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Education and Farm Productivity in Post-'green revolution' Agriculture in Asia

INTRODUCTION

Most of Asia has experienced rapid growth in agricultural productivity, beginning with the 'green revolution' period in the 1960s, when improved wheat and rice varieties were adopted extensively and fertilizer use and investment in irrigation increased. In the wake of these changes, Asian agriculture has now entered a 'post-green revolution period', in which modern varieties cover most medium- and high-potential areas (including many rainfed areas) and input use is quite high. Increasing productivity now requires continued investment in research to raise the production frontier (for example, by releasing newer generations of high-yielding varieties). In addition, as this paper shows, substantial opportunities exist to raise productivity through using available resources in agriculture more efficiently to move closer to the current production frontier.

The 'green revolution' approach to agricultural development was a manifestation of Schultz's (1964) 'high pay-off input' hypothesis. Following the failure of the community development approach to promoting agricultural change in the 1940s and 1950s (which emphasized, among other things, investment in agricultural extension), the 'poor but efficient' hypothesis of small-farmer agriculture came to be widely accepted. According to this hypothesis, farmers were already using their limited resources efficiently, so there were low returns to investment in education, agricultural extension and farm management efforts to utilize available resources more efficiently. Change had to come instead from introducing new, high-yielding technology to raise the production frontier.

While it is generally accepted that the 'high pay-off input' approach paid high dividends, it may have led to relative neglect of the human capital dimension of agricultural development. It is a fundamental tenet of this paper that, in the new 'post-green revolution' stage of agricultural development, there are high returns to improving farmers' information and skills to enhance the efficiency with which they use the new technology. This opportunity arises from a

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combination of factors: the complexity of 'post-green revolution' agriculture, resulting from agricultural intensification and the wide range of external inputs used; and the dynamic technical and economic environment in which farmers must now make decisions. At this stage of agricultural development in Asia, there are likely to be significant opportunities to substitute increased skills and information for higher levels of input use, and to use that knowledge to conserve the resource base (Byerlee, 1992). A good example of such an opportunity is integrated pest management to reduce pesticide use through better information on insect populations. In addition, new research discoveries lead to rapid change in the technical environment, while the increasing commercialization of agriculture and recent policy reforms have often caused sharp changes in the economic environment.

The importance of investment in human capital in this new stage of agricultural development is, of course, consistent with another important contribution of Schultz (1975), which is that formal schooling will have 'value in dealing with disequilibria' in a technically dynamic agriculture through more rapid adjustment in resource use towards the economic optimum. While this aspect of Schultz's work has been applied largely in the context of agriculture in industrialized countries, there is little doubt that it is now equally applicable to Asian agriculture, where the concept of 'poor but efficient' farmers first evolved.

Many studies in various parts of the developing world have analysed the economic efficiency with which farmers use their stock of resources and technologies and identified factors that influence the level of efficiency; for a comprehensive review, see Ali and Byerlee (1991). This paper updates that review, emphasizing the role of investment in farmers' human capital through formal schooling to increase efficiency in Asian agriculture.

CONCEPTUAL FRAMEWORK

Types and measures of inefficiencies

It is generally accepted that, for a given technological frontier, there are two types of inefficiencies: technical and allocative (Farrell, 1957). Technical inefficiency arises when less than maximum output is obtained from a given combination of inputs (that is, failure to operate on the production frontier).[1] Allocative inefficiency arises when inputs are used in combinations that do not minimize the cost of producing a given level of output (that is, failure to equate the ratio of marginal product of each input to the ratio of input and output prices).

Perfect technical and allocative efficiency implies that the firm is minimizing cost for a given level of output (that is, operating on the expansion path). If there are fixed factors or economies of scale, further allocative gains might be made by movement along the expansion path to the profit-maximization point (that is, scale errors). A final source of inefficiency is failure immediately to adopt available technology that moves the production frontier upwards (Jamison and Lau, 1982).

Two major approaches, the *frontier* and the *direct* approach, have been used to measure technical inefficiency and its causes.[2] In the frontier approach, deviation from the production frontier is used as the measure of technical inefficiency.[3] The level of technical inefficiency for an individual farmer can then be related to his or her managerial characteristics, such as technical knowledge and skills, education and extension contacts, as well as to institutional factors such as farm size, tenancy, access to credit and supply of inputs. Hence a two-stage process is used:

$$Y_n = f(X, E) + u_n,\ u_n = \mathrm{h}(M),$$

where Y_n is output, X is the vector of inputs under the farmer's control, E is the set of environmental variables not directly under the farmer's control, u_n is the measure of an individual farmer's technical inefficiency and M is a set of non-conventional inputs, reflecting farmers' managerial skills and the institutional environment.[4]

In the *direct* or non-frontier approach, on the other hand, all the variables, including conventional inputs, non-conventional inputs and environmental variables, are included directly in the production function: that is, $Y = f(X, M, E)$. This approach allows for interaction effects of the conventional and non-conventional variables; however, it does not provide an absolute measure of technical inefficiency.

There are advantages and disadvantages to each of these estimation methods, although we consider the frontier approach to be conceptually superior, but more difficult to apply in practice. In this paper we will consider both approaches in order to accumulate evidence on the importance of managerial qualities (education and technical knowledge) for farm productivity in a modernizing Asian agriculture. A further refinement of the frontier approach, based on estimation of the *profit frontier*, has been used to estimate both technical and allocative efficiency. As with the stochastic production frontier, deviation from the profit frontier is decomposed into two components: the random error and the error owing to economic inefficiency, which can be further disaggregated into technical and allocative inefficiency. These inefficiencies can in turn be related to the effect of managerial and other institutional variables. However, in practice the distinction between technical and allocative efficiency may depend on the specification of the production or profit frontier. A more aggregated specification tends to increase technical inefficiencies at the expense of allocative inefficiencies (Ali and Byerlee, 1991).

Effects of formal schooling on efficiency

Various factors are likely to influence the types of efficiencies enumerated above in different ways. These can be classified broadly into (1) information and managerial qualities of farmers, including education; (2) risk effects; (3) input supply problems; and (4) institutional factors, such as tenancy and imperfect capital markets. In general, the major source of technical and allocative inefficiency is likely to be the management qualities of farmers, such as formal schooling, extension contacts, and technical knowledge and skills. For other types of inefficiencies, information and managerial qualities may also be important, though less so than the other factors, such as risk and capital constraints (Ali and Byerlee, 1991; Jamison and Moock, 1984; Cotlear, 1986). In a rapidly changing technical and economic environment, education is hypothesized to have major allocative effects by allowing farmers to adjust more quickly to a new equilibrium (Schultz, 1975; Huffman, 1974). In addition to reducing economic inefficiencies, formal schooling may increase farm productivity by accelerating the rate of adoption of new technologies and enabling the production frontier to move upwards more rapidly.

A number of specific products of education may influence farm efficiency. Normally, schooling does not *directly* provide information related to agriculture (Fuller, 1985), but it does impart basic competencies (literacy, numeracy and abstract reasoning ability) that enable farmers to adapt and learn new techniques more easily (Jamison and Moock, 1984; Cotlear, 1986). In other words, education develops the ability to 'learn to learn' (Welch, 1970) through skills in acquiring and evaluating information about improved techniques and economic opportunities. In this case, schooling may act as a substitute for extension. The skills fostered through education become particularly important in a dynamic agriculture, where the value of extension advice may depreciate rapidly (Welch, 1970).

Schooling may also *indirectly* affect the efficiency of resource use through more efficient 'transmission of information' obtained from many sources (for example, contacts with other farmers or with extension and other agencies related to agriculture). For example, literate farmers can use a wide range of written information, and in this way schooling may enhance farmers' ability to learn new techniques with a lower learning cost (Ram, 1981; Cotlear, 1986). Extension costs can be reduced dramatically by investing in literacy for the farming population (Byerlee, 1987).[5] Thus the relationship between schooling and extension may also be complementary.

EVIDENCE ON EDUCATION AND FARM PRODUCTIVITY IN ASIA

Estimates of inefficiency in Asian farming

Table 1 summarizes results of studies to estimate levels of inefficiencies on Asian farms using the frontier production approach (see Ali and Byerlee, 1991, for details). Substantial evidence now exists that technical inefficiency is quite high; the average level of inefficiency is about 30 per cent in the studies in Table 1, with wide variation, from 16 per cent to over 50 per cent. There may be two major reasons for such wide variation in these estimates. First, although most of these studies have estimated a stochastic frontier production function, the results are still quite sensitive to the number of inputs specified, the level of aggregation of these inputs and the inclusion of environmental variables (soil type and other field-specific characteristics). Second, these estimates have been obtained at different points in time and refer to different agricultural settings (for example, traditional versus modernizing agriculture).

Despite the number of studies available, the evidence on whether farmers' technical inefficiency is higher in traditional environments or in modernizing

TABLE 1 *Summary of empirical estimates of technical inefficiency and its causes in Asian agriculture*

Source, location and year of study	Crop	Method of estimation	Average % inefficiency	Factors influencing inefficiency
Kalirajan (1981) (Tamil Nadu, India, 1978)	Rice	Stochastic frontier with MLE (CD)	53	Education (–) Experience (–)** Knowledge (–)** Extension contact (–)** Share tenant (+)
Kalirajan and Flinn (1981) (Bulcan, Philippines, 1980)	Rice	Stochastic frontier with MLE (CD)	20	Education (–) Age (–) Tenant (–) Extension contact (–)** Planting method **
Lingard *et al.* (1983) (Central Luzon, Philippines, 1970–79)	Rice	Analysis of covariance with firm-specific dummies (CD)	50	Education (–)** Age (–) Credit access (–)** Share tenant (+)** Land title
Kalirajan and Flinn (1983) (Bicol, Philippines, 1980)	Rice	Stochastic frontier with MLE (TL)	50	Education (–) Age (–) Experience (–)** Extension contact (–)** Planting method**

Belbase and Grabowski (1985) (Nepal, 1974–5)	(a) Rice (b) Maize	Probabilistic (CD)	(a) 16 (b) 33	Education (–)** Income (–)** Nutrition (–)** Experience (–)
Flinn and Ali (1986) (Punjab, Pakistan, 1982)	Rice	Stochastic frontier with MLE (CD)	21	Education (–)** Own tenancy (–) Farm size (+) Crop establishment (+)* Late fertilizer (+)** Water problem (+)*
Hussain (1989) (NWFP, Pakistan, 1987)	Wheat	Stochastic frontier with MLE (CD)	31	New seed (–)* Seed treatment (–)** Density (–)* Weeds (+) Sowing date (–) Knowledge score (–)*

Notes: MLE: maximum likelihood estimates; CD: Cobb Douglas; TL: translog; and *, ** denote significance at 5% and 10% levels, respectively.

Source: Updated from Ali and Byerlee (1991). Includes only studies that have tested the effect of education. See Ali and Byerlee (1991) for a more complete listing.

environments and whether Asian farmers' technical inefficiency has grown or diminished over time is still inconclusive. Since most of these studies have been conducted in modernizing agricultural settings, it is difficult to compare technical efficiencies between traditional and modernizing environments. Ali and Byerlee (1991), however, concluded that the weight of evidence indicates that technical inefficiency is lower in a modernizing agricultural environment.

The evidence on whether technical efficiency has changed over time is even less conclusive. Following the conceptual framework developed above, technical inefficiency is expected to increase with the introduction of 'green revolution' types of technology and then decline in the post- 'green revolution' period as farmers learn to use the new technology. To measure such changes, it would be desirable to observe technical inefficiency of the same panel of farms over several years. Only two studies of this kind are available. Battese and Coelli (1991), using panel data, rejected the hypothesis that the level of technical inefficiency of individual rice farmers in a village in India did not vary over time. They found that the level of inefficiency fell from a range of 11–32 per cent in 1975–6 to 4–11 per cent in 1984–5. Dawson and Lingard (1989) used discrete points in time (1970, 1974, 1979 and 1982) to estimate technical inefficiency of a sample of rice farmers in Central Luzon, Philippines. Their results suggest no consistent trend, although the lowest level of inefficiency was observed in 1982. Since both studies correspond to the 'post-green revolution' period, they tend to support the hypothesis stated above.

A large number of studies in the 1970s and 1980s have tested for allocative inefficiencies of farmers in Asian countries by comparing the marginal value product (MVP) of inputs to their prices. These studies show a wide range of variation in K, the ratio of MVP of an input to its price (see Ali and Byerlee, 1991, for details). In general, the value of K tends to be higher for modern inputs such as fertilizer than for traditional inputs such as land and labour (Ali and Byerlee, 1991). However, these studies do not estimate absolute levels of allocative efficiencies and do not relate inefficiencies to farmers' managerial qualities. More recent studies have used a profit frontier for jointly estimating technical and allocative efficiencies, and the results generally indicate that technical inefficiency is substantially higher than allocative inefficiency (Ali and Byerlee, 1991).

Evidence on the relationship between education and efficiency

The relationship between education and efficiency and farm productivity in Asia has been analysed in numerous studies. The frontier studies summarized in Table 1 have related firm-specific technical efficiency to farmers' managerial qualities (for example, variables such as farmers' education, technical knowledge, experience and extension contacts) and other characteristics of farmers. Most of these studies have found an expected and significant effect of one or several of the management variables on technical efficiency. Education was found to be important in most of these studies as well (Table 1).

Some studies have related education and other characteristics of farmers to economic or profit efficiency, including the effects on both technical and allocative efficiency. Evidence on the effects of education on allocative efficiency is less conclusive than in the case of technical efficiency. At least three of these studies found a positive relationship between allocative efficiency and the level of formal schooling (Herdt and Mandac, 1981; Pudasaini, 1983; Ali and Flinn, 1989). However, capital scarcity, risk and input supply problems may be more important determinants of allocative inefficiency. Finally, to date no studies in Asia have examined the effect of formal schooling on the speed with which farmers adjust their use of modern inputs in the light of changes in the technical and economic environment (for example, Huffman, 1974, or Pingali and Carson, 1985, for the United States).

Many studies in Asia have included formal education or an index of farmers' technical knowledge as variables in the production function (the non-frontier or direct approach) to analyse the effect of education on productivity. Reviews of this literature are provided in Lockheed *et al.* (1980), Jamison and Lau (1982), Ali and Byerlee (1991) and Talik (1993). Most studies from Asia report that education had a positive and significant effect on farm productivity, ranging up to 30 per cent. Jamison and Lau (1982), summarizing analyses of 14 data sets from Asia, found that education had a positive effect on farm productivity in all cases and that this effect was nearly always statistically significant. Over all countries, including non-Asian developing regions, Jamison and Lau found that the average effect of the equivalent of at least four years of education on productivity was 9.5 per cent in a modernizing environment and only 1.3 per cent in a traditional setting. More recent studies in Asia in the 1980s and 1990s further support these conclusions. For example, in Nepal the completion of at least seven years of schooling increased productivity in wheat by 27–31 per cent and in rice by 13 per cent (Jamison and Moock, 1984). The effect of a similar level of education on farm productivity has been estimated to be 9 per cent in India (Duraisamy, 1992), 7–11 per cent in the Punjab, Pakistan (Butt, 1984) and 9–20 per cent for modern varieties of wheat and rice in Pakistan (Azhar, 1991). Other studies have expressed the effect of education in terms of the average increase in productivity per year of schooling. Compared with an average effect on productivity of about 2 per cent per year of schooling observed by Jamison and Lau (1982), recent studies have estimated effects ranging from 1 per cent per year in northwestern India (Feder *et al.*, 1987) to 2 per cent in the Philippines for farmers using agrochemicals (Cobb, 1987), to 2–3 per cent in Thailand (Chao and Lau, 1987) and to 4 per cent in India (Antle, 1984). In addition, in the Punjab of Pakistan, education was found to have a significant positive effect on productivity for farmers planting modern wheat or rice varieties, but it had no effect for farmers planting traditional varieties, again supporting the hypothesis that the link between education and productivity is greatest in a modernizing agriculture (Azhar, 1991).

Finally, numerous studies have shown that education has a positive effect on adoption of new technology; that is, on the rate at which the production frontier is shifted upwards (see Feder *et al.*, 1985, for a review). Recent studies from Asia support these findings: for example, Lin (1991) for China and Hussain *et al.* (1993) for Pakistan, although contrasting views are found in Pitt and Sumodiningrat (1991) for varietal choice in Indonesia. The effect of education may be largest in the early stages of adoption of a new technology (Hussain *et al.*, 1993).

Despite widespread and conclusive evidence that education is important in increasing farm productivity in Asia, few studies have investigated the specific products imparted by formal schooling that influence farm-level efficiency. Some studies have tried to estimate farmers' technical knowledge on the basis of tests of their knowledge of extension recommendations and, more importantly, their understanding of the scientific basis for using particular practices. These studies have generally shown critical deficiencies in farmers' technical knowledge of new inputs (Bhati, 1973; Hussain, 1989; Hussain *et al.*, 1993; Feder and Slade, 1984). In nearly all cases, educational level had a strong and significant effect on farmers' technical knowledge, implying that at least part of the benefit of education is the enhanced ability to acquire new knowledge. Very few attempts have been made to measure the effect of cognitive skills imparted through education, such as literacy, numeracy and abstract reasoning, on productivity. One study in Nepal that specifically measured cognitive skills found only a very weak relationship between those skills and education (Jamison and Moock, 1984).

We do not have convincing evidence on the threshold level of investment in education required to ensure increased efficiency in a modernizing agriculture. In India, elementary education was considered the threshold level during the 1960s (Talik, 1993). However, in the 'post-green revolution' period there may be high returns to secondary education (Heyneman, 1983). Some studies suggest that there are significant returns to secondary education relative to primary education (Talik, 1993; Butt, 1984; Duraisamy, 1992; Azhar, 1991) but, given wide variation in the quality of education, there are likely to be important trade-offs in the quantity and quality of education.

Interaction of formal and non-formal education in productivity

Non-formal education to reduce illiteracy in the rural population and disseminate knowledge of agricultural technology is also reported to be significant in improving farmers' productivity in some Asian countries. In China, spare time schools, winter schools, short-term literacy classes, educational radio and instruction in tea houses have given encouraging results in reducing illiteracy, increasing innovative skills and improving agricultural efficiency (Tao-Zhang, 1981). Adult educational activities (exposure to agricultural radio broadcasts and out-of-school literacy classes) were positively associated with farm productivity in Bangladesh (Fuller, 1983).

In Asia, the public-sector agricultural extension system is considered a major source of non-formal education related to agriculture. Although the issue is beyond the scope of this survey, it is important to note that the contribution of extension to agricultural development, although quite variable, has been found to be positive in several Asian countries (Talik, 1993; Feder and Slade, 1984; Duraisamy, 1992). Agricultural extension was shown to be a source of improved efficiency in some of the frontier studies shown in Table 1 (see Kalirajan, 1981; Kalirajan and Flinn, 1981, 1983). Several other studies in

Asia report a positive correlation between education and extension contact. Farmers who had higher levels of formal education participated more in non-formal education and extension activities in rural India (Talik, 1993) and similar findings have been reported recently for Pakistan (Hussain *et al.*, 1993). This suggests that education and extension may be complements (Lockheed *et al.*, 1980) but, as discussed above, education may also be a substitute for extension. For example, Sims (1985) partly attributes higher productivity in the Punjab of India compared to the Punjab of Pakistan to Indian farmers' better information and skills, which are not superior because of better extension services (which she rates as poor in both cases), but because Indian farmers' higher educational level enables them to seek out information for themselves.

Whether schooling is complementary to, or acts as a substitute for, extension probably depends on the technological environment in which farmers operate. For example, in Pakistan in the 'green revolution' period, schooling played a complementary role to extension wince the so-called 'progressive farmers' with large land holdings and higher levels of schooling were the main target for extension messages and demonstrations. However, the value of extension messages has diminished and in some cases become increasingly irrelevant in the 'post-green revolution' period since more educated farmers are able to bypass extension to obtain information from other sources, such as the private sector, or even from abroad.

Investment in schooling in rural Asia

The evidence reviewed above has focused on the relationship between education and farm productivity. We now turn to a very brief review of trends in Asian farmers' educational status and of prospects that current investments in rural schooling will meet the needs of Asian agriculture in the next century. Table 2 provides some indicators of investment in education for different parts of Asia and for other developing regions. Adult literacy rates in the Asian regions ranged from 42 per cent to 84 per cent during 1988–90, but they are always lower for the rural population, especially rural women. Literacy rates are lowest in South Asia (the major exception is Sri Lanka, which ranks among the highest in the developing world). However, literacy rates throughout developing countries, including Asia, have risen sharply during the past decade; in some Asian countries (for example, Korea, Indonesia and Sri Lanka) the increase is remarkable. Most of the increase in literacy rates has been achieved through formal schooling. For example, enrolment in primary and secondary school in South Asia rose from 45 per cent to 62 per cent of the school age population over the period 1970–90. Likewise the share of expenditure on education as a percentage of GNP in South Asia grew from 2.1 per cent in 1960 to 3.4 per cent in 1988, although it is still low as a share of public expenditures. In East and Southeast Asia, where economic growth is fastest, school enrolment and investment in education are considerably higher.

Although levels of education in most developing countries have risen, they are still lower than the levels that present-day industrialized countries experi-

TABLE 2 *Indicators of investment in education in developing countries*

Region	Adult literacy rate (%)		Primary and secondary enrolment (%)		Education expenditures			Mean years of schooling (adults 25+, 1990)	
					Percentage of GNP		Percentage of public-sector expenditures		
	1970	1990	1970	1987–90	1960	1988–90	1988–90	Male	Female
South Asia	33	42	45	62	2.1	3.4	9.0	3.5	1.3
Southeast Asia	67	84	59	76	n.a.	2.9	9.1	5.2	3.6
East Asia	n.a.	74	66	88	n.a.	2.8	12.8	6.2	3.7
Arab countries	30	51	46	71	3.5	6.1	17.1	3.9	1.7
Sub-Saharan Africa	28	47	26	46	2.4	3.4	13.9	2.2	1.0
Latin America	76	85	69	86	2.1	3.6	16.4	5.3	5.1
All developing countries	46	65	55	73	2.2	3.4	11.9	4.6	2.7

Note: n.a. = not available

Source: UNDP (1993).

enced 150 years ago (World Bank, 1991). Even for countries in East and Southeast Asia, which have the best record of investing in rural education, average adult educational levels of about five to six years of schooling (and less for females) remain well below those in industrialized countries, which now average over ten years. Numerous factors may contribute to lower levels of education in developing countries. High population growth combined with slow economic growth limits the allocation of resources to education (Tan and Mingat, 1992). Higher-income Asian countries generally have lower growth in the school-age population and report higher levels of education than the lower income countries, although there are clear exceptions, such as Sri Lanka. Investment in education ultimately depends on household decisions to send children to school.

Unfortunately, few studies analyse rural household decisions to invest in children's education or the effect of policy variables (such as the supply of schools) on these decisions (for example, Sabot, 1989, 1992). However, it is likely that investment in education is biased towards larger farmers and higher-income households. Although investment by agricultural households in education may be driven more by perceived opportunities for higher earnings in non-farm employment than by increasing agricultural productivity (Sabot, 1989, 1991), this situation may be changing. There is growing evidence that investment in education for those who work in agriculture now gives returns as high as in urban areas (Jamison and Lau, 1982; Jamison and Moock, 1984; Talik, 1993).

CONCLUSIONS

The evidence presented in this paper suggests that there are substantial opportunities to increase productivity in Asian agriculture by increasing the efficiency with which resources are used at the farm level. This review of farm-level studies in Asia suggests that the average level of technical inefficiency in Asia is about 30 per cent. Another group of studies also reveals substantial allocative inefficiencies, especially for modern production inputs such as fertilizers and other chemicals. While there is some evidence that levels of inefficiencies have declined over time, further research will be needed to observe trends in the level of inefficiencies in panels of farmers.

A large body of literature relates farmers' level of inefficiencies to human capital variables, especially formal schooling and informal education (extension). These studies strongly suggest that formal education improves farmers' ability to use new technologies more efficiently as well as to adopt new technologies more rapidly. In some cases, non-formal education (such as agricultural extension and adult literacy) has also been reported to be an important determinant of productivity. These results call for higher investment in formal schooling in rural areas as well as in extension services to accelerate agricultural productivity. However, there is growing evidence that, in a modernizing agriculture, extension meets deficiencies in rural education to only a limited extent. Investment in rural education may make extension much more cost-effective by allowing much greater use of written materials. Over the long run, education may increasingly take the place of extension by enabling farmers to acquire information and skills from a wider range of sources.

The need for education has become more important because of the complexities of farming systems as well as the rapid pace of change in the technical and economic environment in 'post-green revolution' agriculture. Indeed, because of substantial inequalities in the distribution of education in the rural population, both between and within countries, it is possible that biases in investment in education towards higher-income households will lead to growing inequalities in rural incomes in the future, both within and between countries. For example, in Pakistan, Byerlee (1987) found that 71 per cent of large farmers (with more than 10 ha of land) were literate, compared to only 32 per cent of small farmers (with less than 5 ha of land).

One way to meet future needs for human capital investments in agriculture is to aim for universal primary education in rural areas to provide some minimum competency in literacy, numeracy and cognitive skills. Several countries in Southeast and East Asia are close to this goal, but the populous countries in South Asia are still far from achieving this target. Furthermore, there is mounting evidence that, in 'post-green revolution' agriculture, there may be high returns to secondary education. Here even many of the fast-growing countries of Southeast and East Asia may be lagging. More work is needed to identify how specific policy measures foster increased investment in rural education. Expanding the number of elementary schools in rural areas where the majority of the people are farmers is likely to improve school attendance. Efforts to improve the quality of education will be as important as increasing the quantity of education. Some of the resources needed for this expanded investment may come from shifting public-sector resources from higher education – which costs very much more per capita – to primary and secondary education (Tan and Mingat, 1992).[6]

Investment in formal schooling has long-term pay-offs, since the educational level of farmers for many years into the future has already been established by past investments. In Asia, the average expected educational attainment of the *current school-age population* is still less than four years in Bangladesh and Nepal, compared to 11 years in Korea (Tan and Mingat, 1992). Even with increased investment in education over the past 20 years, large numbers of farmers in the next generation, mostly in South Asia, will be poorly prepared to participate in the modernizing process of Asian agriculture. For this reason, other means of imparting some of the skills provided by formal education, such as adult literacy programmes and other non-formal methods, will also be needed to provide the skills for tomorrow's farmers.

NOTES

[1]A usual definition of the production frontier is the maximum output that can be obtained by farmers from a given level of inputs.

[2]The interpretation and measurement of these efficiency indices depends upon the assumptions made about the economic environment that decision makers face (including their goals and objectives). Measurement of inefficiencies is also very dependent on the specification of the production function (including the functional form and the specification and level of aggregation

of inputs). These issues are discussed in detail in Hussain (1989) and Ali and Byerlee (1991). Various methodological refinements have been made to alleviate and address some of these issues, especially the measurement of technical efficiency (Battese, 1992).

[3]A number of approaches have been used to estimate the production frontier and each has different implications for estimates of technical inefficiency. These are reviewed extensively by Ali and Byerlee (1991) and Battese (1992).

[4]A three-stage process may be more appropriate, including (1) estimation of the level of individual farmer inefficiency, (2) estimation of the causes of inefficiencies in terms of the managerial practices used by farmers (such as timing and method of using inputs) and (3) estimation of the influence of managerial qualities on the use of these management practices (Hussain, 1989).

[5]The quantity and quality of formal schooling may differ markedly in their effect on farmers' formation of competencies and transmission of information. Sabot (1989, 1992), in the context of the rural labour wage market in Pakistan, suggests that cognitive skills were determined more by the quality than by the quantity of education. A social rate of return of 11 per cent was estimated for investment in improving the quality of primary schooling.

[6]Tan and Mingat (1992) estimate that the cost of primary, secondary and higher education per capita as a percentage of GNP is 10 per cent, 19 per cent and 149 per cent, respectively.

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