate' ability. For a discussion of screening that includes many references to this literature, see Bowman (1976b). For a general discussion of the education–earnings correlation, see Blaug (1972).

8. This multipurpose survey was undertaken in substantial part to provide the data for the analyses reported in this paper. The survey was conducted by New ERA, a Nepalese research and consulting organization, and was designed jointly by staff of New ERA and the World Bank.

9. These lists had been prepared in connection with the malaria eradication campaign.

10. See Shrestha, Baidya, and Shrestha (1982) for a complete account of data collection, the sample areas and the instruments used.

11. This is but one in a set of papers based on the Terai data set. The others include Cochrane (1981), Cochrane, Joshi and Nandwani (1981), Jamison and

Lockheed (1982), Leslie, Baidya and Nandwani (1981), Martorell, Leslie and Moock (forthcoming), and Moock and Leslie (1982).

12. For example, we got an answer to the question on recent extension contact (variable 15) from only 661 of the 683 farm heads; and, of the 659 farmers who grew early paddy in 1977–78, only 638 provided us with an output estimate (variable EP1).

13. Under the New Educational System Plan of 1971, the first seven years are divided into three years of what is called 'primary' and four years of 'lower secondary' schooling. This is followed by three years of 'upper secondary' school, upon completion of which a student may qualify for training at Tribhuvan University.

14. The T & V system was introduced in Bara as part of the Narayani Zone Irrigation Development Project, financed by an International Development Association Credit. For a description of the T & V system, see Benor and Harrison (1977). The reason we chose to split the sample between Bara and Rautahat districts was to provide for inclusion of farmers exposed to T & V and farmers not so exposed but who were farming in otherwise similar circumstances. A thorough evaluation of the impact of extension exposure in general or of the T & V system in particular is beyond the scope of this paper. The World Bank has, however, initiated a major evaluation of the T & V system in several states of India; first results of this effort are now available (Feder and Slade, 1983).

15. A typical question was 'If the cost of one mango is 8 annas, how much will 10 mangoes cost?'

16. This is the sum of variables 12 and 13.

17. This is an approximation only. The proportionate change in output that results when E_i increases by one unit, from E_i to E_i+1, is actually the following where Y_0 is output at E_i, and Y_1 output at E_i+1:

$$\frac{Y_1-Y_0}{Y_0} = \frac{Y_1}{Y_0} - 1 = \frac{e^{\gamma_i(E_i+1)}}{e^{\gamma_i E_i}} - 1 = e^{\gamma_i} - 1$$

This value is approximated by γ_i when γ_i is a small fraction. (The larger the absolute value of γ_i, the poorer γ_i is as an approximation of e^{γ_i}–1.)

18. We did, however, run Chow tests (Chow, 1960) for the three education groups (0, 1–6, and 7+ years) and for the two extension groups (contact and no contact) and found that the regression slopes for the other variables in the production equations do not differ significantly across these groups. The largest F ratio in any of the six tests (two characteristics times three crops) was 1.18, with 16 and 286 degrees of freedom. For an example of an analysis in which individual input elasticities depend on educational background, see Moock (1981).

19. The regressions were estimated on the World Bank's Burroughs B7700 computer using the multiple regression subprogram of SPSS, Version H, Release 8.1 (Nie *et al.*, 1975).

20. However, when the absolute t-value for any variable brought into the equation is small, that variable may be excluded from subsequent steps. An exception to this rule applies to the pair of schooling indicators (variables 12 and 13) since the impact of educational attainment is central to this study and since the elimination of either one of the pair of variables would alter the interpretation of the remaining regression coefficient.

21. By the 'direct effects' of family background, we mean those not mediated by education and cognitive skills (see Figure 1).

22. Computed from the regression coefficients for variable 7. For example, in equation (W3):

$$\text{estimated effect} = e^{0.301} - 1 = 0.35\,.$$

See note 17.

23. The nonlinearity of educational attainment in the Cobb–Douglas production functions is pursued more fully below. See Table 6.

24. The present value ranges from Rs. 830 ($64) to Rs. 6649 ($511) as we apply different discount rates ranging from 20% to 0% per annum.

25. The maximum likelihood estimates of the logit parameters were computed on the World Bank's B7700 computer using the Quail 3.0 package (Berkman *et al.*, 1977).

26. Cf. Rogers (1971).

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