Human Capital, Education, and Agriculture

by

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Abstract

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Education is widely recognized as the most important form of human capital, and health as the second most important form. The primary focus is on schooling where private and social real rates of return remain high in low and middle income countries for elementary and secondary schooling. The paper reviews broad effects of education in agriculture, and examines some of the prospects and potential for the future. Conclusions include: (i) schooling cannot be viewed as unconditionally productive in agriculture. It s impact is conditioned by the price and technology environment and options for off-farm work and migration. (ii) With rapid advances and fall prices of communication and information technologies, farm people of the future will need strong basic schooling to adopt and use these technologies so as to participate successfully in the new global information system of the 21^{st} century. The structure of agriculture seems likely to change dramatically during the first 25 years, and a new set of adjustments for farm families can be expected.

Key words: Schooling, education, human capital, agriculture, information technologies, training, global agriculture

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Education is widely considered to be the most important form of human capital, and human health is the second most important form (Schultz, 1999). Formal education or general intellectual achievement is obtained primarily in elementary and secondary schools and in colleges and universities. Although the creation of useful skills for work has frequently focused only on formal schooling, there is growing recognition that useful skill creation starts early before an individual's formal schooling and continues after formal schooling ends, i.e., life-long learning, especially in developed countries (Heckman, 1999). Early childhood activities and experiences that are shaped by a child's family and community are very important to the formation of early ability, motivation, and social adaptability. Ability and learning seem to be dynamic complementary processes over time for children (Heckman, 1999). Postschooling forms of learning occur in learning-by-doing (e.g., apprenticeships, on-the-job training) and informal settings. Although some of this learning is difficult to measure, it has the potential to grow in importance over the next two decades with the rapid advances in communication and information technologies, the dramatic fall in the real cost of services from these technologies, and the prospects for rapid global adoption (World Bank, 1999).

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The most recent international empirical evidence shows that the return to schooling, both social and private, remains attractive (Psacharopoulos, 1994). In low-income countries, the social rate of return to investments in primary schooling is very high (about 23%), in secondary schooling is lower but attractive, and in higher education is the lowest (11%). In lower- and upper-middle income countries, the social rates of return to primary and secondary schooling are lower than for low-income countries, but the ordering of rates of return across schooling completion levels remains the same (Psacharopoulos, 1994, p. 1331).

The objective of this paper is to provide a review of the broad effects of education in agriculture and examine some of the prospects and potential for the future. Worldwide, about one-half of the labor force continues to be employed in agriculture. In the low-income countries, which account for about 55% of the world's population, the share of the labor force in agriculture exceeds 65%, but in developed countries, which account for about 15% of the world's population, the share of the labor force in agriculture is only 5% (World Bank, 2000). In what are now the developed countries, the long-term increase in agricultural productivity associated with advances in knowledge has been a major factor in the long-term transformation from an agrarian to an urban-based, service-oriented society (Johnson, 2000). The essay will be organized as follows: a conceptual framework, summary of empirical evidence, rapid changes on the horizon.

A Conceptual Framework

Growth in knowledge is a major factor causing the long-term rise in labor productivity, real wage rates, and per capita incomes in market economies. First, as the stock of knowledge grows, the opportunities for individuals to invest in specialized knowledge (e.g., schooling, training) that raises their productivity occurs (Becker and Murphy, 1993; Jones, 1998, p. 71-87). The returns to labor's specialization arise through workers taking on narrower and more specialized tasks. To get output produced, this means that workers who have different skills must frequently cooperate together. "Team production" within or across firms, however, raises special incentive problems (Becker and Murphy, 1993; Gibbons, 1998). As the degree of specialization of labor and tasks increases, the number of different tasks and specialists that must be coordinated increases. If growth through knowledge creation and transmission is to continue, markets must organize in a way to efficiently coordinate team labor. Economies that have high coordination/transaction costs because of weak institutions (i.e., absence of private property, weak contracts, suppressed prices and markets) make it very difficult for workers and firms to specialize, given any stock of knowledge, and reduce labor productivity and per capita incomes (Williamson, 1985). Second, as the stock of knowledge grows, the opportunities to produce new technologies that become embodied in new capital goods (e.g., Romer, 1990) and intermediate goods (see Jones, 1998, p. 88-107; Huffman and Evenson, 1993) occur.

Agricultural production has a large biological component where differences exist between crops and livestock. The seasonal and spatial nature of crop production places severe constraints on large-scale or specialized units and mechanized production. With plant biological (clocks) processes sequenced by day-length and temperature, little opportunity exists to use mechanization to speed up the production processes, even on large farms. Because planting and harvesting for any given crop must occur within a narrow time window at any location, a major limit to size of specialized enterprises occurs. In temperate climate regions, crop rotation, or nonspecialized production, has historically been one important method for controlling pest and disease problems in crops and balancing soil nutrient availability with plant nutrient needs. Chemical and biological control of pests and chemical fertilizer applications are relatively new technological alternatives to crop rotation, and they have facilitated crop specialization. Livestock production, however, is relatively free of constraints due to seasonal and spatial attributes. It is economically feasible to speed up or slow the rate of production by changing the diet and activity level of animals and poultry during the growing and finishing phases.

When firms are heterogeneous within a sector due to specialized resources—e.g., land, climate, knowledge—the potential impact of new technologies will differ across them. It is costly for entrepreneurs to acquire information, evaluate available technologies, and adopt only the new ones that are expected to benefit them. Considerable evidence exists that schooling of entrepreneurs is a valuable skill when the technology is changing; for example, when agriculture undergoes a transition from traditional to modernizing (Schultz, 1975; Becker, 1993; Huffman, 1998).

Multiperiod Agricultural Household Model

The decisions of agricultural households have been modeled from different perspectives depending on the central issue researchers are emphasizing. When human capital investment decisions—e.g., how much schooling, informal training, and information to obtain or whether to adopt a new technology—are the central focus, models of multiperiod household utility maximization with human capital production or innovation provide a useful guide to empirical models. When household members have obtained their human capital, e.g., formal education, and the impacts of this human capital on other outcomes—e.g., occupational choice, hours of work, purchased input use, wage rates, income—are the central focus, one-period static agricultural household models provide a useful guide to researchers (Singh et al., 1986). In particular, behavioral models provide one useful guide to researchers for deciding which variables should be treated as endogenous and which are exogenous or causal variables.

Consider a risk-neutral household living three periods. In each period, the farm household consumes human capital services and purchased goods that give utility. The production of human capital investment uses human capital services from the existing stock, purchased inputs, and a fixed individual household-specific genetic or innate ability factor and exhibits decreasing returns to scale in production. The production of farm output uses variable inputs of human capital services of household members and purchased inputs and is conditional on technology and agro-climatic conditions. The farm production technology exhibits decreasing returns to scale in the variable inputs (see Huffman, 1999 for details).

This modeling strategy treats human capital investment as changing the quantity of human capital services available for all uses but does not change the real wage for a unit of human capital services. Human capital depreciates at some constant rate, and available human capital services in each time period are allocated among leisure, human capital production, farm production, and wage work. The household faces a multiperiod discounted cash income constraint in maximizing its intertemporal utility function.

The following important results follow from this model. First, they provide the optimal size of the human capital investment in each period. It is the quantity or rate where the present value of the marginal return from a unit equals the present value of the marginal cost. Second, insights about the tendency for investing in skill to weaken or strengthen ties to farming are obtained by examining the present value of the marginal return to investment in human capital.

There are two effects--the change in the present value of the additional farm production that results from allocating part of an incremental unit of human capital services to this activity and the change in the present value of the additional labor market earnings that results from allocating the remaining part of an increment of human capital services to nonfarm wage work.

The allocation of an increment of human capital services between farm production and off-farm work is quite sensitive to the relative impact of human capital on the marginal product of labor in farm and nonfarm work or to the elasticity of demand faced by the individual for human capital services. If the marginal product of human capital services is low in farm production but relatively large in nonfarm wage work, and it is optimal to invest in human capital, then an agricultural household will increase the share of employed human capital services allocated to nonfarm wage work.

Third, given the three-period lifetime, a comparison of the present value of the marginal return to an investment in period t and t+1 shows that delaying the investment from t to t+1 significantly reduces the present value of the marginal return. Hence, it is optimal for agricultural households to make large human capital investments early in an individual's life rather than later. Furthermore, it is never optimal in this model for a household to invest any resources in human capital production in the final period (t+2), because there is cost but no return (see figure 1).

Fourth, because the marginal cost of human capital production is increasing, it will frequently be optimal for an agricultural household to spread its human capital investment in an individual over more than one period, even with finite life and associated reduction in the present value of the marginal return. Spreading the investment over time is a good decision when the cost saving exceeds the reduction in returns due to delaying (see figure 1). Fifth, if the length of life were to be extended to four periods (e.g., due to better public health measures), this would increase the demand for human capital investment, and other things being equal, increase life-time human capital (e.g., schooling) investment per individual (see also Huffman, 1999).

Some Implications

Schooling and learning-by-doing may be productive or unproductive in agriculture depending on economic conditions, but in economies with freely mobile resources, agriculture must compete with other sectors for skilled (and unskilled) labor. The wage for similarly skilled labor need not be equal across sectors, but in equilibrium the marginal compensation, including monetary value of nonmonetary attributes of the farm and nonfarm work, will be equal. Recently the U.S. farm-nonfarm compensating differential has been small (Huffman, 1996). Although technical change in agriculture is frequently at least as large as in the nonfarm sector of countries, the opportunities for raising labor productivity in agriculture through task specialization and coordination may be modest compared with the nonfarm sector. On a farm, the skilled individual may face a more inelastic demand for his/her services than in a large nonfarm business. Also, due to poor infrastructure and institutions, the agricultural sector may in some cases face small market size and high coordination costs that put it at a disadvantage.

In some agricultural environments, informal learning rather than schooling may be a more important form of human capital, while in other environments, schooling may be a better public investment (Schultz, 1964; Huffman, 1985, 1991; Becker, 1993, p. 1-13; Johnson, 2000). For example, in a traditional environment as exists in some low-income countries, accumulated experience is a better investment than schooling. Information accumulated informally does not depreciate when the decision-making environment is static. However, when the political and economic environments are changing in a market economy, or new technologies are regularly becoming available, skills obtained from formal schooling prove an important foundation for informal postschool learning. Most new agricultural technologies are geo-climatic and (or) land-specific, and changing technologies cause rapid depreciation in land-specific human capital. Being able to make good decisions on information acquisition and technology adoption is a valuable skill. Hence, a changing agricultural environment increases the expected return to formal schooling through allocative efficiency effects, which seem likely to be more important than technical efficiency effects.

Summary of Empirical Evidence

The following material summarizes a careful review of the literature, but the details are reported in Huffman (1999).

Choice About Where to Work

Worldwide, about one-half of the labor force works in agriculture (World Bank, 2000). A large majority are unpaid farm workers--the farmers who make decisions and work, and other farm family members who work generally without direct compensation—and a minority are hired (nonfarm family) workers. Hired workers are generally of two types: regular full time and seasonal. Seasonal labor demand variation arises largely from the definite seasonal pattern to biological events in plants, which creates unusually large labor demand at planting, weeding, and/or harvest time. The supply of seasonal agricultural labor frequently has a local component and a migratory component.

Over the long term the share of the labor force employed in agriculture has declined dramatically in what are now developed countries, but slowly or not at all in low-income or developing countries (OECD, 1995; Johnson, 2000). Decisions on schooling by families and communities are an important factor determining whether individuals work in agriculture or elsewhere. Even in developed countries where farmers are relatively well educated, hired farm workers generally have significantly less education.

Choosing agriculture. Whether to work in agriculture or in another industry is an important decision worldwide. In India and China, which account for about 40% of the world's population, and in other low-income countries, about 65% of the labor force in 1990 was employed in agriculture. In western Europe, less than 10% of the labor force was employed in agriculture, and in the United States the share was only 3%. In noncentrally planned countries, individuals make a choice of an occupation/industry for work. Schooling decisions affect later occupational choice decisions.

Migration. As economic conditions change in interconnected labor markets, workers in free societies invest in migration to improve their future economic welfare (see the three-period model in the previous section), which tends to reduce or eliminate intermarket wage differences. This complicates the problem of explaining migration, because individuals are acting on anticipated wage rate differences rather than the ex post values. Schooling plays a significant role in these adjustments or reallocations because of its effect on the costs and returns to migration.

Off-farm work. Although farmers tend to be tied to the land and to be geographically immobile, off-farm work of farmers is a relatively common international phenomenon. Since the 1950s and 1960s, aggregate demand for operator and family farm labor in all of the developed countries has declined (see OECD, 1995), the demand for housework in farm households has generally declined as family sizes have declined and labor-saving household technologies have been adopted, and the real nonfarm wage has generally increased. Faced with needing to make adjustments in labor allocation, farm households in developed countries have frequently chosen to continue in farming but also to supply labor of some of its members to the nonfarm sector (e.g., OECD, 1994).

Summary. Overall, the review of the literature (Huffman, 1999) shows that the quantity and quality of individuals' schooling affects their choice of where to work. In the United States, completing secondary schooling reduces the likelihood of an individual choosing an occupation in agriculture. Among U.S. hired farm workers, schooling completion levels are low and have not risen as immigrant workers having less than 8 years of schooling have become an increasing share of the workforce. U.S. domestic and undocumented migratory farm workers seem to function relatively well with low levels of schooling. For individuals in developed countries who are farmers and continue farming, additional schooling increases the likelihood that they will participate in off-farm wage work, but not necessarily for those in Green Revolution areas of developing countries. Higher schooling levels are in general associated with a population that is more geographically mobile.

Technology Adoption and Information Acquisition

The decision to adopt new technologies is an investment decision, because significant costs are incurred in obtaining information and learning about the performance characteristics of one or more new technologies, and the benefits are distributed over time. Furthermore, for any given farmer only a small share of the new technologies that become available will be profitable to adopt. This means that there is a large amount of uncertainty facing farmers, and additional schooling may help them make better adoption decisions and increase farm profitability. Because additional schooling affects the amount of knowledge that a farmer has about how technologies might work and his or her information evaluation skills, additional schooling may affect his or her choice of the type and amount of information to acquire. Hence, the three-period model of the previous section provides a useful guide.

When technology is new and widely profitable, farmers' schooling has been shown to be positively related to the probability of adoption. When a technology has been available for an extended period (e.g., several years) or it is not widely profitable, farmers' schooling is generally unrelated to adoption/use of the technology. Schooling has been shown to affect choice of information channels about new technologies.

Although successful adoption of innovations clearly requires information, few studies have considered the important joint decisions of information acquisition and new technology adoption. This seems to be a fruitful area for new research. When several information sources exist, early adopters might prefer sources that facilitate faster learning about the innovation. The information channels for early adopters might also be different from those for late adopters.

Wozniak (1993) is an exception in that he examined farmers' joint decisions on information acquisition and technology adoption. He considered the adoption of two technologies—one new and one mature—and four channels of information—one active and one for both extension and private sector information providers. In the study, he found that farmers' education significantly increased the probability of adopting new and mature technologies and acquiring information from extension by talking with extension personnel (passive) and attending demonstrations or meetings (active) about the use of new products or procedures sponsored by extension. Farmers' education did not have a statistically significant effect on acquiring information by talking with private industry personnel or attending demonstrations or meetings on the use of new products or procedures sponsored by private companies. Farmers were more likely to be early adopters if they acquired information actively or passively from private industry than if they acquired information from extension. For both new and mature innovations, positive and significant interaction effects existed between farmers' acquisition of information from public and private sources, i.e., public and private information acquisition seems to be complementary.

Summary. Overall, the review of the literature (Huffman, 1999) shows that additional schooling of farmers increases the rate of early adoption of useful agricultural technologies in developed and developing countries. A surprisingly small amount of research, however, has examined farmers' joint decisions on information acquisition and technology adoption, and this is an area for much needed new research.

Agricultural Production

Education of farmers and other farm labor has the potential for contributing to agricultural production as reflected in gross output/transformation functions, and in value-added or profit functions. These effects are frequently referenced as technical efficiency effects, allocative efficiency effects, or economic efficiency effects of education. When the effects of schooling on production are considered in a gross output-complete input specification, the marginal product of education, a measure of technical efficiency, is limited by the other things that are held constant. A value-added or profit function representation of production accommodates a much broader set of effects of farmers' education associated with allocative efficiency—the adoption of new inputs in a profitable manner, the allocation of land (and other quasi-fixed inputs) efficiently among alternative uses, the allocation of variable inputs efficiently, and the efficient choice of an output mix. The empirical evidence has shown that the productivity of farmers' education is enhanced by a wider range of choices, and Welch (1970) is generally given credit for delineating these substantive differences.

Summary. Overall, in developing, transition, and developed countries, the review of the literature (Huffman, 1999) shows that farmers' schooling has generally greater value through allocative than technical efficiency effects. The positive allocative effects are, however, closely associated with a farming environment where technologies are changing and relative prices are changing. Farmers' schooling has infrequently been shown to increase crop yields or gross farm output, because technical-efficiency gains from skills provided by farmers' schooling seem generally to be small.[1] Farmers' schooling has also been shown to change the optimal mix or composition of farm inputs and outputs where production is multiinput and multioutput.

Total Factor Productivity Decomposition

Productivity statistics, measuring output per unit of input, started in the 1950s showing seemingly costless increases in output. Three main classes of methods have been applied in sources of productivity analysis: (1) imputation-accounting methods, (2) statistical meta-production function methods, and (3) statistical productivity decomposition methods (Evenson, 1999). In all of these methods, there is considerable investment in data construction, especially trying to accurately account for quality and quantity of inputs and outputs. Schooling enters primarily at two places: (1) schooling of agricultural labor can reasonably be expected to enhance labor quality or the effective units of labor, and (2) schooling of the farmer or decision maker may more generally increase productivity by enhancing economic efficiency in agriculture.

Summary. In agricultural productivity data sets, the incorporation of labor quality adjustments has not been uniform. One strand of the literature, started by Griliches and continued by Ball et al. 1997) at the USDA, emphasizes effective units of labor, which is the product of agricultural labor quantity (days or hours) and an index of labor quality. This approach can lead to overadjusting for quality effects. Another strand of the literature places labor quality effects in the productivity index (residual) and uses an education index, generally for farm operators, to explain total-factor-productivity levels. When the latter approach has been followed, farmers' schooling has generally had a positive and significant effect on agricultural productivity. In cross-country studies of agricultural labor productivity, it has been difficult to obtain a satisfactory empirical measure of schooling. Consequently, the weak effects of education in cross-country studies seem more likely to be due to data problems than absence of real effects. Although the progress may be slow, this is an area where progress can be made.

Knowledge Creation and Transfer

Knowledge creation can occur informally, e.g., through accumulated experiences of farmers, mechanical innovations by farmers and blacksmith shops, and in formal institutions that specialize in the development and transmission of knowledge (i.e., universities and research institutes). Informal research can occur with little or no education, but the rate of knowledge accumulation is very slow (Johnson, 2000). Successful institutionalized research requires scientists who have considerable ability that has been polished with intensive higher education and training (Huffman and Evenson, 1993). Institutionalized research has been the source of rapid knowledge creation leading to new agricultural technologies (e.g., chemicals, pharmaceuticals, plant varieties) and increases in agricultural productivity.

Research produces discoveries that are pure public goods, being nonrival and nonexcludable, and discoveries and innovations that are impure public goods because they are partially excludable, e.g., due to spatial limits associated with heterogeneous geo-climatic conditions, specie limits, or intellectual property rights (Huffman and Just, 1999; Kanbur and Sandler, 1999). With knowledge that is a pure public good, the social opportunity cost of additional users is zero. Hence, acquisition of knowledge can frequently occur through transfers or spillovers, but using this knowledge generally requires further research to modify and adapt the discovery to local geo-climatic conditions. Adaptive research, however, requires less highly trained scientists.

Summary. Knowledge creation, acquisition, and adaptation, which are part of the services sector, are important channels for impacts of higher education on agriculture. The productivity of agricultural research centers differs worldwide, but for developing countries, borrowing discoveries made by others and adapting them to local agro-climatic conditions will be generally more efficient than creating basic advances in knowledge.

Household Income

The emphasis is on impacts of education on incomes of agricultural workers and farm households. The impact of schooling on incomes of hired agricultural labor seems small in developed countries and insignificant in other countries. In a study of Florida farm workers, Emerson (1989) found a very small positive and significant effect of workers' schooling on earnings (1.4% per year for migrants and 1.6% per year for nonmigrants, holding weeks worked per year constant). The coefficients for experience were about 50% larger for migrants than for nonmigrants. Furthermore, domestic farm workers sorted or self-selected themselves into migratory and nonmigratory groups in a manner that was consistent with the theory of comparative advantage--i.e., migrants earned more as migrants than they would as nonmigrants, and nonmigrants earned more as nonmigrants than they would as migrants.

In developing countries, transportation and communication are relatively expensive, average schooling completed is low, and housing in a new location may be difficult to find. Hence, workers tend to be less geographically mobile than in the United States, and rural labor markets less integrated.

For farm or landed households, the effects of schooling on income arise primarily from impacts on farm profit or value added and off-farm earnings. Farmers' schooling increases farm profit in an environment where technology and relative prices are changing, but in other agricultural environments where technology and prices are not changing or where farmers' schooling is below the permanent literacy level, farmers' schooling seems unlikely to have a significant impact on farm profit, value added, or household income (Huffman, 1999). Furthermore, in an agricultural environment where farmers have a large number of opportunities to make good/bad decisions and schooling completion levels differ significantly across farmers, additional schooling of full-time farmers can be expected to increase net-farm income, controlling for their age. When price and technology policies greatly limit farmers' decision- making opportunities, farmers vary in their extent of farm/off-farm work, or little variation exists in farmers' schooling, weak or negative schooling and net farm income relationships may exist.

Summary. Overall, the review of the literature (Huffman, 1999) shows that the effects of education on incomes of hired farm workers are mixed. If hired farm workers work piece-rate, schooling doesn't affect their wage, but experience may be important if they can acquire skills by specializing in a particular type of work. If they are time-pay wage workers, added schooling may have a small positive impact on their wage. For farm household members in developed and developing countries, the impact of schooling on farm profit or value added is positive when technology is changing rapidly. In developed countries, schooling has been shown to have a positive impact on the off-farm wage and off-farm earnings, but in developing countries the results are mixed, e.g., negative in the India Green Revolution areas and positive in China. In developed countries, schooling of husbands and wives has a positive effect on farm household (net) income, and in developing countries, the impact is probably positive. Empirical studies, however, have infrequently focused on the effects of education on household or family income.

Nonmarket Returns

Nonmarket work associated with caring for a family is an important activity of married women. For married women with education living in rural areas, nonfarm employment opportunities are more limited than for women in urban areas. The education of married women has been shown to be productive in home production. Mother's education improves her children's health as measured by birth weight, nutrition status, and survival rate (Schultz, 1993, 1997). The primary reason is that the most important deliverer of health care to a child is the mother. Schooling equips her with general and specific knowledge and the means and confidence to seek new ideas. The impact of mothers' schooling on child health is largest in unsanitary environments and in areas that are farther from health care facilities, e.g., larger in rural than in urban areas.

Married women with education also have fewer children, especially holding husbands' education and wage constant (Schultz, 1993). This reduction is associated with smaller desired family size and more efficient use of contraceptive information. With a smaller family size, larger investments per child in health and schooling are possible, and this improves the adult standard of living prospects of a family's children.

Summary. Schooling for married women in rural areas has been shown to increase their productivity at home and to increase their participation in off-farm work in areas that offer employment opportunities for women having education. Hence, the return to women's schooling is positive, and it is frequently larger than for investments in men's schooling.

Rapid Changes on the Horizon

Agriculture worldwide can expect to undergo some dramatic changes in the early 21st century, and investments in education will be important.

Communication and Information Technologies

The stock of knowledge about technologies and attributes of goods is growing rapidly, creating knowledge gaps. The potential for communicating knowledge is growing rapidly with a coming together or integration of new technologies associated with computers and telephony into a large global network of interconnected communication and information systems (World Bank, 1999). This includes the use of satellites, fiber optics, and wireless technologies. Wireless communication technologies have great potential for low fixed-cost infrastructure in sparsely populated, difficult terrains and harsh climates, which frequently describe rural areas. Wireless technologies have been advancing rapidly, and the cost has been falling.

The new communication and information technologies have potential for agriculture. New markets for agricultural inputs, outputs, and consumer goods can be and are being created. Farmers and other household members can get direct access at low cost to price information for distant markets and contract in distant markets. This has the potential to improve dramatically the general efficiency with which markets operate, reducing spatial price differentials and opportunities for intermediaries/traders, which can be large in "spatially thin markets for goods" and sparsely populated areas. The potential is great in developing countries. However, since buyers and sellers in these markets do not know one another and do not have direct contact, participants in these markets must develop new skills to judge the quality of products and the reputation of individuals, and new institutions may be needed to guarantee product quality, enforce contracts, and police fraud (World Bank, 1999).

This new technology provides a potentially new source of knowledge/information for farm household members. A large amount of information is becoming available in virtual libraries containing information that can be used for decision making on production and management practices for farm businesses and consumer information for households. A new type of extension or dissemination of information is emerging, because the real cost of storing and disseminating information, once created, is falling rapidly. New information clubs to reduce the cost of specialized information seem likely to emerge (Kunbur and Sandler, 1999).

New types of education programs are becoming available using these new information technologies, and the market is expected to grow in the future. This includes long-distance access to formal degree programs, e.g., a Harvard undergraduate degree by someone living in rural India, long-distance access to web-libraries, journals, books, bulletins, and other published materials. The potential exists for the information to be used in informal learning, postschool and preschool. It frequently has a flexibility dimension that enables self-pacing of effort and progress and picking the most relevant information. It has some disadvantages of low interpersonal interaction with teachers/instructors/professors and other students, but e-mail interactions are possible.

New institutions are needed that specialize in verifying information, including scientific discoveries and quality dimensions of commercially available goods and services. The necessary information is costly to create but is a public good once provided, so private incentives lead to major underprovision (Cornes and Sandler, 1996; Kanbur and Sandler, 1999). Problems with highly variable quality, unverifiable quality, customer service, and general information problems can prevent large social gains from these new information technologies (Molho, 1997; World Bank, 1999).

Restructuring of Agriculture

During the coming quarter century, a major restructuring of agriculture in many countries and regions seems likely building on new agricultural and communication technologies, innovations in organizational structures, greater openness to world trade in goods and services and transfers of technologies, including intellectual property, and integration of rural economies into the larger economy (Thompson, 1999). In general, there will be widespread economic pressures for successful farms to become larger, more specialized, but less labor intensive. This will mean a decline in the share of the labor force in agriculture in most countries. A major public issue will become what to do with excess adult labor in agriculture or displaced labor from agriculture.

Public retraining programs for unskilled and narrowly skilled displaced adult workers is one possibility, but much evidence now exists that public training programs of this type have very low social rates of return in Western developed countries and sometimes yield negative rates of return (Heckman, et al., 1999). Training programs for young people have a better record, and solid evidence exists that investing in social and cognitive skills of preschool children has a good social payoff. Early motivation for work is important, and it comes from a child's family and community and can be reinforced in older children by tying schooling and working together. In fact, the agricultural sector has provided many opportunities for young children to work with their parents or for others while they are growing up, but this opportunity for useful work at a young age is lost in urban societies. Hence, motivating the young for work is a greater social problem in urban than agrarian societies, and this problem is expected to get worse. Furthermore, a move to year-round full-time schooling for children with no time for working, which has been proposed in some western developed countries, would be the wrong direction for new schooling policy. The practice of teenagers and young adults working in the private sector in apprenticeship and internship programs has been shown to be a good investment (Heckman, 1999).

Early experiences and learning before school age appear to be important to the development of an individual's long-term learning potential. Strong primary education provides much of the needed foundation for later learning that tends to be highly correlated with ability at age 8, and measured ability in children is well set by age 14. An early foundation for life-long learning has large social payoffs, and later in life investments are a poor substitute (Heckman, 1999). Life-long learning will become the description of education for a large share of the world's population during the early 21st century and the main human tool for absorbing and using productively the rapidly growing knowledge base that is being made available globally at low cost through modern communication and information systems. This is the future route to useful knowledge gap reductions.

Conclusions

Countries face important decisions on how to allocate public resources. The choice and adaptation of institutional structures seem likely to be as important as decisions on schooling, health, and technology policies. Weak and inefficient institutions lower the expected private return to all forms of nonpolitical investments and increase the uncertainty about these returns. Hence, weak institutions can undermine future economic growth and development.

Schooling cannot be viewed as unconditionally productive in agriculture. It requires a price and technology environment that is dynamic and the option for off-farm work and migration out of rural areas. In a modernizing economy, investments in schooling of children in rural areas will increase their long-term income or standard of living prospects. Some of them will, however, work in agriculture, some in nonagricultural employment, and some at nonmarket activities. Where openness and economic incentives exist, schooling will facilitate migration to reduce regional and occupational compensation differentials, and young and more educated adults will be the most responsive to these incentives.

With the rapid advances in communication and information technologies that are occurring and increased availability at low cost, farm people of the future will need strong basic education in order to participate in this new global information system. We expect to see dramatic new options for learning from distant sources (e.g., degree programs, short courses), obtaining information about new technologies (i.e., new types of extension using web-sites and e-mail), rapid access to price information on agricultural outputs and inputs in widely dispersed markets, and contracting in new types of virtual markets. In the future, these new communication and information technologies seem likely to place new demands on the skills of farm people to use information and to speed structural change in agriculture globally. A new set of adjustments for farm families can be expected.

Public retraining programs for unskilled and narrowly skilled displaced adult workers have a poor return in Western developed countries. Prospects are no better for low and middle income countries. Broadening and strengthening the training of young boys and girls seems a better social investment. Long-term positive effects exist from preschool social and cognitive skill development. Motivating the young to work has generally not been a problem in farm families or low-income countries, but it has only recently been rediscovered that this has important payoffs in nonagrarian societies. The rate of return will be very high to investments in primary schooling in low-income countries, and in other countries, strong primary schooling will be needed to provide the foundation for later formal and informal learning. With the advances in communication and information systems and their dispersion globally, lifetime learning will become important to a large share of the population in the future.

It remains somewhat puzzling why schooling in agriculture does not have broader direct effects and is not unconditionally productive. One hypothesis is that the dominance of agriculture by biological processes, which are controlled largely by climate and its land surface area-intensive nature, greatly limits the potential for raising labor productivity through skill specialization and cooperation. The big payoff to agriculture from highly skilled labor comes from knowledge creation through institutionalized research and development.

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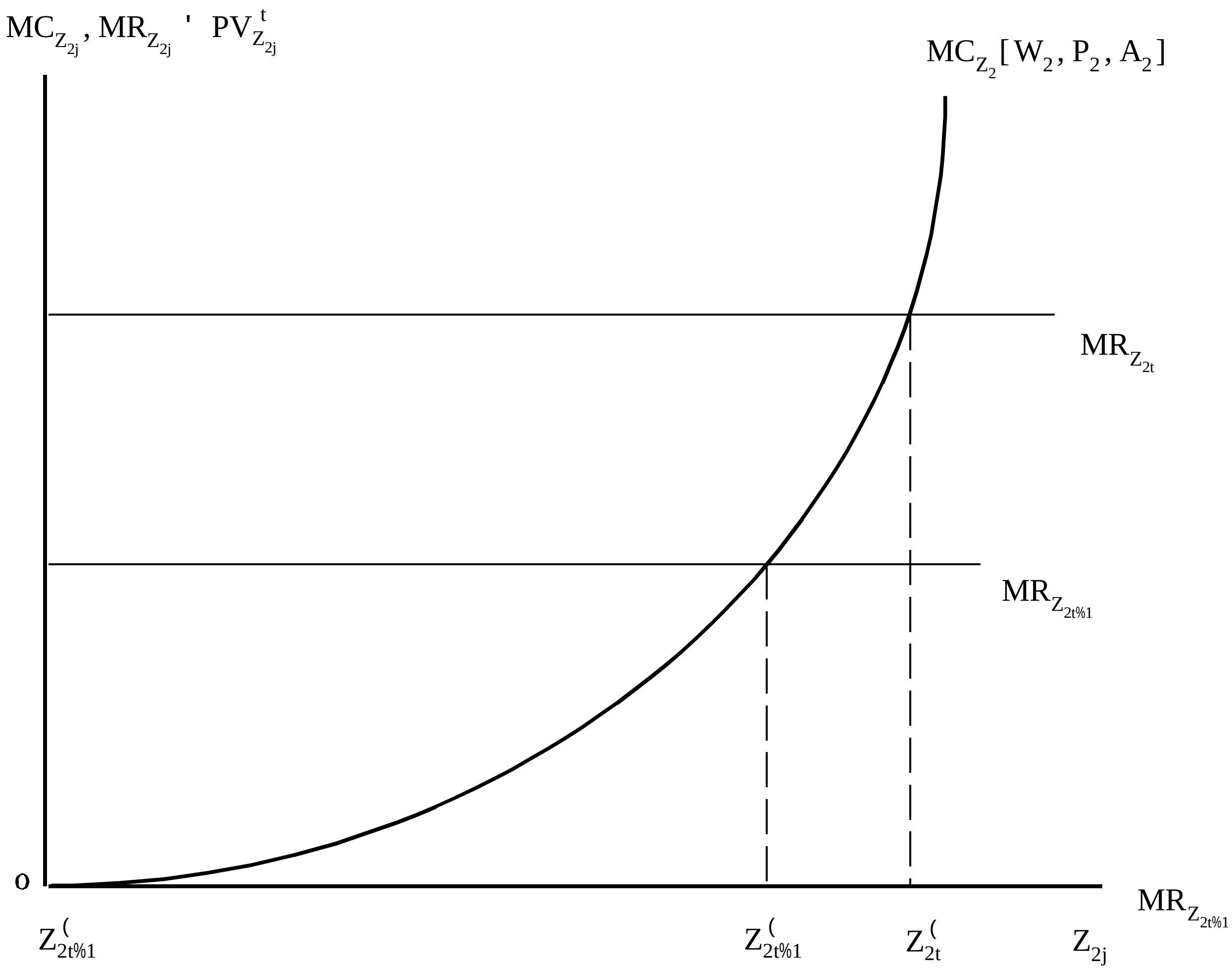

Figure 1. Optimal Production of Human Capital

Endnotes:

1. For green revolution Asia, Hussain and Byerlee (1994) concluded that technical and allocative efficiency effects of schooling are relatively equal in importance.