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Marlaine E. Lockheed, Dean T. Jamison, and Lawrence J. Lau

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Marlaine E. Lockheed
Educational Testing Service

Dean T. Jamison
World Bank

Lawrence J. Lau
Stanford University

Development strategies increasingly emphasize agricultural development, employment, and equity; it is therefore important to examine the role of education in light of these new emphases. The educational requirements of a capital-intensive, industrially focused growth strategy can be expected to differ in important ways from the requirements of a strategy placing greater emphasis on employment and agriculture; nonetheless, much of the research on the economic benefits of education is limited to the examination of data from the urban wage sector. The policy conclusion emerging recently from this research has typically been that there is over-investment in education, particularly at the higher levels. It is now being argued, however, that this conclusion—based as it is on the structure of earnings and employment in the formal urban labor market—is inapplicable to the new growth strategies. For example, John Mellor has argued that "all aspects of agricultural growth through technological change are based on expanding the number of rural supporting institutions to benefit the small farmer, who is a crucial part of the overall high-growth strategy. Because of the agricultural sector's massive size, the intensity of use of trained manpower, and stress on broad participation in growth, an emphasis on rural development requires a huge expansion of education

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at all levels. Also, the broader the participation in rural development, the more intensive the requirements for trained manpower."[1]

Mellor thus views investment in education in rural areas as a central ingredient in a strategy to improve agricultural productivity, principally through its complementarity with new inputs such as chemical fertilizers and pesticides, irrigation, high-yielding varieties, and effective research and extension services. But while Mellor rejects the conclusion that there is typically overinvestment in education, he offers little concrete evidence that education will play the role he expects it to. The plausibility of Mellor's argument—and the importance of its conclusions for investment policy in education—suggests the desirability of testing carefully its empirical validity.

Our purpose in this paper is to synthesize the conclusions of a number of studies—many of them quite recent—of the effect of a farmer's educational level and exposure to extension services on his productivity.[2] We focus on studies using data from individual farms in low-income regions.[3] We examine these studies for the information they contain

[1] John Mellor, *The New Economics of Growth* (Ithaca, N.Y.: Cornell University Press, 1976), p. 74.

[2] A number of studies have examined the impact of education on farmers' willingness to adopt innovations; an early and important study in this area is that of P. Roy, F. Waisanen, and Everett Rogers, *The Impact of Communication on Rural Development: An Investigation in Costa Rica and India* (Paris: Unesco, 1969). Villaume provides a valuable review of this literature as well as an assessment of the direct and indirect impact of literacy on adoption of innovations in Brazil and India (see John M. Villaume, "Literacy and the Adoption of Agricultural Innovations" [Ph.D. diss., Harvard University, 1977], chap. 2).

[3] Griliches, Gisser, Fane, Khaldi, and Huffman have studied the effect of education on agricultural productivity using aggregated data (at the county or state level) in the United States; they found education levels positively associated with increased efficiency and, in the study by Gisser, with increased propensity to emigrate from rural areas (see Zvi Griliches, "The Sources of Measured Productivity Growth: United States Agriculture, 1940–60," *Journal of Political Economy* 71 [1963]: 331–46, and "Research Expenditures, Education, and the Aggregate Agricultural Production Function," *American Economic Review* 54 [1964]: 961–74; Micha Gisser, "Schooling and the Farm Problem," *Econometrica* 33 [1965]: 582–92; George Fane, "Education and the Managerial Efficiency of Farmers," *Review of Economics and Statistics* [1975]: 452–61; Nabil Khaldi, "Education and Allocative Efficiency in U.S. Agriculture," *American Journal of Agricultural Economics* 57 [1975]: 650–57; Wallace E. Huffman, "Decision Making: The Role of Education," *American Journal of Agricultural Economics* 56 [1974]: 85–97, and "Allocative Efficiency: The Role of Human Capital," *Quarterly Journal of Economics* 91 [1977]: 59–79). Using similar methods, Hayami and Hayami and Ruttan found that educational level is an important determinant of agricultural productivity differences among nations (see Yujira Hayami, "Sources of Agricultural Productivity Gap among Selected Countries," *American Journal of Agricultural Economics* 51 [1969]: 564–75; and Yujira Hayami and Vernon W. Ruttan, "Agricultural Productivity Differences among Countries," *American Economic Review* 60 [1970]: 895–911). Herdt, using much the same methodology with Indian data aggregated at the state level, found no positive effects of education, although Ram found that education contributed strongly to the productivity of Indian agriculture with data disaggregated from the state to the district level (see Robert W. Herdt, "Resource Productivity in Indian Agriculture," *American Journal of Agricultural Economics* 53 [1971]: 517–21; and Rati Ram, "Educa-

concerning the correctness of three hypotheses: (1) higher levels of formal education increase farmers' efficiency; (2) education has a higher payoff for farmers in a changing, modernizing environment than in a static, traditional one (as suggested by Schultz);[4] and (3) exposure to extension services improves farmers' productivity. Following the suggestion of Glass, we draw quantitative data from each study on the magnitude of the effects of education;[5] this is done in a format that allows comparison across studies. As the studies differ from one another along many dimensions (including, in particular, the quality of data and data analysis), any conclusions from comparisons across them must be drawn with care. None-

tion as a Quasi-Factor of Production: The Case of India's Agriculture" [Ph.D. diss., University of Chicago, 1976]). Also using Indian district-level data, Harker found that average literacy levels increased productivity and, more strongly, increased the utilization of fertilizer (see B. Harker, "Rural Literacy Influence on Indian Agriculture," unpublished paper [Oakland University, Rochester, Mich., n.d.]). In other related studies, Beal found that both education and extension utilization contributed to a subjective measure of farmer performance in England, Page found that exposure to technical education increased foresters' efficiency in Ghana, Gerhart found that more educated Kenyan farmers were more likely to adopt hybrid maizes, and Rosenzweig found that more educated Punjabi farmers were more likely to adopt high-yielding varieties (see D. W. Beal, "The Capacity to Succeed in Farming," *Farm Economist* 10 [1963]: 114–24; John Page, "Technical Efficiency and Economic Performance: Some Evidence from Ghana," mimeographed [1978]; J. Gerhart, "The Diffusion of Hybrid Maize in Western Kenya," abridged [Mexico City: Centro Internacional de Majoramiento de Maiz y Trigo, 1975]; and Mark R. Rosenzweig, "Schooling, Allocative Ability and the Green Revolution" [paper delivered at the meeting of the Eastern Economic Association, Washington, D.C., April 1978]). On the other hand, Morss et al. concluded that the average literacy level of farmers being reached by agricultural development projects was not a determinant of project success (see Elliott Morss, John Hatch, Donald Mickelwait, and Charles Sweet, *Strategies for Small Farmer Development* [Boulder, Colo.: Westview Press, 1976]). Although economists only began to pay systematic attention to these issues in the 1960s (beginning with the seminal work of T. Schultz), the educational research literature of the 1920s had already begun to consider the role of education in improving agricultural productivity. Folks, as early as 1920, e.g., reported on studies showing a strong influence of education on agricultural productivity in Indiana, Missouri, and New York (see Gertrude Folks, "Farm Labor vs. School Attendance," *American Child* 2 [1920]: 73–89).

[4] When agricultural conditions are static, proper practices can be formalized and passed from generation to generation by example and adage. Buck provided interesting examples from China, e.g., from Shantung, "Plant millet after millet and you will end by weeping" (see J. L. Buck, *Land Utilization in China* [1937; reprint ed., New York: Council on Economic and Cultural Affairs, Inc., 1956]). Evenson, Bowman, and Ram provided thoughtful interpretations of how research, extension, and education are interrelated in transforming static environments into modernizing ones, and Harma discussed specific ways in which education and information would be useful in improving productivity in a range of agricultural activities (see Robert Evenson, "Research, Extension, and Schooling in Agricultural Development," in *Education and Rural Development*, ed. J. Sheffield and P. Foster [London: Evans Brothers, 1974]; Mary Jean Bowman, *Rural People and Rural Economic Development* [Paris: International Institute for Educational Planning, 1976]; Ram; and Risto Harma, "Farmer Entrepreneur and His Prerequisite Prior Education in Agricultural Development," mimeographed [Washington, D.C.: World Bank, 1978]).

[5] Gene V Glass, "Primary, Secondary and Metaanalysis of Research," *Educational Researcher* 5 (1976): 3–8.

theless, subject to a number of caveats, we are able to draw generalizable conclusions.

The paper is organized as follows: Section I briefly discusses the methods of analysis used in the studies we review, Section II describes the studies, and Section III summarizes the results of 18 studies of the effect of formal education on agricultural productivity. Of these 18 studies, nine contained information on the exposure of farmers to nonformal education (extension), and Section IV reviews the findings of the effectiveness of extension in these studies. Section V summarizes our conclusions. Appendix A contains supplemental information on the studies reviewed, and Appendix B provides a bibliography of the studies referred to in various tables.

I. Methods of Analysis

Yotopoulos conducted the first of the studies we review and used a production function for agricultural output as his basic tool for analyzing the impact of education on productivity.[6] Subsequent studies used much the same methodology. We begin this section with a discussion of how a farmer's productivity and efficiency can be assessed from use of production functions and, if available, from price data.

The studies we review typically use data from a survey of several hundred farm households in a particular locale. These surveys contain data, for each farm, on some or all of the following variables: gross output of the farm (e.g., kilograms of rice), land area under cultivation, person days of family labor used, quantity and type of equipment used, the educational levels of the members of the household, and exposure of the farmer to extension services. Given a data set of this sort, the researcher can assess the effect of education on productivity by estimating a production function relating the quantity of farm output to the level of each of the inputs, including the farmer's education.

To take a simple example: let V = gross output (in kilograms), T = area under cultivation (in hectares), L = labor input (in person days), E = education level of the household head (in years of formal schooling completed), and EXT = indicator of exposure of the farmer to extension ($EXT = 1$ if exposed, $EXT = 0$ if not exposed). The studies we review use variations of either the Cobb-Douglas (or ln-ln) production function or the linear production function to relate output, V, to the various inputs in one of the following ways:

$$\ln V = \alpha_0 + \alpha_1 \ln L + \alpha_2 \ln T + \beta \ln E + \gamma EXT \,, \tag{1}$$

$$\ln V = \alpha_0 + \alpha_1 \ln L + \alpha_2 \ln T + \beta E + \gamma EXT \,, \tag{2}$$

or

$$\ln V = \alpha_0 + \alpha_1 \ln L + \alpha_2 \ln T + \beta D + \gamma EXT \,, \tag{3}$$

[6] Pan A. Yotopoulos, "The Greek Farmer and the Use of His Resources," *Balkan Studies* 8 (1967): 365–86.

where D is an indicator variable that takes the value 1 if E takes a value in a specified range, and 0 otherwise; or

$$V = \alpha_0 + \alpha_1 L + \alpha_2 T + \beta E \,, \tag{4}$$

or

$$V = \alpha_0 + \alpha_1 L + \alpha_2 T + \beta D \,. \tag{5}$$

In specifications (1) through (3), the α 's give the elasticities of output with respect to the various inputs.[7] In specifications (4) and (5), the α_i's give the marginal product of the various inputs. In specification (1), β gives the elasticity of output with respect to years of education. In specification (2), β gives the percentage increase in output in response to a unit change in education. In specification (3), β gives the percentage increase in output of a farm with the farmer's educational level specified as D, compared with the base case, which is usually no education. (For example, if D signified "completed primary school," β would give the percentage increase in output of a farmer who graduated from primary school over that of one who had received no schooling.) In specification (4), β gives the marginal increase in output in response to a unit change in education. In specification (5), β gives the increase in output of a farm with the farmer's specified number of years of education, compared with the base case.

All of the studies we review use production functions of one of these general forms in which β provides a measure of the productivity of education. Similarly, γ provides a measure of the productivity of agricultural extension. In the better empirical studies that we review, far more complete specifications of the production function, including many more independent variables, are used than in this simplified example.

Most estimates of the effects of education on labor productivity use wage rate as a proxy for marginal productivity and examine the effect of an individual's educational level, with other variables controlled, on the wage he or she receives. This is reasonable, assuming competitive labor markets and an absence of "screening" mechanisms whereby the individual's education may simply signal productive qualities to an employer without actually enhancing them. (Bowman provides a valuable discussion of screening and its implications, with references to a now-extensive literature.)[8] Direct estimation of the marginal product of education through its coefficient in a production function provides an alternative to using wages that is superior in a number of respects: (1) no assumptions need

[7] The "elasticity" of variable Y with respect to variable X is the percentage change in Y induced by a 1% change in X. An elasticity of .2, for example, would imply that a 1% increase in X would result in a .2% increase in Y. The coefficients of indicator variables have analogous interpretations. The coefficient of an indicator variable, like D in specification (3), is approximately the percentage increase in output that would result if the indicator variable had the value 1 rather than 0.

[8] Mary Jean Bowman, "Through Education to Earnings?" *Proceedings of the National Academy of Education* 3 (1976): 261–69.

be made about equivalence of wages and the marginal product of labor; (2) the possibility of screening does not confound an interpretation of the results (though omitted variables may); and (3) only in this way is it possible to obtain estimates of the effect of education on productivity in sectors, such as agriculture, that may rely relatively little on wage employment.[9]

In addition to examining the effect of education on productivity, it is also possible to examine whether it affects allocative efficiency, that is, the extent to which farmers optimally choose their mix of input and output in light of their production functions and prevailing prices. In a seminal article, Welch discusses ways of assessing the effect of education on allocative efficiency.[10] Several of the studies we review have examined the issue of allocative efficiency by comparing actual with optimal allocation decisions in light of an estimated production function, and, in one case, farm-specific price data were available that allowed an estimation of profit and factor demand functions to test allocative efficiency. This was done for a sample of farms in Thailand. Jamison and Lau provide a thorough discussion of alternative types of efficiency,[11] and Lau explicates the use of profit functions as a tool for assessing allocative efficiency.[12] Studies by Müller and by Shapiro and Müller have analyzed the relationship between information and technical efficiency and have provided empirical support

[9] Though estimation of the effects of education on production is in principle possible in other sectors, studies so far have focused on agriculture. Two partial exceptions are Simmons's study of Tunisian shoe manufacturing and an examination of the effects of literacy in the nineteenth-century U.S. textile industry (mentioned in Samuel Bowles and Herbert Gintis, *Schooling in Capitalist America* [New York: Basic Books, 1976], p. 110; and see John Simmons, "The Determinants of Earnings: Towards an Improved Model," in *Change in Tunisia*, ed. R. A. Stone and J. Simmons [Albany: State University of New York Press, 1976], pp. 249–62). Both of these studies used piece rates to approximate marginal productivity. A more important exception is in the education industry itself, where there have been numerous studies of the effects of teachers' educational levels on their productivity (as measured by their students' performance on tests; for a tabular summary of results, see Dean T. Jamison, Patrick Suppes, and Stuart Wells, "The Effectiveness of Alternative Instructional Media: A Survey," *Review of Educational Research* 44 [1974]: 1–67).

[10] Finis Welch, "Education in Production," *Journal of Political Economy* 78 (1970): 32–59.

[11] Dean T. Jamison and Lawrence J. Lau, *Farmer Education and Farm Efficiency* (Baltimore: Johns Hopkins University Press, in press). In addition to discussing productivity (sometimes called technical efficiency), Jamison and Lau define a notion of "market efficiency," which refers to the extent to which an agent in a noncompetitive market environment can obtain relatively high prices for his outputs and relatively low prices for his inputs. Wharton hypothesized that farmers' education would improve market efficiency (see C. R. Wharton, Jr., "Education and Agricultural Growth: The Role of Education in Early-Stage Agriculture," in *Education and Economic Development*, ed. C. A. Anderson and M. J. Bowman [Chicago: Aldine Publishing Co., 1965], p. 211). However, Jamison and Lau found little evidence that education improved the market efficiency of farmers in Thailand.

[12] Lawrence J. Lau, "Applications of Profit Functions," in *Production Economics: A Dual Approach to Theory and Applications*, ed. M. A. Fuss and D. L. McFadden (Amsterdam: North-Holland Publishing Co., 1978).

for the notion that familiarity with information sources improves productivity in dairy farming in the United States and cotton farming in Tanzania.[13] In this paper we note those studies that examine allocative efficiency as well as productivity.

II. Studies: Bases of Comparison and Criteria for Selection

This paper summarizes the analyses of 37 data sets discussed in 18 studies on education and small-farm production in 13 countries of Africa, Asia, Europe, and Latin America. In 17 of the data sets the effects of education on technical efficiency in the production of a cereal crop (rice, wheat, or maize) were examined; in the remaining data sets, the effect of education on the production of a mixed crop, typically including a cereal, was examined. Only a study of dairy farms by Sadan, Nachmias, and Bar-Lev did not examine efficiency in terms of field-crop production.[14] Table 1 summarizes salient features of the data bases, and table A1 in Appendix A provides more detail on the variables used in each analysis. In this section we review some sources of inconsistency across the studies, describe the criteria by which we restricted the sample of studies for further analysis, and indicate the limitations of a broad comparative summary of this sort.

Although we have attempted to identify similarities across widely differing studies, a number of factors limit the scope of generalizations. The most important of these are differences in the sample characteristics, differences in the methods of analysis, and differences in the specification or measurement of both dependent and independent variables (particularly the education variables). Furthermore, as previously noted, there is substantial variation across studies in the quality of data, data analysis, and reporting; this further limits the adequacy of our comparisons across studies.

1. Sample characteristics: Of the 37 data sets, only 16 were reported to have been collected using an explicit sampling design. The data sets also varied in the number of farms that were surveyed, the size distribution of the farms, the type of crop grown, and in regional characteristics. Moreover, education was frequently not of primary importance to those undertaking the original data-collection efforts.

2. Methods of analysis: The primary method of analysis used in the studies was multiple regression with both dependent and independent variables in logarithmic form, resulting in a production function commonly referred to in economic literature as the "Cobb-Douglas" type. In several

[13] Jürgen Müller, "On Sources of Measured Technical Efficiency: The Impact of Information," *American Journal of Agricultural Economics* 56 (1974): 730–38; and K. H. Shapiro and Jürgen Muller, "Sources of Technical Efficiency: The Roles of Modernization and Information," *Economic Development and Cultural Change* 25 (1977): 293–310.

[14] Ezra Sadan, Chare Nachmias, and Gideon Bar-Lev, "Education and Economic Performance of Occidental and Oriental Family Farm Operators," *World Development* 4 (1976): 445–55.

TABLE 1

DESCRIPTION OF DATA BASE USED IN EACH STUDY

Reference	Country, Date of Data Collection, and Sample Characteristics
Calkins 1976	Nepal, 1973 74; sample of small farms in 5 panchayats of Nuwakot district of central Nepal; rice and wheat
Chaudhri 1974	India, 1961 64; reanalysis of a sample population of 21 villages in the wheat belt of Punjab, Haryana, and Uttar Pradesh; wheat
Halim 1976	Philippines, 1963, 1968, 1973; subsample of an earlier random sample of households in 28 representative rice-producing barrios of Laguna district
Haller 1972	Colombia, 1969; stratified random sample of farms in Chinchiná, Espinal, Malaga, and Moniquira regions; tobacco, coffee, corn, cassava, guayaba, cotton, sesame, rice, and livestock
Harker 1973	Japan, 1966; representative sample of 971 middle-aged rice farmers in Central and Southern Honshu, Shikoku, and in the Fukuoka areas of Kyushu; rice
Hong 1975	Korea, 1961; subsample of random census sample of 1,200 farm households in 9 provinces; rice and other crops
Hopcraft 1974	Kenya, 1969 70; subsample of a stratified random sample of 1,700 small farms collected for the Small Farm Enterprise Cost Survey; maize, livestock, and tea
Jamison and Lau 1978	Malaysia, 1973; subsample of FAO IBRD survey of 800 rural farming households in monoculture paddy area of Muda Irrigation Project, Kedah and Perlis States, West Malaysia; rice
Jamison and Lau 1978	Korea, 1973; subsamples of a national survey of 2,254 farms in 9 regions of South Korea; rice and other crops
Jamison and Lau 1978	Thailand, 1972 73; reanalysis of a stratified random sample of farm households from 22 villages in the Chiang Mai Valley; rice
Moock 1973	Kenya, 1971-72; farms in Vihiga division that received loans for the purchase of hybrid maize seeds and fertilizer and comparison farms that were not loan recipients; maize
Pachico and Ashby 1976	Brazil, 1970; sample of farm households in 4 communities of southern Brazil collected by University of Rio Grande de Sul; mixed field crop and livestock
Patrick and Kehrberg 1973	Brazil, 1969; survey of 620 farms in 5 regions of eastern Brazil; maize, beans, coffee, beef cattle, and dairy cattle
Pudasaini 1976	Nepal, 1975; random sample of 102 traditional and mechanized farms in Bara district; rice, wheat, and sugarcane
Sadan, Nachmias, and Bar-Lev 1976	Israel, 1969 70; population of 1,841 dairy farms under the supervision of the Settlement Agency in Israel
Sharma 1974	Nepal, 1968 69; subsample of a stratified random sample of households in 15 village panchayats in Rupandehi; rice and wheat
Sidhu 1976, 1978	India, 1967-71; sample of 150 farms in the Ferozepur district of Punjab, 1968 69; farms in 4 districts of Punjab, 1970-71; wheat
Wu 1971	Taiwan, 1964 66; records of bookkeeping farms: 249 farms in 25 hsiangs collected in 1964; 246 farms in 26 hsiangs collected in 1965; 154 farms in 13 hsiangs collected in 1966; rice, banana, pineapple, sweet potatoes, sugarcane, and poultry
Wu 1977	Taiwan, 1964 66; reanalysis of a sample of 310 bookkeeping farms in 3 mixed farming regions; presumably same data set as Wu (1971)
Yotopoulos 1967	Greece, 1963; subsample of a random sample of 650 households in 110 villages and 3 cities of Epirus; wheat and cotton

of the studies, however, the description of the specification of the production equation was so inadequate that we were unable to determine whether the variables were actually expressed in logarithmic form. Appendix table A1 indicates the specifications of the equations where we were able to determine them.

3. Specification and measurement of the dependent variable: Although most of these studies were described as studies of *production*, the analysis of 23 of the 37 data sets used the *value* of crop production as the dependent variable. Since the value of a crop is dependent on price structures (which may vary widely between and across regions), comparisons between studies that examine the *quantity* of output and those that examine the *value* of output must be made with some caution. The studies also included a variety of different field crops; the dependent variables included both single field crops (typically rice, wheat, or maize) and mixed field crops (including, e.g., bananas, cotton, vegetables, and sugar cane), both separately or in combination with cereal crops.

4. Specification and measurement of the independent education variable: There are three sources of variations across studies regarding the education variable used: (1) whose education is measured, (2) what the education measure is, and (3) how the measure is expressed. The educational level of the production unit was measured in these studies by the education of the head of the household, the aggregate education of the family members, or the aggregate education of farm workers. Education aggregates typically excluded the education of nonworkers, the very young, or the very old. The quantity of education was the number of years attended or completed, the number of grades or levels attended or completed, or simply a measure of literacy. Educational level was expressed as either an indicator or a continuous variable; continuous variables were sometimes entered in the production functions in logarithmic form and sometimes in natural form.

Whenever possible, we have reported results of equations in which we use the number of years or grades completed by the head of the household; however, when more than one education variable has been analyzed, we have attempted to note differences in the estimated effects.

5. Specification and measurement of other input factors: The widest discrepancies among these studies are reflected by the extent to which other production variables are included in the specification of the production function. Land, labor, and capital are generally included, but in different ways. Land may be entered into the function as a quantity or as a value. Labor is often differentiated into family or hired, and the variable may be in time or value terms. Capital may be entered as a single variable or differentiated into several factors. Other factor input variables may include the quantity or use of fertilizer, the use of irrigation, the types of seed, and regional indicator variables.

Because of the differences in samples, outputs, and factor inputs among these studies, we restricted our summary histograms and regressions to include (1) only agricultural production function studies (this eliminated Harker);[15] (2) only studies in which the dependent variable was a field crop or an aggregate of several field crops (this eliminated Sadan et al.), (3) only studies in which a percentage gain per year of education could be computed (this eliminated Calkins, Chaudhri, and Hong);[16] and (4) we did not include Hopcraft's maize production function reported in table 2 because of its finding of a negative effect of labor on output.[17] This process of elimination reduced to 31 the number of data sets, the analyses of which we report.

III. Formal Education's Effects on Efficiency

Overall Effects

We have hypothesized that education will have a positive effect on farmer efficiency; overall, we find confirmation for this hypothesis. Table 2 reports, for each of our 37 data sets, the coefficients of education on agricultural productivity, the statistical significance of the estimate, and (for the 31 data sets where it was possible) the estimated percentage increase in output for each additional year of education. Perusing table 2 will give a broad sense of the range of findings and the diversity of the studies. In six of these data sets education was found to have a negative (but statistically insignificant) effect, but, in the remaining 31, the effect was positive and usually significant. Table A2 in Appendix A contains additional information; in particular, it shows the estimated values for the coefficients of other than education variables in the production functions.

The percentage increase in output for 1 additional year of education at the mean educational level of the sample can be computed for most of the studies we review. The appropriate formula depends on the particular specification of the production function that is used in the study. Let $\bar{E}$ be the average educational level of the sample and β be the estimated coefficient of education; then the percentage increase in output for 1

[15] Bruce R. Harker, "The Contribution of Schooling to Agricultural Modernization: An Empirical Analysis," in *Education and Rural Development*, ed. P. Foster and J. R. Sheffield (London: Evans Brothers, 1974).

[16] P. Calkins, "Shiva's Trident: The Effect of Improving Horticulture on Income, Employment and Nutrition" (Ph.D. diss., Cornell University, 1976); D. P. Chaudhri, "Effect of Farmer's Education on Agricultural Productivity and Employment: A Case Study of Punjab and Haryana States of India (1960–1972)," mimeographed (Armidale: University of New England, 1974); and K. Y. Hong, "An Estimated Economic Contribution of Schooling and Extension in Korean Agriculture" (Ph.D. diss., University of the Philippines at Los Banos, 1975).

[17] Peter N. Hopcraft, "Human Resources and Technical Skills in Agricultural Development: An Economic Evaluation of Educative Investments in Kenya's Small Farm Sector" (Ph.D. diss., Stanford University, 1974). Hopcraft's production function for aggregate crop output has a positive labor coefficient.

additional year of education may be calculated by computing the ratio of the value of output when the level of education is ½ year greater than $\bar{E}$, Y_1, to the value when it is ½ year less, Y_0, subtracting one, and multiplying by 100. If the production function is specified as in equation (1), we have:

$$\text{percentage increase} = \left(\frac{Y_1}{Y_0} - 1\right) \times 100 = \left[\frac{(\bar{E} + 0.5)^{\beta}}{(\bar{E} - 0.5)^{\beta}} - 1\right] \times 100$$

$$= \left[\left(\frac{\bar{E} + 0.5}{\bar{E} - 0.5}\right)^{\beta} - 1\right] \times 100\,.$$

For production function (2),

$$\text{percentage increase} = \left[\frac{e^{\beta(\bar{E}+0.5)}}{e^{\beta(\bar{E}-0.5)}} - 1\right] \times 100$$

$$= [e^{\beta} - 1] \times 100\,.$$

For production function (3), if there are N years of education in the level specified by D,

$$\text{percentage increase} = \left[\frac{e^{\beta} - 1}{N}\right] \times 100\,.$$

(In the calculation for production function [3], it is assumed that the percentage increase due to education can be proportionally attributed to the years of education.) For production function (4),

$$\text{percentage increase}$$

$$= \left[\frac{\alpha_0 + \alpha_1 L + \alpha_2 T + \beta(\bar{E} + 0.5) + \gamma EXT}{\alpha_0 + \alpha_1 L + \alpha_2 T + \beta(\bar{E} - 0.5) + \gamma EXT} - 1\right] \times 100$$

$$= \left[\frac{\beta}{\alpha_0 + \alpha_1 L + \alpha_2 T + \beta(\bar{E} - 0.5) + \gamma EXT}\right] \times 100\,.$$

For production function (5), if there are N years of education in the level specified by D,

$$\text{percentage increase} = \left[\frac{\beta}{\alpha_0 + \alpha_1 L + \alpha_2 T + \gamma EXT}\right] \times 100/N\,.$$

In order to summarize our findings, we created histograms (based on the 31 studies that were not omitted for technical or comparison reasons) of numbers of studies by percentage decrease or increase in output attributable to a farmer's having 4 years of education rather than none; our estimate of the effect of 4 years is, however, simply four times the effect of 1 year as computed from the formulas just given. (This averages out threshold effects of the sort that some of the studies we review found.) We use 4 years because it is an often-stated minimum for the basic education cycle. Change was rounded to nearest 0.5% in order to group the studies, which were aggregated in 4.0% intervals. The histogram in figure 1 shows that the mean gain in production for 4 years of education was about 8.7%, with a standard deviation of 9.0%.

TABLE 2

FORMAL EDUCATION AND AGRICULTURAL PRODUCTIVITY

Study	N	Coefficient of Education on Agricultural Productivity	t-Statistic	R^2	Estimated Increase in Output for One Additional Year of Education (%)[a]	Comments
Brazil, Candelaria (Pachico and Ashby 1976)	117	.126	.89	.71	2.69	Education was positively related to output among highly commercialized farms
Brazil, Garibaldi (Pachico and Ashby 1976)	101	.207	1.92	.69	4.60	Education was positively related to output among highly commercialized farms
Brazil, Guarani (Pachico and Ashby 1976)	63	.072	.55	.67	1.49	Preliminary analysis of data indicated that less than 5 yr of schooling had no significant effect on output
Brazil, Taquarz (Pachico and Ashby 1976)	101	.244	1.66	.68	5.53	Education was positively related to output among highly commercialized farms
Brazil, Alto Saõ Francisco (Patrick and Kehrberg 1973)	82	−.013	−.65	.44	−1.29	Returns of schooling were negative in the traditional agriculture regions but became positive and increased as the regions were more modern among the five samples in the Patrick and Kehrberg study
Brazil, Conceicao de Castelo (Patrick and Kehrberg 1973)	54	−.009	−.75	.82	−.90	...
Brazil, Paracatu (Patrick and Kehrberg 1973)	86	−.017	−1.41	.59	−1.69	...
Brazil, Resende (Patrick and Kehrberg 1973)	62	.010	1.11	.55	1.01	...

[a] These figures were computed from the formulas in the text.

TABLE 2 (*Continued*)

Study	N	Coefficient of Education on Agricultural Productivity	t-Statistic	R^2	Estimated Increase in Output for One Additional Year of Education (%)[a]	Comments
Brazil, Vicosa (Patrick and Kehrberg 1973).......	337	.023	2.86	.62	2.33	...
Colombia, Chinchiná (Haller 1972)............	77	−.008	−.13	.75	−.29	...
Colombia, Espinal (Haller 1972)............	74	.140	1.80	.71	6.10	...
Colombia, Málaga (Haller 1972)............	74	.047	.94	.53	3.09	...
Colombia, Moniquirá (Haller 1972)............	75	−.049	−1.02	.79	−3.12	...
Greece (Yotopoulos 1967)...	430	.138	2.06	.79	6.47	The marginal product for one yr of education was 606.40 drachmas
India, Punjab, Haryana, and Uttar Pradesh (Chaudhri 1974)..........	1,038	Family average = .116	5.04	.59	Insufficient information to calculate	Marginal product of family education was calculated as Rs 107.04/yr; marginal product of education of household head was calculated as Rs 153.12/yr; no base was given; Chaudhri (1979) provides further analysis based on this same data set and calculates rates of return to education that are high indeed
		Household head = .114	3.65	.59	...	

[a] These figures were computed from the formulas in the text.

TABLE 2 (*Continued*)

Study	N	Coefficient of Education on Agricultural Productivity	t-Statistic	R^2	Estimated Increase in Output for One Additional Year of Education (%)[a]	Comments
India, Punjab (Sidhu 1976) (traditional and Mexican wheat varieties)..........	236	.038	1.90	.92	1.49	Education was found to be related to production efficiency but more strongly to allocative efficiency
India, Punjab (Sidhu 1976) (Mexican wheat).........	369	.036	2.25	.92	1.41	In an analysis using gross farm sales as dependent variable Sidhu finds a positive effect of education, not quite statistically significant, resulting in a 1.1% increase in value of sales for one yr of education; Sidhu and Baanante (1978) use profit and factor demand functions with the same data and find a positive (but statistically insignificant) impact of education
Israel (Sadan, Nachmias, and Bar-Lev 1976)........	1,841	21.100	4.20	Not given	Marginal value added was US $21 per year of wife's schooling (1.08 of gross value added of production)	...
Japan, Honshu, Shikoku, and Kyushu (Harker 1973)....	971	Correlation: With gross farm sales .02;* with communication behavior and agricultural adoption variables added, .31**	...	.38	Not applicable	...

[a] These figures were computed from the formulas in the text.
* N.S.
** $P < .001$.

TABLE 2 (*Continued*)

Study	N	Coefficient of Education on Agricultural Productivity	t-Statistic	R^2	Estimated Increase in Output for One Additional Year of Education (%)[a]	Comments
Kenya, Vihiga (Moock 1973)	152	Indicator (4 or more yr) .067	1.60	.64	1.73	An indicator variable for 1–3 yr of education had a negative coefficient
Kenya (Hopcraft 1974)......	674	Indicator (2–3 yr) −.023	−.30	.56	−3.26	These results are for maize production, for which the coefficient of labor on output was negative; the production function for aggregate output, which had a positive labor coefficient, had education coefficients that were essentially zero
		Indicator (4–6 yr) −.163	−2.19			
		Indicator (primary school) −.148	−1.50			
Korea (Hong 1975).........	895	Log linear .712	3.05	.85	Units of equation were hard to interpret so this figure could not be computed	Some empirical conclusions of this study are difficult to interpret
		Cobb-Douglas .927	1.46	.85		
Korea (Jamison and Lau 1978) (mechanical farms)...	1,363	Continuous .022	4.97	.66	2.22	Analysis also undertaken with discrete variables representing different education levels
Korea (Jamison and Lau 1978) (nonmechanical farms)..................	541	Continuous .023	2.95	.61	2.33	The coefficient of labor on output was negative in this study
Malaysia, Kedah and Perlis (Jamison and Lau 1978)...	403	Indicator (literate) .109	1.61	.69	5.11	. .
		Indicator (1–3 yr) .071	1.14			
		Indicator (≧4 yr) .186	2.60			
Nepal, Bara (Pudasaini 1976)	102	.014	1.71	.90	1.3	There was a positive effect of schooling on farm revenue; tractor hiring and pumpset-owning farms (the modernizing variable) were found to be more efficient than traditional, while tractor owning farms and farms owning both tractors and pumpsets were not significantly different from traditional farms in terms of efficiency

[a] These figures were computed from the formulas in the text.

TABLE 2 (*Continued*)

Study	N	Coefficient of Education on Agricultural Productivity	t-Statistic	R^2	Estimated Increase in Output for One Additional Year of Education (%)[a]	Comments
Nepal, Nuwakot (Calkins 1976)......................	540	Indicator (7 or more yr) .53	3.53	.77	Could not be computed because M's of other independent variables not given	The coefficient for 0 yr education was not significantly different from the one for 1–6 yr education. However, for 7 or more yr the coefficient was significant; the evidence thus suggests a minimum threshold of 6–7 yr before education affects productivity
Nepal, Rupandehi (Sharma 1974) (wheat farms)......	87	Indicator (literate) .142	1.80	.84	5.09 (computed using literate as equivalent to 3 yr education)	...
Nepal, Rupandehi (Sharma 1974) (rice farms)........	138	Indicator (literate) .082	1.78	.95	2.85 (computed using literate as equivalent to 3 yr education)	...
Philippines, Laguna, 1963 (Halim 1976).............	274	.020	1.53	.77	2.0	...
Philippines, Laguna, 1968 (Halim 1976).............	273	.019	1.26	.70	1.92	...
Philippines, Laguna, 1973 (Halim 1976).............	220	.027	2.25	.80	2.74	...
Taiwan (Wu 1971) (rice farms)	333	.007	.53	.60	.7	Simple rate of returns for 1 yr additional schooling computed from 1–12 yr decreased at a steady rate; thus, there was no evidence of a threshold effect
Taiwan (Wu 1971) (banana and pineapple farms)......	316	.038	2.83	.65	3.87	...

[a] These figures were computed from the formulas in the text.

TABLE 2 (*Continued*)

Study	N	Coefficient of Education on Agricultural Productivity	t-Statistic	R^2	Estimated Increase in Output for One Additional Year of Education (%)[a]	Comments
Taiwan (Wu 1977)..........	310	.009 Quadratic form(s), −.066 .005	.95 1.82 2.12	.87	.9	Marginal productivity of education in crop production changes from negative to positive at 6.6 yr of schooling of the farm operator; the quadratic formula shows this clearly: where $a_1S + a_2S^2$ was entered in equation—$a_1 = -.066$, $a_2 = .005$
Thailand, Chiang Mai (Jamison and Lau 1978) (farms using chemical fertilizer)................	91	.031	2.10	.76	3.15	The coefficient for education has an increase between the indicator for primary education (4 yr) and over 4 yr: indicator (<4 yr) = .030, indicator (=4 yr) = .124, indicator (>4 yr) = .280, for all equations
Thailand, Chiang Mai (Jamison and Lau 1978) (farms using chemical fertilizer)................	184	.024	2.27	.81	2.43	The coefficient for education has an increase between the indicator for primary education (4 yr) and over 4 yr: indicator (<4 yr) = .066, indicator (=4 yr) = .108, indicator (>4 yr) = .132, for all equations

[a] These figures were computed from the formulas in the text.

In order to assess the reliability of our estimates of percentage gain in production for 4 years of education, we also estimated the standard errors of these estimates, based on the estimated standard errors of the coefficients in the respective studies. Table A2 in Appendix A shows these estimated standard errors, which varied greatly across studies. To compensate for these differences in reliability, we weighted the percentage gains by the reciprocals of the corresponding estimated standard errors and generated a bar graph, shown in figure 2. Thus, the more reliable an estimate is, the heavier the weight. The results differ little from those of figure 1, with a mean gain for 4 years of education estimated as 7.4%, and a standard deviation of 6.8%—figures slightly lower than those estimated from the unweighted sample.

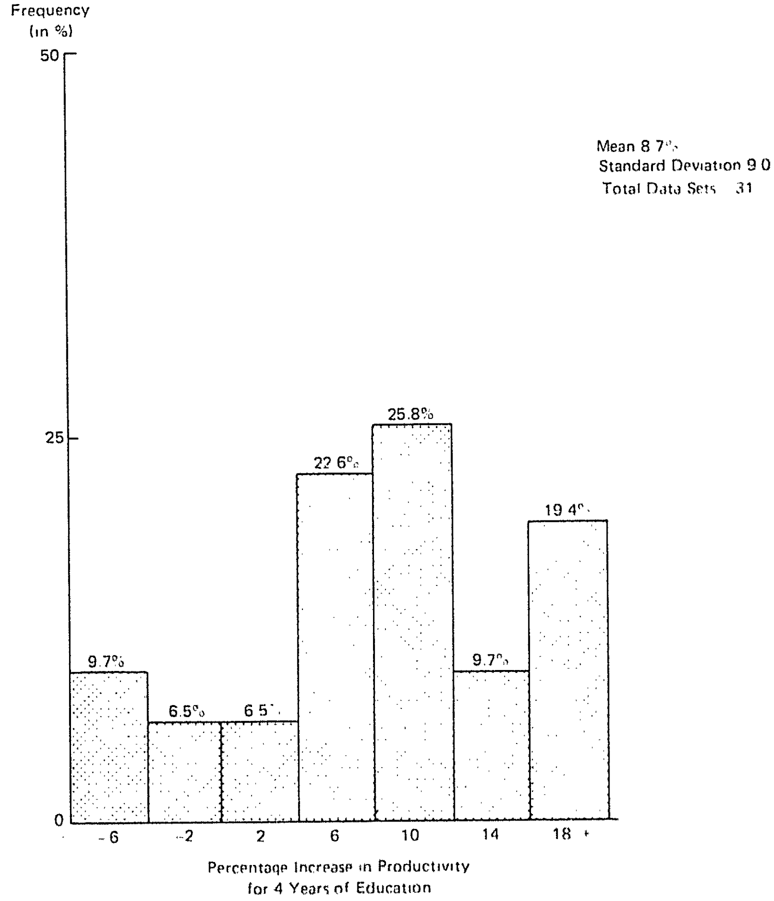

FIG. 1.—Results of studies relating schooling to agricultural productivity

Modernizing Environment

As we have noted, aspects of the environmental context may be important determinants of the effects of education on production. In particular, Schultz has argued that education is likely to be effective principally under modernizing conditions.[18] In order to test this hypothesis, we divided the studies according to whether they reflected modernizing or nonmodernizing environments.

The criteria for identifying an environment as nonmodern included primitive technology, traditional farming practices and crops, and little reported innovation or exposure to new methods. The criteria for identify-

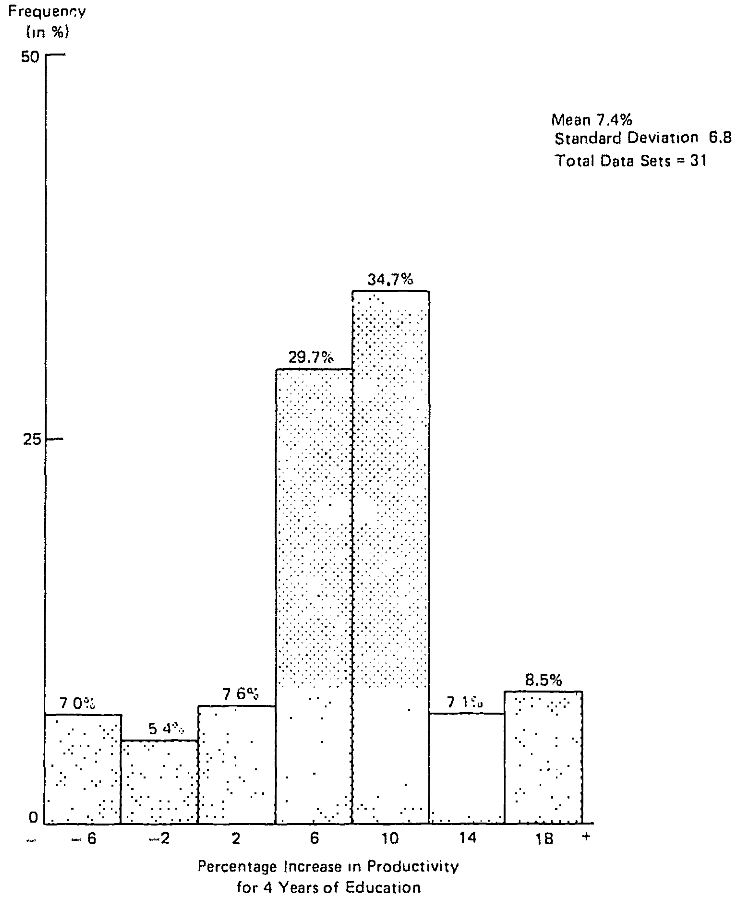

FIG. 2.—Results of studies relating schooling to agricultural productivity (weighted by reciprocal of the standard error).

[18] Theodore W. Schultz, "The Value of the Ability to Deal with Disequilibria," *Journal of Economic Literature* 13 (1975): 872–76.

ing an environment as modern, conversely, included the availability of new crop varieties, innovative planting methods, erosion control, and the availability of capital inputs such as insecticides, fertilizers, and tractors or machines. Some other indicators of this type of environment were market-oriented production and exposure to extension services. In some cases, authors of the studies were explicitly testing Schultz's hypothesis, and for those we simply accepted the author's classification of whether the sample's environment was modernizing. In other cases, where information was available, we made our own subjective assessment. We were able to make a modern-nonmodern classification for 23 of the 31 studies.

We assess the impact of a modernizing environment in two separate ways. First we divide the bar graph of figure 2 into modern and nonmodern subsamples; figure 3 displays the results of this division. Under modernizing conditions, the effects of education are substantially greater than under traditional conditions. Over all of the studies, the mean increase in output for 4 years of education under traditional conditions was 1.3%, compared with 9.5% under modern or modernizing conditions.

A second way of assessing the effect of a modernizing environment on the productivity of education is to conduct a regression analysis of our estimates of the percentage of increase in farm output per 4 years of education as a function of environmental characteristics such as the adult literacy rate in the country, modernizing environment, regional availability of extension services, the type of crop (rice vs. other crops), and real GNP per capita. Since our estimates of the percentage gains are themselves random variables with different variances, the ordinary least-squares estimator is inefficient, although it remains unbiased under standard assumptions. To correct for the heteroscedasticity we have used the generalized least-squares estimator with an estimated diagonal variance-covariance matrix constructed from our estimates of the variances of the percentage gains. The detailed definitions of the independent variables used are given in table 3. For a number of studies, it is not possible to determine whether the environment was modernizing or whether agricultural extension was available. We resort, therefore, to the use of two dummy variables each to represent the effects of modernizing environment and agricultural extension.

A number of regressions with different combinations of the independent variables were run. We report in table 4 only those regressions with at least one statistically significant estimated coefficient (defined as a coefficient with a t-statistic exceeding 1.96 in absolute value). We uniformly find that agricultural extension, crop type, real GNP, and literacy rate have statistically insignificant effects on the percentage gain. On the other hand, a nonmodernizing environment appears to have a decidedly negative effect on the percentage gain. The difference in the percentage increase in productivity between a modern and a nonmodern environment is consistently estimated to be around 10%. The equation with the highest $\bar{R}^2$, the coefficient of multiple determination adjusted for degrees of freedom, indicates that in a nonmodern, nonrice-growing environment, the mean percentage increase may even be negative.

In order to identify further the nature of the environmental influence on the effectiveness of education, we dropped from our regression analysis those studies for which the modernizing/nonmodernizing classification is unavailable, and with the reduced sample we ran further regressions. Table 5 reports the results. The modernizing environment variable is strongly significant. On average, the percentage gain as a result of 4 years of education is 10% higher in a modernizing environment than in a traditional environment. The coefficient of the crop-type variable remains

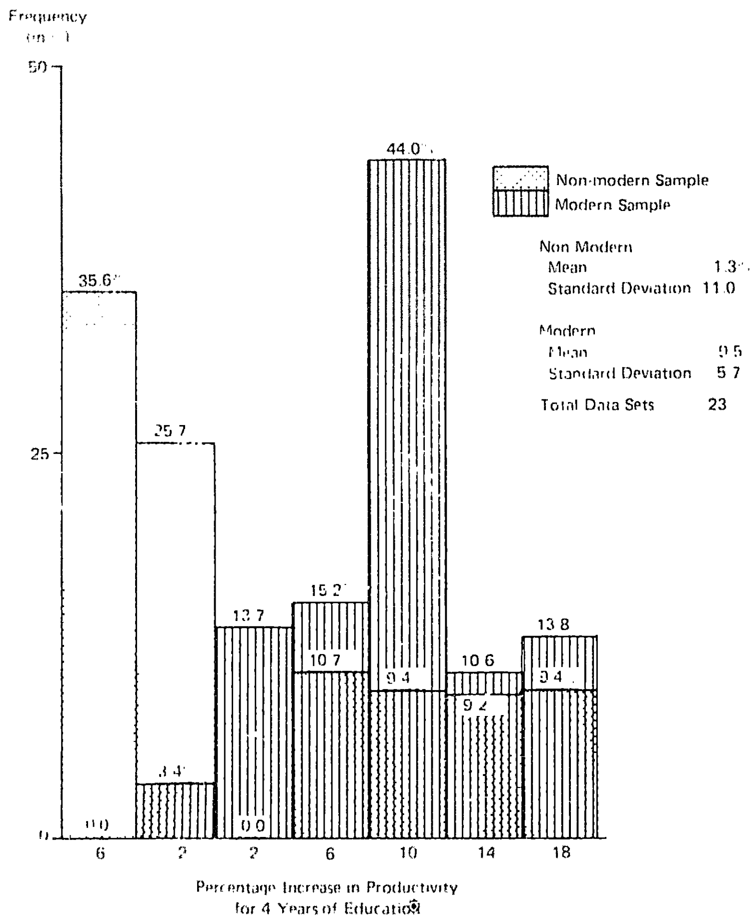

FIG. 3. Effects of schooling on agricultural productivity: study results grouped by modern and nonmodern samples (weighted by the reciprocal of the standard error).

TABLE 3

NAMES AND DEFINITIONS OF VARIABLES USED IN REGRESSIONS REPORTED IN TABLES 4 AND 5

Variable Name	Definition
MOD1........	Indicator of modernizing environment (1 = modernizing, 0 = either traditional or no information available)
MOD−1......	Indicator of traditional environment (1 = traditional, 0 = either modernizing or no information available)
EXT1.........	Indicator of availability of extension services (1 = services available, 0 = either no services available or no information available)
EXT−1.......	Indicator of lack of extension services (1 = services not available, 0 = either services available or no information available)
CROP........	Indicator of crop type (1 = rice, 0 = other)
GNP.........	Per capita gross national product in 1975 US$
LIT...........	Adult literacy rate expressed as %
MOD.........	Indicator of modernizing environment (1 = modernizing, 0 = traditional)
M1C1.........	Indicator of sample partition (1 = modernizing rice environment, 0 = other)
M1C0.........	Indicator of sample partition (1 = modernizing nonrice environment, 0 = other)
M0C1.........	Indicator of sample partition (1 = traditional rice environment, 0 = other)
M0C0.........	Indicator of sample partition (1 = traditional nonrice environment, 0 = other)

statistically insignificant. Even by splitting the independent variables into four dummy variables, as defined in table 3, we found no evidence of environment-crop type interaction. We could not reject the hypothesis that the effect of a modernizing environment is independent of the type of crop (rice or nonrice)—the t-statistic for the null hypothesis has a value of 0.34.

IV. Nonformal Education and Efficiency

We have further hypothesized that exposure to extension or other nonformal agricultural education experience should have a positive effect on output. In table 6 we summarize the analyses of 16 of our data sets for which information on nonformal education was provided.[19] Of these studies, eight provided evidence that extension was significantly positively related to productivity, one provided evidence that extension was significantly negatively related to productivity, and the remaining seven showed no significant effect.

Comparability of these results across studies is limited because of the actual measure of exposure to nonformal education, which may be indi-

[19] We should stress explicitly at this point that this survey of the literature is not intended to cover studies of the effectiveness of agricultural extension or other nonformal education provided for farmers. We merely report here any results available concerning extension effectiveness in the 18 studies listed in table 1; those studies were ones including an assessment of the contribution of formal education to agricultural productivity. Benor and Harrison reported experiences with extension services considerably more effective than those reviewed here; they provide an extensive discussion of the possibilities for reforming extension systems to improve productivity (see Daniel Benor and James Q. Harrison, *Agricultural Extension: The Training and Visit System* [Washington, D.C.: World Bank, 1977]).

TABLE 4—REGRESSION ANALYSIS: DETERMINANTS OF PRODUCTIVITY GAIN AS A RESULT OF 4 YEARS OF EDUCATION ($N = 31$)

Independent Variables	Alternative Specifications							
	1	2	3	4	5	6	7	8
Constant	6.33	6.00	5.48	6.77	5.04	6.33	3.19	6.05
	(4.52)	(3.45)	(3.28)	(4.32)	(2.16)	(4.45)	(.97)	(3.41)
MOD1	2.25	2.46	2.85	3.27	.96	2.10	.65	2.32
	(1.31)	(1.27)	(1.55)	(1.39)	(.38)	(1.17)	(.25)	(1.15)
MOD−1	−8.05	−8.01	−7.20	−6.24	−9.03	−8.05	−9.39	−7.92
	(−2.55)	(−2.29)	(−2.18)	(−1.47)	(−2.59)	(−2.51)	(−2.50)	(−2.22)
EXT1	...	.34	...	...	...	...	.61	.18
		(.18)					(.33)	(.09)
EXT−1	...	1.07	...	...	...	...	3.19	1.03
		(.32)					(.80)	(.30)
CROP	...	...	1.93	...	...	...	...	...
			(.95)					
GNP	...	...	...	0	...	...	...	...
				(−.65)				
LIT	...	...	...	...	.03	...	.06	...
					(.70)		(1.00)	
MODICROP	...	...	...	...	...	1.09	...	1.02
						(.37)		(.32)
$\bar{R}^2$	.46	.42	.46	.45	.45	.45	.42	.40

NOTE.—This table shows the estimated coefficients with their t-statistics in parentheses below them. The data on which the regressions were based are reported in Appendix table A2. To take into account the differences in the variances of our estimates of the percentage productivity gains, we have used generalized least squares with an estimated variance-covariance matrix for our regression. Our dependent variable is the percentage increase in output for 4 yr education. Let $Y_1, \ldots, Y_T$ be the percentage gains and the row vectors $X_1, \ldots, X_T$ be the independent variables; our regression model is: $Y_i = X_i \delta + \xi_i$, $i = 1, \ldots, T$, where

$$V(Y) = V(\xi) = \begin{bmatrix} V(Y_1) & & 0 \\ & V(Y_2) & \\ & & \ddots \\ 0 & & V(Y_T) \end{bmatrix} .$$

By transforming both the dependent and the independent variables, we obtain:

$$\frac{Y_i}{\sqrt{V(Y_i)}} = \frac{X_i\delta}{\sqrt{V(Y_i)}} + \frac{\xi_i}{\sqrt{V(Y_i)}}, \qquad i = 1, \ldots, T .$$

which, by a redefinition of variables, becomes: $Y_i^* = X_i^*\delta + \xi_i^*$, $i = 1, \ldots, T$, with $V(\xi_i^*) = I$, so that ordinary least squares can be applied. But $V(Y)$ is unknown. We substitute for $V(Y)$ by a consistent estimator of $V(Y)$ calculated from the estimated variance-covariance matrices of the coefficients of each of the underlying studies (see Appendix table A2, n.†).

TABLE 5

REGRESSION ANALYSIS: DETERMINANTS OF PRODUCTIVITY GAIN AS A RESULT OF 4 YEARS OF EDUCATION (N = 23)

Independent Variables	Alternative Specifications 1	2	3	4
Constant	−1.72 (−.56)	−1.72 (−.57)	7.14 (5.47)	...
MOD	10.16 (3.07)	10.31 (3.22)	...	...
CROP	1.09 (.34)	...	2.39 (.64)	...
M1C1	...	...	...	9.53 (3.20)
M1C0	...	...	...	8.44 (7.15)
M0C1	...	...	...	...
M0C0	...	...	...	−1.72 −(.56)
$\bar{R}^2$	.47	.50	.26	.47

NOTE.—This table shows the estimated coefficients with their t-statistics in parentheses below them. See note to table 4 for information on data sources and regression methods.

cated by the number of contacts a farmer has with the extension agent, the monetary investment in extension in that region, or the years of exposure to nonformal education. In addition, extreme variability in the program content and method of communication may also reduce cross-study comparability.

We also explored whether formal education and nonformal education acted as substitutes or complements. A few studies incorporated interaction terms between formal and nonformal education in their production-function regressions. Most of the coefficients of interaction were positive, suggesting, therefore, a possible complementary relationship between the two forms of education, even though few of the coefficients were statistically significant.

V. Conclusions

This paper surveys the findings of 18 studies conducted in low-income countries concerning the extent to which the educational level of small farmers affects their production efficiency.[20] The 18 studies include analyses

[20] A number of studies have been published or come to our attention subsequent to acceptance of this paper; among these is a paper by Welch including a review with (qualitative) conclusions similar to ours (see Finis Welch, "The Role of Investments in Human Capital in Agriculture," in *Distortions of Agricultural Incentives*, ed. Theodore W. Schultz [Bloomington: University of Indiana Press, 1979], pp. 259–81). In other specific studies, Bhalla found that education enhanced productivity in an all-India sample of over 2,000 farmers; Bhati found that the technical knowledge of Malaysian farmers was related to their productivity; Freire found that education is significantly associated with the productivity of Guatemalan farmers and with their propensity to use innovative methods; Halim and Husain found the education of farm operators in Bangladesh to enhance output, though not quite statistically significant, while the highest education level of anyone in the farm household bore a negative but insignificant

of 37 sets of farm data that allow, with other variables controlled, a statistical estimation of the effect of education. In six of these data sets, education was found to have a negative (but statistically insignificant) effect, but in the remaining 31, the effect was positive and usually statistically significant. Though combining the results of disparate studies must be done with caution, our overall conclusion is that farm productivity increases, on the average, by 7.4% as a result of a farmer's completing 4 additional years of elementary education rather than none; the 7.4% is a weighted average of values from those studies for which an estimate could be computed. A number of studies showed evidence of a threshold number of years (4-6) at which the effect of education became more pronounced.

The effects of education were much more likely to be positive in modernizing agricultural environments than in traditional ones, which we ascertained both by inspection and by regressing (across studies) the measured effects of education on productivity against the degree of modernization of the environment and other variables. We conclude that our results lend support to T. W. Schultz's hypothesis that the effectiveness of education is enhanced in a modernizing environment.

Appendix A

Supplemental Information on Studies

The appendix contains supplemental information on the studies reviewed in the body of the paper. It is organized into two tables. Appendix table A1 contains (for each sample of farms in each of the papers) information on the sample size, the nature of the education variable(s) and productivity variable(s) used, whether allocative or technical efficiency was examined, and other variables used in the analysis. Appendix table A2 summarizes quantitative information on the strength of the effects found for education in the various studies and contains "environmental" information (e.g., per capita income, adult literacy rates, modernity) on the social context of the regions where the samples were drawn.

relation to productivity; Singh found, in the Haryana state of India, that education (particularly secondary education) enhanced farmers' productivity; and Valdes found that the education of agricultural laborers in Chile was significantly associated with their daily wages. These results, though not incorporated in the analyses we report, are consistent with our findings. (Bhalla's findings are not yet reported, but a description of his sample and a report of other analyses based upon it are in Surjit S. Bhalla, "Farm Size, Productivity, and Technical Change in Indian Agriculture," in *Agrarian Structure and Productivity in Developing Countries*, by R. Albert Berry and William R. Cline [Baltimore: Johns Hopkins University Press, 1979], pp. 141-93. For reports on the other studies see U. N. Bhati, "Farmers' Technical Knowledge and Income—a Case Study of Padi Farmers of West Malaysia," *Malayan Economic Review* 18 [1973]: 36-47; Maria Freire, *The Role of Education in Rural Guatemala: The Case of Farmers' Efficiency*, [Ph.D. thesis, University of California, Berkeley, 1979]; Abdul Halim and Mohammed M. Husain, "Time Allocation and Its Effect on Rice Production and Farm Income in Three Villages of Mymensingh District," Graduate Training Institute Publication no. 12 [Mymensingh: Bangladesh Agricultural University, 1979]; Baldev Singh, "Impact of Education on Farm Production," *Economic and Political Weekly* [September 1974], A92-A96; and Alberto Valdes E., "Wages and Schooling of Agricultural Workers in Chile," *Economic Development and Cultural Change* 19 [1971]: 313-29.)

TABLE 6

NONFORMAL EDUCATION AND AGRICULTURAL PRODUCTIVITY

Study	N	Nonformal Education Variable	Coefficient on Productivity	t-Statistic	R^2	Evidence of Interaction with Formal Education	Comments
Brazil (Pachico and Ashby 1976) . . .	382 (total sample)	N contacts between the farm operator and government Ext agent	−.010	−2.50	.65	The interaction term between schooling and Ext indicates these factors to be complements, but the relation was statistically insignificant	. . .
Brazil, Alto Saõ Francisco (Patrick and Kehrberg 1973).	82	N direct contacts between farmer and Ext agent	.004	.98	.44	Not applicable	Mean social benefit-cost ratio for Ext contacts was reported as 1.35
Brazil, Conceicao de Castelo (Patrick and Kehrberg 1973).	54	N direct contacts between farmer and Ext agent	.009	2.65	.82	Not applicable	Mean social benefit-cost ratio for Ext contacts was reported as 3.02
Brazil, Paracatu (Patrick and Kehrberg 1973).	86	N direct contacts between farmer and Ext agent	.001	.20	.59	Not applicable	Mean social benefit-cost ratio for Ext contacts was reported as .42
Brazil, Resende (Patrick and Kehrberg 1973).	62	N direct contacts between farmer and Ext agent	.001	1.11	.55	Not applicable	Mean social benefit-cost ratio for Ext contacts was reported as .165
Brazil, Vicosa (Patrick and Kehrberg 1973).	337	N direct contacts between farmer and Ext agent	.003	1.03	.62	Not applicable	Mean social benefit-cost ratio for Ext contacts was reported as .68
Japan (Harker 1973).	971	Use of agricultural magazines, Ext agents, and agricultural broadcasts	$r = .14$	. . .*	.38	Not applicable	A path analysis was utilized; coefficient is standardized partial correlation coefficient

NOTE.—Ext = extension, Ed = education.
* $P < .001$.

TABLE 6 (*Continued*)

Study	N	Nonformal Education Variable	Coefficient on Productivity	t-Statistic	R^2	Evidence of Interaction with Formal Education	Comments
Kenya (Hopcraft 1974)...........	674	Ext visits:					
		indicator (1–3),	.153	1.67	.56	Not applicable	Interaction between schooling and extension was significant and negative
		indicator (4–7),	.272	2.72			
		indicator (>7);	.035	.47			
		Farmers' training center course:					
		indicator (1 course),	−.014	.12			
		indicator (≥2 courses);	.135	1.23			
		Demonstrations:					
		indicator (1 or 2),	.393	4.68			
		indicator (≥3)	.197	1.83			
Kenya (Moock 1973).............	152	Ext index computed by multiplying rotated factor scores of different Ext measures by standardized observations and summing the products	.003	.77	.64	Moock (1978), in a reanalysis of his original data, finds a negative interaction between Ed and Ext	...
Korea (Hong 1975)..............	895	Log-linear investment in Ext	.832	3.55	.85	Log-linear Ext × Ed $B = .6039$ $t = -3.871$	Investment in Ext had a significant effect on both technical and allocative efficiency; one won investment in Ext per farm per year brought 4.49 won to rice production per yr; Ext efforts for older farmers with more schooling contributed more than Ext efforts for younger ones
		Log-log investment in Ext	3.240	6.00	.85	Cobb-Douglas Ext × Ed $B = .605$ $t = 121.0$	
Malaysia (Jamison and Lau 1978)...	403	Exposure to adult agricultural Ext classes	.237	1.73	.69	Not applicable	...

NOTE.—Ext = extension, Ed = education.
* $P < .001$.

TABLE 6 (*Continued*)

Study	N	Nonformal Education Variable	Coefficient on Productivity	t-Statistic	R^2	Evidence of Interaction with Formal Education	Comments
Philippines (Halim 1976) 1963 sample	274	N weighted Ext contacts	.00663	3.44	.77	Formal schooling × Ext $B = -.00028$, $t = .205$; Formal schooling × Ext × barrio, development index $B = .00008$, $t = .727$	Overall rate of return to Ext was P 8.12 for each P 5.69 invested or 70% (combined samples); schooling and Ext effects were found to be negatively related in all periods, but when a development index (constructed by Guttman scaling) was added the relation was positive; schooling and Ext effects could substitute for each other in less developed barrios, but the effects could be complementary in the dynamic conditions of more developed barrios
Philippines (Halim 1976) 1968 sample	273	N weighted Ext contacts	.004	2.40	.70	Formal schooling × Ext $B = -.00038$, $t = -.118$; Formal schooling × Ext × barrio, development index, $B = .00001$, $t = .333$	See comments, 1963 sample
Philippines (Halim 1976) 1973 sample	220	N weighted Ext contacts, 1963–68	0	−.77	.80	Formal schooling × Ext $B = -.0006$, $t = -.352$; Formal schooling × Ext × barrio, development index, $B = .0001$, $t = 1.00$	See comments, 1963 sample

NOTE.—Ext = extension, Ed = education.
* $P < .001$.

TABLE 6 (*Continued*)

Study	N	Nonformal Education Variable	Coefficient on Productivity	t-Statistic	R^2	Evidence of Interaction with Formal Education	Comments
Thailand (Jamison and Lau 1978)...	91 (farms using chemical fertilizer)	N Ext visits to village	−.123	−1.53	.78	A_5Ex_1 = 1 if Ext available, B = .015, t = .718, A_5Ex_0 = 1 if Ext not available, B = .036 t = 2.316	Ext had negative coefficient and Ed had positive coefficients on farm profits for farms using chemical fertilizer
Thailand (Jamison and Lau 1978)...	184 (farms not using chemical fertilizer)	Whether Ext was available in village	.085	2.22	.81	A_5Ex_1 = 1 if Ext available, B = −.032, t = 2.695; A_5Ex_0 = 1 if Ext not available, B = −.016, t = 1.291	Ed and Ext had positive coefficients on farm profits for farms not using chemical fertilizer

NOTE.—Ext = extension, Ed = education.
* $P < .001$.

TABLE A1

INFORMATION CONTAINED IN STUDIES OF SMALL-FARM PRODUCTIVITY

Country and Site	Reference	N	Modernizing Environment	Education Variable	Dependent Variable	Types of Analysis Efficiency/ Specification*	Other Variables
Brazil:							
Candelaria......	Pachico and Ashby 1976	117	No	$D > 5$ yr of schooling completed by farm operator	Value of farm production	Technical/eq. (3)	Land Q, human labor, machine labor V, animal labor V, purchased inputs V
Garibaldi.......	Pachico and Ashby 1976	101	Yes	$D > 5$ yr of schooling completed by farm operator	Value of farm production	Technical/eq. (3)	Land Q, human labor, machine labor V, animal labor V, purchased inputs V
Guarani........	Pachico and Ashby 1976	63	No	$D > 5$ yr of schooling completed by farm operator	Value of farm production	Technical/eq. (3)	Land Q, human labor, machine labor V, animal labor V, purchased inputs V
Taquari........	Pachico and Ashby 1976	101	Yes	$D > 5$ yr of schooling completed by farm operator	Value of farm production	Technical/eq. (3)	Land Q, human labor, machine labor V, animal labor V, purchased inputs V
Alto Saõ Francisco.....	Patrick and Kehrberg 1973	82	Transition	Years of schooling completed by farm operator	Value of farm production, less value of purchased nonlabor inputs	Technical and allocative/eq. (2)	Farm resources V
Conceicao de Castelo.......	Patrick and Kehrberg 1973	54	No	Years of schooling completed by farm operator	Value of farm production, less value of purchased nonlabor inputs	Technical and allocative/eq. (2)	Farm resources V

NOTE.—D = dummy variable, Q = measure of quantity, V = measure of value.
* The specifications are labeled eqq. (1)–(5), and these refer to eqq. (1)–(5) in text.

TABLE A1 (*Continued*)

Country and Site	Reference	N	Modernizing Environment	Education Variable	Dependent Variable	Types of Analysis Efficiency/ Specification*	Other Variables
Paracatu.......	Patrick and Kehrberg 1973	86	No	Years of schooling completed by farm operator	Value of farm production, less value of purchased nonlabor inputs	Technical and allocative/eq. (2)	Farm resources V
Resende........	Patrick and Kehrberg 1973	62	Yes	Years of schooling completed by farm operator	Value of farm production, less value of purchased nonlabor inputs	Technical and allocative/eq. (2)	Farm resources V
Vicosa.........	Patrick and Kehrberg 1973	337	Yes	Years of schooling completed by farm operator	Value of farm production, less value of purchased nonlabor inputs	Technical and allocative/eq. (2)	Farm resources V
Colombia:							
Chinchiná......	Haller 1972	77	Yes	Average of grades of schooling completed by working farm family members over 14 yr; M = 2.8 grades	Value of farm production	Technical/eq. (1), internal rate of return	Land V, family labor Q, hired labor Q, power capital V, fixed capital V
Espinal.........	Haller 1972	74	Yes	Average of grades of schooling completed by working farm family members over 14 yr; M = 2.4 grades	Value of farm production	Technical/eq. (1)	Land V, family labor Q, hired labor Q, power capital V, fixed capital V

NOTE.—D = dummy variable, Q = measure of quantity, V = measure of value.
* The specifications are labeled eqq. (1)–(5), and these refer to eqq. (1)–(5) in text.

TABLE A1 (*Continued*)

Country and Site	Reference	N	Modernizing Environment	Education Variable	Dependent Variable	Types of Analysis Efficiency/ Specification*	Other Variables
Málaga........	Haller 1972	74	No	Average of grades of schooling completed by working farm family members over 14 yr; M = 1.6 grades	Value of farm production	Technical/eq. (1)	Land V, family labor Q, hired labor Q, power capital V, fixed capital V
Moniquirá......	Haller 1972	75	No	Average of grades of schooling completed by working farm family members over 14 yr; M = 1.6 grades	Value of farm production	Technical/eq. (1)	Land V, family labor Q, hired labor Q, power capital V, fixed capital V
Greece:							
Epirus.........	Yotopoulos 1967	430	No	Average of years of schooling completed by farm household members, age 15–69 yr; M = 2.24 yr	Value of agricultural production	Technical/eq. (1)	Land Q, human labor Q, animal labor V, machine labor V, services V
India:							
Punjab, Haryana, Uttar Pradesh	Chaudhri 1974	1,038	...	Average years of schooling completed by all agricultural workers in household; years of schooling completed by household head	Value of agricultural production	Technical/eq. (1)	Irrigated land Q, cultivated land Q, human labor V, chemical fertilizer V, manure V, bullocks Q

NOTE.—D = dummy variable, Q = measure of quantity, V = measure of value.
* The specifications are labeled eqq. (1)–(5), and these refer to eqq. (1)–(5) in text.

TABLE A1 (*Continued*)

Country and Site	Reference	N	Modernizing Environment	Education Variable	Dependent Variable	Types of Analysis Efficiency/ Specification*	Other Variables
Punjab.........	Sidhu 1976	236 (traditional and Mexican wheat)	...	Average years of schooling completed by farm household members over 13 yr; M estimated to be 2.6 from subsamples	Wheat production Q, sale value of farm production	Technical/eq. (1)	Land Q, labor Q, capital services V, fertilizers V, wheat type D
Punjab.........	Sidhu 1976	369 (Mexican wheat)	...	Average years of schooling completed by farm household members over 13 yr; M estimated to be 2.6 from subsamples	Wheat production Q, sale value of farm production	Technical/eq. (1)	Land Q, labor Q, capital services V, fertilizers V, year
Israel...........	Sadan, Nachmias, and Bar-Lev 1976	1,841	Mixed	Years of schooling completed by farm operator's wife	Gross value added of farm production	Technical/eq. (4)	Herd Q, irrigation D, family size
Japan:							
Honshu, Shikoku, and Kyushu......	Harker 1973	971	Yes	Years of schooling completed by farmer	Gross farm sales	Technical/eq. (4) (path analysis)	Use of agricultural media and agents, ownership of power implements, father's education, farm location, age, land
Kenya:							
Vihiga.........	Moock 1973	152	Yes	$D \geq 4$ yr of schooling completed by farm manager	Bags of maize produced	Technical/eq. (3)	Interplanted crop D, hybrid seed D, plant population Q, insecticide D, rate of phosphate Q, previous season, labor Q, crop damage Q, extension contact D, loan recipient D, migration/age Q, female manager D

NOTE.—D = dummy variable, Q = measure of quantity, V = measure of value
* The specifications are labeled eqq. (1)–(5), and these refer to eqq. (1)–(5) in text.

TABLE A1 (*Continued*)

Country and Site	Reference	N	Modernizing Environment	Education Variable	Dependent Variable	Types of Analysis Efficiency/ Specification*	Other Variables
Kenya...........	Hopcraft 1974	674	Mixed	Dummy variables for schooling of household head	Bags of maize produced (other regressions examined livestock, tea, and aggregate output)	Technical/eq. (3)	Cultivated land Q, labor Q, purchased inputs V, extension visits Q
Korea............	Hong 1975	895	...	Years of schooling completed by farm operator; $M = 4.2$ yr	Value of rice production	Technical	Land Q, labor Q, capital V, extension V, age of farm operator, age^2, interactions
Korea............	Jamison and Lau 1978	1,363 (mechanical farms)	...	Average number of years of education	Value of agricultural production	Technical/eq. (2)	Land Q, human labor Q, animal labor Q, machine labor, capital V, fertilizers and pesticides, regions D, sex of head of household D, age of head of household Q
Korea............	Jamison and Lau 1978	541 (non-mechanical farms)	...	Average number of years of education for household members aged 17–60; $M = 4.95$ yr	Value of agricultural production	Technical/eq. (2)	Land Q, human labor Q, animal labor Q, capital V, fertilizers and pesticides, regions D, sex of head of household D, age of head of household Q
Malaysia: Kedah and Perlis........	Jamison and Lau 1977	403	Yes	$D = 0$, $D = 1$–3, $D = 4$ yr of schooling completed by head of household	Rice production Q	Technical/eq. (3)	Cultivated land Q, capital input V, variable input V, labor Q, years of double cropping D

NOTE.—D = dummy variable, Q = measure of quantity, V = measure of value.
* The specifications are labeled eqq. (1)–(5), and these refer to eqq. (1)–(5) in text.

TABLE A1 (*Continued*)

Country and Site	Reference	N	Modernizing Environment	Education Variable	Dependent Variable	Types of Analysis Efficiency/ Specification*	Other Variables
Nepal:							
Bara...........	Pudasaini 1976	102	Mixed	Years of schooling completed by farm operator	Gross farm revenue	Technical/eq. (2)	Land, labor, cash expenses, bullocks V, machines and tools V, land fragments, animal labor, tractor labor, pumpset used, tractor and pumpset used D
Nuwakot.......	Calkins 1976	540	No	$D \geq 6$ yr total schooling obtained by family members	Value of farm production	Technical	Land V, family labor Q, hired labor Q, bartered labor Q, farmyard manure Q, chemical fertilizer Q, capital V, altitude Q, nutritional status of laborers Q, interaction terms
Rupandehi.....	Sharma 1974	87 (wheat farms)	Yes	D = literate	Wheat production Q	Technical/eq. (3)	Cultivated land Q, labor Q, seed Q, organic manure Q
Rupandehi.....	Sharma 1974	138 (rice farms)	Yes	D = literate	Rice production Q	Technical/eq. (3)	Cultivated land Q, labor Q, seed Q, organic manure Q
Philippines:							
Laguna 1963....	Halim 1976	274	...	Average years of schooling completed by all agricultural workers in household (weighted)	Average annual rice production, net farm earnings	Technical/eq. (2)	Cultivated land Q, labor Q, operating expenditures V, extension contacts Q, barrio development index D, type of extension D

NOTE.—D = dummy variable, Q = measure of quantity, V = measure of value.
* The specifications are labeled eqq. (1)–(5), and these refer to eqq. (1)-(5) in text.

TABLE A1 (*Continued*)

Country and Site	Reference	N	Modernizing Environment	Education Variable	Dependent Variable	Types of Analysis Efficiency Specification*	Other Variables
Laguna 1968....	Halim 1976	273	...	Average years of schooling completed by all agricultural workers in household (weighted)	Average annual rice production, net farm earnings	Technical/eq. (2)	Cultivated land Q, labor Q, operating expenditures V, extension contacts Q, barrio development index D, type of extension D
Laguna 1973....	Halim 1976	220	...	Average years of schooling completed by all agricultural workers in household (weighted)	Average annual rice production, net farm earnings	Technical/eq. (2)	Cultivated land Q, labor Q, operating expenditures V, extension contacts Q, barrio development index D, type of extension D
Taiwan...........	Wu 1971	333 (rice farms)	Yes	Years of schooling completed by farm operator; 25% are primary graduates	Gross farm income	Technical/eq. (2)	Owned land V, family labor Q, livestock expenses, poultry and livestock V, farm tools and machinery V
Taiwan...........	Wu 1971	316 (banana and pineapple farms)	No	Years of schooling completed by farm operator; 25% are primary graduates	Gross farm income	Technical/eq. (2)	Owned land V, family labor Q, livestock expenses, poultry and livestock V, farm tools and machinery V
Taiwan...........	Wu 1977	310	Yes	Years of schooling completed by farm operator; $M = 6.7$ yr	Gross crop income	Technical and allocative/various specifications	Land Q, labor V, capital V, fertilizer V, other expenses V
Thailand:							
Chiang Mai.....	Jamison and Lau 1978	91 (chemical farms)	Yes	Years of schooling completed by head of household	Rice production Q	Technical and allocative/eq. (2)	Land Q, labor Q, capital V, region D, extension D
Chiang Mai.....	Jamison and Lau 1978	184 (nonchemical farms)	Yes	Years of schooling completed by head of household	Rice production Q	Technical and allocative/eq. (2)	Land Q, labor Q, capital V, region D, extension D

NOTE.—D = dummy variable, Q = measure of quantity, V = measure of value.
* The specifications are labeled eqq. (1)-(5), and these refer to eqq. (1)-(5) in text.

TABLE A2

EDUCATION'S EFFECTS AND ENVIRONMENTAL VARIABLES

Author, Region, and Sample	N	Formal Education: Functional Form*	Formal Education: Gain in Output per 1 Yr Education (%)	Formal Education: SE of Estimate of % Gain†	Nonformal Education: Variable	Nonformal Education: Regression Coefficient on Output	Nonformal Education: t-Statistic	Environmental Variables: Modernizing Environment‡	Environmental Variables: Extension Present or Not§	Environmental Variables: GNP per Capita‖	Environmental Variables: Crop	Environmental Variables: Adult Literacy Rate (%)#
Halim, Philippines:												
1963	274	2	2.2	1.3	Nonlog—of	.0063	3.435	0	1	285.16	Rice	72.0
1968	273	2	1.92	1.5	weighted	.0036	2.4	0	1	343.83	Rice	...
1973	220	2	2.74	1.2	contacts	−.00017	−.772	0	1	314.38	Rice	...
Haller:												
Chinchiná	77	1	−.29	2.2	...	...	...	1	0	...	Coffee	74.0
Espinal	74	1	6.10	3.5	...	...	...	1	0	...	Mixed	...
Málaga	74	1	3.09	3.3	...	...	...	−1	0	452.66	Tobacco	...
Moniquirá	75	1	−3.12	3.0	...	...	...	−1	0	...	Mixed	...
Jamison and Lau:												
Korea:												
Mechanical	1,363	2	2.22	.4	...	...	...	1	0	525.23	Mixed	91.0
Nonmechanical	541	2	2.33	.8	...	...	...	1	0	...	Mixed	...

* Numbers correspond to the Cobb-Douglas production function specifications given in eqq. (1)–(3).

† In order to calculate SE in the estimate of the percentage gain in output for 1 yr of education, one needs the value of the coefficient on education in the original regression (β), the estimated SE in the estimate of β (σ_β), and the functional form of the original regression. For all studies reported in this table the functional form was that of equation (1), (2), or (3) of Sec. I, and the corresponding formulas for SE are:

$$SE = \left[\!\left[\exp\left[2\beta \ln\left(\frac{\bar{E}+0.5}{\bar{E}-0.5}\right)\right] \exp\left[\ln\left(\frac{\bar{E}+0.5}{\bar{E}-0.5}\right)^2 \sigma_\beta^2\right] \left\{ \exp\left[\ln\left(\frac{\bar{E}+0.5}{\bar{E}-0.5}\right)^2 \sigma_\beta^2\right] - 1 \right\} \right]\!\right]^{1/2} \qquad (1')$$

where $\bar{E}$ is the mean number of years of education in the sample;

$$SE = [e^{2\beta} e^{\sigma_\beta^2}(e^{\sigma_\beta^2} - 1)]^{1/2}; \quad \text{and} \qquad (2')$$

$$SE = \left\{ \frac{1}{N^2} [e^{2\beta} e^{\sigma_\beta^2}(e^{\sigma_\beta^2} - 1)] \right\}^{1/2}, \qquad (3')$$

where N is the number of years of completed education signified by the indicator variable D.

‡ −1 = nonmodernizing environment; 1 = modernizing environment; and 0 = no information or a transitional environment.

§ −1 = no extension service available; 1 = availability of extension service in region; and 0 = no information on availability of extension.

‖ Source: "World Tables 1976," updated (Washington, D.C.: World Bank, 1978).

Source: *World Tables 1976* (Baltimore: Johns Hopkins University Press, 1976); India GNP figures are for 1973.

TABLE A2 (*Continued*)

Author, Region, and Sample	N	Functional Form*	Formal Education: Gain in Output per 1 Yr Education (%)	Formal Education: SE of Estimate of % Gain†	Nonformal Education: Variable	Nonformal Education: Regression Coefficient on Output	Nonformal Education: t-Statistic	Environmental Variables: Modernizing Environment‡	Environmental Variables: Extension Present or Not§	Environmental Variables: GNP per Capita‖	Environmental Variables: Crop	Environmental Variables: Adult Literacy Rate (%)#
Jamison and Lau (*cont'd*):												
Malaysia	403	3	5.11	2.2	Adult education participation	.2369	1.732	1	1	764.20	Rice	89.0
Thailand:												
Chemical	91	2	3.15	1.5	Nonlog—whether extension was available in village	−.09182	−1.098	1	1	317.42	Rice	82.0
Nonchemical	184	2	2.43	1.1		.08538	2.225	1	1	...	Rice	...
Moock, Kenya	152	3	1.73	1.1	Factored variables	.0027	0.77	1	1	216.00	Maize	30.0
Pachico and Ashby:												
Candelaria	117	3	2.69	3.3	N of contacts	−.010	−2.5	−1	1	...	Mixed	68.0
Garibaldi	101	3	4.60	2.7		...	...	1	1	...	Mixed	...
Guarani	63	3	1.49	2.9		...	...	−1	1	1,225.87	Mixed	...
Taquari	101	3	5.53	3.8		...	...	1	1	...	Mixed	...
Patrick and Kehrberg:												
Alto Saõ Francisco	82	2	−1.29	2.0	Nonlog—of visits	.00432	.977	0	1	...	Mixed	68.0
Conceicao de Castelo	54	2	−.90	1.2		.00901	2.650	−1	1	...	Coffee	...
Paracatu	86	2	−1.79	1.2		.00056	.203	−1	1	955.04	Mixed	...
Resende	62	2	1.01	.9		.00099	.124	1	1	...	Dairy	...
Viscosa	337	2	2.33	.8		.00268	1.026	1	1	...	Mixed	...
Pudasaini, Nepal	102	2	1.3	.8	...	...	...	0	−1	97.21	Rice	14.0
Sharma, Nepal:												
Wheat	87	3	5.09	3.1	...	...	...	1	−1	108.62	Wheat	14.0
Rice	138	3	2.85	1.7	...	...	...	0	−1	...	Rice	...
Sidhu, India:												
Traditional and Mexican wheat	236	1	1.49	.8	...	...	...	0	0	125.02	Wheat	36.0
Mexican wheat	369	1	1.41	.6	...	...	...	0	0	...	Wheat	36.0
Wu, Taiwan:												
1971, rice	333	2	.70	1.3	...	...	...	1	0	583.69	Rice	73.0
1971, banana and pineapple	316	2	3.87	1.4	...	...	...	1	0	...	Mixed	...
1977	310	2	.9	1.0	...	...	...	1	0	997.35	Mixed	73.0
Yotopoulos, Greece	430	1	6.47	3.2	...	...	...	−1	0	1,356.68	Mixed	82.0

Appendix B

Sources Referred to in Tables 1–6 and A1–A2

Calkins, P. "Shiva's Trident: The Effect of Improving Horticulture on Income, Employment and Nutrition." Ph.D. dissertation, Cornell University, 1976.

Chaudhri, D. P. "Effect of Farmer's Education on Agricultural Productivity and Employment: A Case Study of Punjab and Haryana States of India (1960–1972)." Mimeographed. Armidale: University of New England, 1974.

Chaudhri, D. P. *Education, Innovation and Agricultural Development: A Study of North India (1961–72)*. London: Croom Helm, Ltd., 1979.

Halim, Abdul. "Schooling and Extension and Income Producing Philippine Household [*sic*]." Mimeographed. Bangladesh: Department of Agriculture Extension and Teachers Training, Bangladesh Agricultural University, 1976.

Haller, Thomas E. "Education and Rural Development in Colombia." Ph.D. dissertation, Purdue University, 1972. *Dissertation Abstracts International* 33A, no. 6 (1972): 898. University Microfilms no. 72-30898.

Harker, Bruce R. "The Contribution of Schooling to Agricultural Modernization: An Empirical Analysis." In *Education and Rural Development*, edited by P. Foster and J. R. Sheffield. London: Evans Bros., 1973.

Hong, K. Y. "An Estimated Economic Contribution of Schooling and Extension in Korean Agriculture." Ph.D. dissertation, University of the Philippines at Los Banos, 1975.

Hopcraft, Peter N. "Human Resources and Technical Skills in Agricultural Development: An Economic Evaluation of Educative Investments in Kenya's Small-Farm Sector." Ph.D. dissertation, Stanford University, 1974.

Jamison, Dean T., and Lau, Lawrence J. *Farmer Education and Farm Efficiency*. Baltimore: Johns Hopkins University Press, in press.

Moock, Peter R. "Managerial Ability in Small Farm Production: An Analysis of Maize Yields in the Vihiga Division of Kenya." Ph.D. dissertation, Columbia University, 1973.

Moock, Peter R. "Education and Technical Efficiency in Small Farm Production." Paper presented at the Comparative and International Education Society Annual Meeting, Mexico City, March 1978.

Pachico, Douglas H., and Ashby, Jacquiline A. "Investments in Human Capital and Farm Productivity: Some Evidence from Brazil." Unpublished paper, Cornell University, Ithaca, N.Y., 1976.

Patrick, George F., and Kehrberg, Earl W. "Costs and Returns of Education in Five Agricultural Areas of Eastern Brazil." *American Journal of Agricultural Economics* 55 (1973): 145–54.

Pudasaini, Som P. "Resource Productivity Income and Employment in Traditional and Mechanized Farming of Bara District, Nepal." Master's thesis, University of the Philippines at Los Banos, 1976.

Sadan, Ezra; Nachmias, Chava; and Bar-Lev, Gideon. "Education and Economic Performance of Occidental and Oriental Family Farm Operators." *World Development* 4 (1976): 445–55.

Sharma, Shalik R. "Technical Efficiency in Traditional Agriculture: An Econometric Analysis of the Rupandehi District of Nepal." Master's thesis, Australian National University, 1974.

Sidhu, Surjit S. "The Productive Value of Education in Agricultural Development." *Economic Development and Cultural Change*, in press.

Sidhu, Surjit S., and Baanante, Carlos A. "Farm-level Fertilizer Demand for Mexican Wheat Varieties in the Indian Punjab." *American Journal of Agricultural Economics*, in press.

Wu, Craig C. "The Contribution of Education to Farm Production in a Transitional Farm Economy." Ph.D. dissertation, Vanderbilt University, 1971. *Dissertation Abstracts International* 32A, no. 5 (1971): 338. University Microfilms no. 71-29338.

Wu, Craig C. "Education in Farm Production: The Case of Taiwan." *American Journal of Agricultural Economics* 59 (November 1977): 699–709.

Yotopoulos, Pan A. "The Greek Farmer and the Use of His Resources." *Balkan Studies* 8 (1967): 365–86.

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