Just, R.E., and D. Zilberman (1988), "The effects of agricultural development policies on income distribution and technological change in agriculture", Journal of Development Economics 28:193–216.

Just, R.E., D. Zilberman, D. Parker and M. Phillips (1988), "The economic impacts of BARD research on the U.S.", Report prepared for the Commission to Evaluate BARD, June, 1988.

Khanna, M., and D. Zilberman (1997), "Incentives, precision technology and environmental quality", Ecological Economics 23(1):25–43.

Kislev, Y., and N. Schori-Bachrach (1973), "The process of an innovation cycle", American Journal of Agricultural Economics 55(1):28–37.

Klette, T.J., and Z. Griliches (1997), "Empirical patterns of firm growth and R&D investment: A quality ladder model interpretation", Working paper 5945 (National Bureau of Economic Research, Cambridge, MA).

Lehvall, P., and C. Wahlbin (1973), "A study of some assumptions underlying innovation diffusion functions", Swedish Journal of Economics 75:362–377.

Lichtenberg, E. (1989), "Land quality, irrigation development, and cropping patterns in the northern High Plains", American Journal of Agricultural Economics 71(1):187–194.

Mahajan, V., and R.A. Peterson (1985), Models for Innovation Diffusion (Sage Publications, Beverly Hills, CA).

Mansfield, E. (1963), "The speed of response of firms to new techniques", Quarterly Journal of Economics 77:290–311.

McDonald, R., and D. Siegel (1986), "The value of waiting to invest", Quarterly Journal of Economics 101:707–728.

McGuirk, A., and Y. Mundlak (1991), "Incentives and constraints in the transformation of Punjab agriculture", Research Report 87 (International Food Policy Research Institute, Washington, DC).

McWilliams, B., and D. Zilberman (1996), "Time of technology adoption and learning by doing", Economics of Innovation and New Technology 4:139–154.

Mundlak, Y. (1997), "Agricultural production functions: A critical survey", Working paper (The Center for Agricultural Economic Research, Rehovot, Israel).

Norgaard, R.B. (1988), "The biological control of cassava mealybug in Africa", American Journal of Agricultural Economics 70(2):366–371.

Olmstead, A.L., and P. Rhode (1993), "Induced innovation in American agriculture: A reconsideration", Journal of Political Economy 101(1):100–118.

Olmstead, J. (1998), Emerging markets in water: Investments in institutional and technological change, Ph.D. Dissertation (Department of Agricultural and Resource Economics, University of California, Berkeley).

Parker, D., and D. Zilberman (1993), "Hedonic estimation of quality factors affecting the farm-retail margin", American Journal of Agricultural Economics 75(2):458–466.

Parker, D., D. Zilberman and F. Castillo (1998), "Office of technology transfer: Privatizing university innovations for agriculture", Choices:19–25.

Rausser, G. (1999), "Private/public research: Knowledge assets and future scenarios, Invited fellows address", Annual meeting of the American Agricultural Economics Association, Nashville, TN, August 10, 1999.

Rausser, G., S. Scotchmer and L. Simon (1999), "Intellectual property and market structure in agriculture", Work in progress (Department of Agricultural and Resource Economics, University of California, Berkeley).

Rausser, G., and P. Zusman (1991), Political-Economic Analysis: Explanation and Prescription (Cambridge University Press, New York).

Rogers, E. (1962), Diffusion of Innovations (Free Press of Glencoe, New York).

Roumasset, J.A. (1976), Rice and Risk: Decision-Making among Low-Income Farmers (North-Holland, Amsterdam).

Schmitz, A., and D. Seckler (1970), "Mechanized agriculture and social welfare: The case of the tomato harvester", American Journal of Agricultural Economics 52(4):569–577.

Schultz, T.W. (1964), Transforming Traditional Agriculture (Yale University Press, New Haven, CT).

Stoneman, P., and N. Ireland (1983), "Technological diffusion, expectations and welfare", Oxford Economic Papers 38:283–304.

Sunding, D. (1996), "Measuring the marginal cost of nonuniform environmental regulations", American Journal of Agricultural Economics 78:1098–1107.

Thurow, A.P., W.G. Boggess and C.B. Moss (1997), "An *ex ante* approach to modeling investment in new technology", in: D. Parker and Y. Tsur, eds., Decentralization and Coordination of Water Resource Management (Kluwer Academic Publishers).

United States Bureau of the Census (1975, September), Historical Statistics of the United States. Colonial Times to 1970, Parts 1&2 (United States Department of Commerce, Washington, DC).

United States Bureau of the Census (1980, October), Statistical Abstract of the United States 1980, 101st Edition (United States Department of Commerce, Washington, DC).

United States Bureau of the Census (1998, October)), Statistical Abstract of the United States 1998, 118th Edition (United States Department of Commerce, Washington, DC).

Wann, J., and R. Sexton (1992), "Imperfect competition in multiproduct food industries with application to pear processing", American Journal of Agricultural Economics 74(4):989–990.

Wright, B.D. (1983), "The economics of invention incentives: Patents, prizes, and research contracts", The American Economic Review 73(4):691–707.

Zilberman, D. (1984), "Technological change, government policies, and exhaustible resources in agriculture", American Journal of Agricultural Economics 66(5):634–640.

Zilberman, D. (1985), "Technological change, government policies and exhaustible resources in agriculture", American Journal of Agricultural Economics 66(5):634–640.

Zilberman, D., and A. Heiman (1997), "The value of economic research", American Journal of Agricultural Economics 79(5):1539–1544.

Zilberman, D., D. Sunding, R. Howitt, A. Dinar and N. MacDougall (1994), "Water for California agriculture: Lessons from the drought and new water market reform", Choices:25–28.

Zilberman, D., D. Sunding and M. Khanna (1997), "The changing nature of agricultural markets: Implications for privatization of technology, information transfer, and the role of land-grant research and extension", in: S. Wolf, ed.", Privatization of Information and Agricultural Industrialization (CRC Press, Boca Raton, FL).

Zilberman, D., C. Yarkin and A. Heiman (1998), "Agricultural biotechnology: Economic and international implications", Mimeograph (Department of Agricultural and Resource Economics, University of California, Berkeley).

Chapter 5

STRUCTURAL CHANGE IN AGRICULTURAL PRODUCTION: ECONOMICS, TECHNOLOGY AND POLICY

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Contents

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Abstract

Over the last few decades, the structure of agricultural production around the world has been changing. An economic analysis of the factors influencing this evolution is presented. Special attention is given to the role of technology and resource mobility. Linkages with changes in market conditions are also evaluated.

Keywords

agricultural production, structure, technology, resource mobility

JEL classification: Q11

1. Introduction

The process of food production has changed significantly over time and over space. Changes have been influenced by the dynamic interactions between improved technologies and increasing human population [Boserup (1965)]. Over the centuries, the production process has evolved from simple forms of food gathering (e.g., hunting and fishing) to complex biotechnologies (e.g., genetic engineering). Hunting and fishing activities remain important sources of food in some parts of the world, and extensive production systems (e.g., pastoralism) still play significant roles in food production where population density is low and/or land productivity is low. However, intensive forms of production are now commonly found around the world. These intensive forms have typically been associated with high population densities, productive land, and rapid technological progress.

The evolving organization and structure of agricultural production remains a subject of considerable interest. Historically, land rights and relations have evolved in response to changing population density, market access, and agrarian policy [Boserup (1965), Binswanger et al. (1993), Binswanger and Deininger (1997)]. At the microeconomic level, various institutional forms can support food production, from territorial rights associated with hunting and fishing, to collective farms (e.g., the Israeli kibbutz), to private farms. Private farms include large commercial farms relying extensively on hired labor as well as family farms relying mostly on family labor. Around the world, the current prevalence of the family farm as a socioeconomic unit of agricultural production (where it is often difficult to distinguish between production unit and household consumption unit) is particularly noteworthy.

The evolution of farm structure is part of a complex evolution of the farm sector and its role in a global economy. The main function of the farm sector is to feed a growing world population. The world population reached 6 billion people in 1999, up from 5 billion people in 1987. Feeding this growing population is a significant challenge, suggesting a strong and increasing demand for food. In this context, it may be surprising to see that the average real price of food has been declining over the last few decades. This has been possible only because of a large increase in food production and remarkable productivity gains. This stresses the importance of technical change in agriculture.

Another notable characteristic of the food sector is the instability of its markets. Part of the instability is due to weather effects, which affect farm production, farm prices, and farm income. Part of the instability is also due to the low price elasticity of demand for food and the perishability of a number of food commodities. An inelastic food demand means that food prices can react sharply to small changes in food supply. This suggests significant risk in anticipating agricultural prices. The instability of agricultural markets and farm income can raise questions about whether market prices always provide appropriate guides to efficient resource allocation in the food sector [e.g., Innes and Rausser (1989), Newbery and Stiglitz (1981)]. This seems particularly relevant in a period of market liberalization, where the role of government in agriculture is declining around the world, with greater emphasis being given to markets and trade.

2. Tbe structure of agricultural productiou

Since the beginning of the twentieth century, the spread of mechanization, increased land productivity due to technical progress (e.g., the "green revolution"), and rural migrations toward cities have transformed the system of agricultural production around the world. The transformation has taken many forms.

First, migration from rural areas toward urban jobs has been associated with the growth of the industrial and service sector, and with a sharp increase in farm labor productivity due in large part to mechanization. In situations of slow economic development, few urban jobs and a slow growth in the industrial sector have restricted the labor migration flow and reduced the demand for farm mechanization. Alternatively, in situations of rapid economic growth, significant labor migrations have reduced the proportion of the active labor force employed in agriculture. Taking place over several decades, this process has transformed farming into a sector employing only a small portion of the active population. In developed countries, such changes have induced a trend toward mechanization and significant increases in farm size.

The product mix produced by farmers has also changed. In general, farms have evolved toward greater product specialization. In developed countries, this can be seen today through the development of large, specialized animal production units in broiler, dairy or pork production (which contrast with the more traditional mixed crop-animal farms).

Agricultural sectors around the world are increasingly relying on trade and market mechanisms as a means of guiding resource allocation in agriculture. This coincides with a decline of food self-sufficiency motive as a guiding force for the organization and structure of farming, at both the micro level and the national level. As trade for food and fiber developed, the role of agricultural markets has become more important both in developed and developing countries. At the national level, this means less reliance on government programs. At the farm level, economic survival pushes managers toward implementing efficient production systems adapted to local conditions, toward developing marketing skills that can take advantage of market opportunities, and toward risk management strategies that can effectively deal with weather risk and changing market conditions.

Finally, the increasing role of contracts in agriculture is worth emphasizing. For example, the broiler sector has exhibited high growth and significant productivity gains over the last 40 years. It has also been associated with the development of vertical integration, where coordination between different stages of the marketing channel is done mostly through contracts. The use of contracts as a control and coordination mechanism is also commonly found in vegetable production, and increasingly in pork production.

3. Farm structure

3.1. Farm size and returns to scale

Issues related to the structure of agriculture and to the survival of the family farm have long been subjects of interest and controversy [see, e.g., Allanson (1992), Gale (1993), Goetz and Debertin (1996), Hearn et al. (1996), Lianos and Parliarou (1986), Weiss (1998)]. At the center of this debate is the relationship between farm size and economic efficiency: are large farms more efficient than small farms? Is it possible to identify an "optimal" farm size? The nature of returns to scale in production can help shed some light on these issues.

Returns to scale reflects the relationship between average production cost and firm size. Increasing (decreasing) returns to scale corresponds to an average cost (per unit of output)[1] being a decreasing (increasing) function of output. And constant returns to scale means that average cost is unaffected by firm size. Alternatively, finding that larger firms exhibit a lower (higher) average cost identifies the presence of economies (diseconomies) of scale. In crop production, it often appears relevant to consider land as a fixed factor. Then, returns to scale can be alternatively measured in terms of the properties of the average return per unit of land: increasing (constant, decreasing) returns to scale corresponds to the average return per unit of land being an increasing (constant, decreasing) function of farm acreage. In this context, the average return per acre is the Ricardian rent, measuring the return to land after all other factors of production have been remunerated [e.g., see Chavas (1993)].[2]

Under free entry and exit, competitive firms producing under increasing returns to scale implies negative profit, giving incentives for firms to either exit the industry or expand. And competitive firms producing under decreasing returns to scale implies positive profit, providing incentives for new firms to enter the industry. Thus, under perfect resource mobility, industry equilibrium is expected to include only firms producing in the region of constant returns to scale (which exhibits neither increasing nor decreasing returns to scale). This has stimulated much research trying to identify the shape of the average cost function as it relates to farm size. Alternatively, in the absence of perfect resource mobility, power relations can become closely linked to land rights and the structure of agricultural production [e.g., De Janvry (1981), Binswanger et al. (1993), Binswanger and Deininger (1997)]. For example, Binswanger et al. argue that the historical emergence of large farms in many developing countries was based on power relations and economic distortions, where the international competitiveness of these farms was often maintained by subsidies involving significant social costs. Such situations motivated agrarian reforms redistributing land with an attempt to improve both equity and efficiency.

[1] In a multi-output framework, the relevant function is the ray-average cost function, i.e., the cost of production per unit of a factor proportionally rescaling all outputs [see Baumol (1982)].

[2] This means that land rent should not be treated as a cost in cost of production studies.

In developing countries, there is debate about the inverse relationship often observed between farm size and productivity [e.g., Rao and Chotigeat (1981), Eswaran and Kotwal (1986), Binswanger et al. (1993)]. The argument is that, compared to large farms, small family farms face lower labor cost because of lower cost of labor supervision. Then, in situations of unequal land distribution, land reform can in principle generate a more egalitarian access to land while increasing farm productivity and efficiency [e.g., by combining "underused" labor from small farms and the landless with "underused" land on very large farms; see Berry and Cline (1979)]. However, small farms may face higher capital cost (e.g., due to credit rationing and capital market imperfections) if large farms have better access to the capital markets. In such a situation, it is possible for the relationship between farm size and productivity to be U-shaped, large farms enjoying a credit cost advantage while small farms enjoy a labor cost advantage [Binswanger et al. (1993)].

In agriculture of developed countries, the empirical evidence suggests that the average cost function has a typical L shape: average cost tends to decline for small farm sizes, and then reach a lower plateau for average to large farm sizes [e.g., Hall and Leveen (1978)]. This suggests three points. First, economies of scale seem to exist for small farms. Second, there is no strong evidence that diseconomies of scale exist for large farms. Third, there is a fairly wide range of farm sizes where average cost is approximately constant [e.g., Kislev and Peterson (1996)]. This has focused some attention on the "minimum efficient" farm size, i.e., the smallest farm size that can capture the benefits of economies of scale. Knowing this minimum efficient size is particularly relevant for the evaluation of the efficiency of farm structure and land reform policy.

One problem is that there is no clear consensus on what the "minimum efficient" farm size is. For example, Hall and Leveen's (1978) analysis suggests that in California this minimum may be around 100 acres of land. But there is also evidence that small farms can be scale-efficient in developed countries [e.g., Garcia et al. (1982)] as well as in developing countries [e.g., Yotopoulos and Lau (1973), Kalirajan (1981)]. For example, Yotopoulos and Lau, and Kalirajan provide evidence that, in India, small farms (fewer than 10 acres) are at least as efficient as large farms. How can we reconcile these apparent inconsistencies?

First, farmers have the option of choosing among different technologies, each one adapted to particular farm sizes. The typical situation is that, for a given technology, average cost tends to decrease with size, up to some capacity beyond which average cost increases. As farm size increases, a switch can take place from one technology to another better adapted to larger sizes (e.g., through capital investment and mechanization), so that the region of decreasing returns to scale is often not observed. Also, the minimum average cost of each technology may be fairly constant across technologies. This implies that the lower-bound envelope of the minimum average cost across technologies (the "long-run average cost" function) is rather flat. This is illustrated by Matulich (1978), in the context of studying the relationship between average cost and herd size in U.S. dairy farms. This suggests that, while increasing returns to scale may well be present for a given technology, the situation of constant returns to scale may be approximately satisfied across technologies for a wide range of farm sizes. This would help explain why there is empirical evidence of increasing returns and constant returns to scale appearing to coexist in agriculture. Also, it helps explain why farm size can vary over such a wide range, both within a country and across countries. This indicates that, as long as farms have access to a technology adapted to their size, there may not be great efficiency gains from changing farm sizes or from land redistribution schemes. The land redistribution programs recently implemented in South Africa or in the former Soviet Union (FSU) have been motivated by both efficiency and equity concerns. This suggests that, provided that they can be implemented without adverse effects on farmers' access to markets or technology, land reform programs can improve wealth equity while maintaining or even enhancing (e.g., due to better incentives under decentralized management in the FSU) agricultural productivity. However, avoiding these adverse effects while redistributing land can be difficult. As a result, the success of land reform policies can vary significantly across countries [e.g., see Lerman (1999), for the recent FSU experience].

Second, the empirical estimation of returns to scale often depends on the measurement of cost. In agriculture, the measurement of the cost of family labor is problematic. Family labor is often valued at its opportunity cost [e.g., Hall and Leveen (1978)]. However, measuring precisely this opportunity cost may be difficult. Also, there are some questions about whether opportunity cost is the appropriate value of family labor. Microeconomic theory suggests that family labor has a "shadow value" which can depend on both its opportunity cost, and on household preferences with respect to time allocation. The latter becomes important when household farm work generates direct utility to the household (in a way similar to leisure in the neoclassical household model). For example, this would happen whenever family members enjoy working on the farm. In this case, the shadow price of family labor is equal to its opportunity cost [e.g., the wage rate in off-farm work), minus the unit value of "enjoying farm work". Note that the neoclassical agricultural household model [e.g., Singh et al. (1986), Benjamin (1992)] implicitly assumes that the shadow value of "enjoying farm work" is zero (farm work then being valued at its opportunity cost). However, there is empirical evidence against the hypothesis that "enjoying farm work" has zero value [see Lopez (1984), for Canadian agriculture]. This is true for "hobby" farms, where agricultural activities are also seen as "leisure" activities. It also seems to characterize a number of part-time farmers. These arguments suggest that, in general, the shadow value of family labor is not always equal to its opportunity cost. This is particularly relevant to the extent that, while many large commercial farms may approximately satisfy the assumptions of the neoclassical agricultural household model, "hobby" farmers and part-time farmers typically have small farms. This suggests that the valuation of family labor may in fact change with farm size: ceteris paribus, the shadow value of labor on some small farms may be lower than on larger farms because of the enjoyment of farm work by "hobby" farmers and some part-time farmers. This also means that the opportunity cost of labor is an upward-biased estimate of the shadow price of family labor on some small farms. In this case, finding high average production cost on small farms may simply reflect this measurement bias (rather than the existence of increasing returns to scale).

Besides technology, many other factors can also influence the choice and efficiency of farm size. They include transaction costs, market imperfections, access to markets, and pecuniary economies. In developing countries, access to markets may vary across farm sizes [e.g., credit rationing is more prevalent on small farms; see Binswanger et al. (1993)]. In general, pecuniary economies are said to exist when larger farms pay lower prices for their inputs (due to lower transaction cost and/or stronger bargaining power), thus lowering their average production cost. And for similar reasons, large farms may receive higher prices for their outputs. Then, pecuniary economies would give larger farms some economic advantage and provide an incentive for increased farm size. When paid by farmers, transaction costs are parts of the cost of production (e.g., monitoring costs, transportation costs, information costs). Also, they can contribute to higher input prices (when paid by farm input suppliers) and lower farm output prices (when paid by food traders and processors). In either case, they tend to reduce farm profitability. Some transaction costs may be higher on large farms (e.g., monitoring cost of hired labor), thus giving some cost advantage to smaller farms [e.g., Eswaran and Kotwal (1986), Binswanger et al. (1993)]. Alternatively, information costs about prices or technology may be higher on smaller farms, thus giving some economic advantage to larger farms and providing incentives to increase farm size. And, as it improves information processing in decision making, higher quality of human capital (e.g., due to education or experience) has been found to be positively related to farm size [Sumner and Leiby (1987)].

Also, tax policy can affect farm size and structure [e.g., Gardner and Pope (1978), Lowenberg and Boehlje (1986)]. Tax policy is often designed to stimulate capital investments (e.g., through investment tax credit or depreciation allowances that reduce taxable income). The associated reduction in taxes and increase in after-tax income is typically greater on capital-intensive farms. To the extent that capital-intensive farms tend to be larger, this means that tax policy can favor larger farms and thus provide an incentive for increasing farm size.

Finally, risk exposure can influence the size and structure of farms. This is relevant since risk markets are typically incomplete in agriculture, implying that most farmers face significant price risk (due to biological lags in the production process) as well as production risk (due to weather effects and pest problems). Being in general risk averse [e.g., Lin et al. (1974), Binswanger (1981), Newbery and Stiglitz (1981), Innes and Rausser (1989), Chavas and Holt (1996)], farmers are made worse off by being exposed to risk. In this context, a risk premium has been used as a measure of the implicit cost of private risk-bearing [Pratt (1964)]. Under some conditions, the average risk premium is expected to increase with farm size [Chavas (1993)]. This suggests that risk exposure gives some economic advantage to smaller farms and provides a disincentive for increasing farm size. Alternatively, larger farms may have access to better risk management strategies that can help reduce their risk exposure. These strategies include diversification strategies and the development of flexible plans that can deal better with unforeseen contingencies (e.g., by investing in forms of capital that have multiple uses). They also include financial and marketing strategies (e.g., hedging, contracts, access to capital and financial markets) that can redistribute risk toward agents who are better informed and/or have a better ability to bear risk. In general, it appears that larger farms are more likely to develop (compared to smaller farms) under conditions of reduced risk exposure and/or more refined risk management schemes.

In addition, there is significant uncertainty about product quality in agriculture. For example, pesticide contamination and biotechnology have raised consumer concerns about food safety. This has stimulated the use of contracts as a way to improve food quality. Also, it has increased the prospects for product differentiation and market segmentation in agricultural markets. For example, some farms have been able to capitalize on the growing demand for "organic" food. By using production techniques that are perceived by consumers to produce higher quality and safer products, they can sell their products at higher prices on differentiated markets. This requires establishing separate marketing channels, often a significant challenge. When feasible, this has allowed some small farms (that are typically more labor-intensive and less capital-intensive) to survive and prosper even while facing relatively high production costs.

Finally, compliance with environmental rules and regulations is increasingly important in agriculture. This is motivated by situations of pollution and externalities where farming has adverse impacts on the environment (e.g., nitrate contamination of groundwater). The associated costs can affect the choice of size and location of production units. These effects depend on the environmental externalities generated, the nature of the regulations, and the abatement technology available. In some cases, large farm operations may increase pollution problems by concentrating the pollutants in a few locations (e.g., as in livestock production). Then, environmental regulations would likely have a greater impact on large production units. This may favor smaller farms. Alternatively, it may be that larger farms have access to better abatement technology, which would improve their ability to manage agricultural externalities.

3.2. Economies of scope and diversification

Farms are typically multi-product firms. Most produce more than one output, either implementing crop rotation practices or using an integrated crop-livestock production system. Yet the extent of farm specialization varies both over time and across space. In general, there is a tendency for commercial farms to be more specialized than subsistence farms, with an overall trend toward increased specialization.

The fact that most farms are multi-product firms suggests that the benefits of diversification are significant in agriculture. These benefits take two forms: the presence of economies of scope reflecting the reduced cost associated with producing multiple outputs, and the risk-reducing effects of diversification.

Economies of scope in agricultural activities appear to be significant [e.g., Fernandez-Cornejo et al. (1992), Chavas and Aliber (1993)]. Crop rotations generate well-known benefits. They allow different crops to better exploit the fertility of the soil. For example, corn planted after soybean benefits from the soybean's ability to fix nitrogen. Also, crop rotations contribute to lowering pest populations, thus reducing the need for pesticides. Finally, integrated crop-livestock systems can involve forage production that helps improve land fertility and reduce soil erosion, while manure can ameliorate soil quality and increase crop yields.

As argued above, risk and risk aversion provide incentives for farmers to reduce their risk exposure. To the extent that different activities are influenced differently by weather conditions or pest problems, diversification can be an effective way of reducing farmers' risk exposure. There is empirical evidence that risk reduction is a significant motivation for farm diversification [e.g., Lin et al. (1974)].

Both economies of scope and the risk benefits associated with farm diversification suggest strong incentives for farms to be multi-product enterprises. But this does not explain the historical trend toward more specialized farms. Such a trend indicates that there are also significant benefits to specialization. Such benefits come mainly from improved productivity. Typically, a task is better performed by a specialist than by a general manager. For example, a veterinarian is expected to better manage animal health problems on a farm than a general farm manager. But specialized management may become profitable only on larger firms. Often, the benefits of specialization can be obtained only beyond some minimal scale of operation. This suggests the existence of an important trade-off between farm size and diversification. As farm size increases, the benefits of specialization and the associated enhanced productivity rise, which can counterbalance the benefits of diversification mentioned above. The net effect is that economies of scope tend to decline with farm size. This is supported by empirical evidence of a negative relationship between economies of scope in agriculture and farm size [e.g., Fernandez-Cornejo et al. (1992), Chavas and Aliber (1993)]. This provides an economic rationale for why larger farms tend to be more specialized than smaller farms, as the former are in a better position to capture the benefits of specialization. It also suggests that the trend toward more specialized farm production systems is in large part motivated by productivity improvements.

3.3. Technology and farm organization

Over the last century, agriculture has undergone two remarkable changes: rapid technological change (both in developing and developed countries), and significant reduction in farm labor (mostly in developed and newly industrialized countries). These two factors are not unrelated. First, technical progress was a necessary condition for the decrease in farm labor: without it, feeding the growing urban population would not have been possible. Second, the evolving labor market has had some feedback effects on the nature of technical change in agriculture.

Over the last few decades, productivity growth has been the principal factor responsible for economic growth of agriculture in developed countries [Capalbo and Antle (1988), Ball (1985), Ball et al. (1997)]. For example, over the last four decades, U.S. agriculture has seen an average increase in output of 1.9 percent a year, and an increase in productivity of 1.9 percent a year [Ball et al. (1997)]. This indicates that technical progress (i.e., significant improvements in land and labor productivity) contributed to most of the increase in farm output. Such remarkable results apply to most developed countries [see, e.g., OECD (1995)]. On average, productivity growth in agriculture has been larger than in many other sectors. For example, Jorgenson and Gollop (1992) found that the growth rate of U.S. agricultural productivity has been four times larger than the corresponding rate in the rest of the economy. This stresses the importance of agricultural technical change in developed countries. However, the extent and nature of agricultural productivity growth in developing countries has been less uniform. Over the last three decades, land productivity and labor productivity have increased significantly in most countries [Pardey et al. (1991), Craig et al. (1997)]. However, sub-Saharan Africa has seen stagnation in its agricultural labor productivity [Craig et al. (1997)].

In developed countries, the twentieth century has seen significant economic growth in the non-farm sector, which increased non-farm employment and raised urban wages. This created some disparity between farm and non-farm income and produced incentives for a large labor migration from farms to urban areas [Schultz (1945)]. It significantly reduced the amount of both family labor and hired labor in agriculture. The decrease in hired labor resulted in the typical farm being a family farm with little or no hired labor. And, given that total farmland has been fairly constant in most developed countries, the decrease in family labor has implied a rise in average farm size over time. This also stimulated the adoption of labor-saving technology in agriculture (e.g., mechanization), yielding large increases in farm labor productivity. It illustrates the existence of feedback effects of resource scarcity on technical change.

More generally, these feedback effects have been associated with the "induced innovation" hypothesis [Binswanger (1974), Hayami and Ruttan (1985)]. This hypothesis states that relative resource scarcity tends to guide technological change toward using additional inputs that are plentiful and inexpensive, while saving on scarce and expensive inputs. This is consistent with labor-saving technological change being stimulated by higher wages. This is also consistent with fertilizer-using technological change found in North American, European, and Asian agriculture in the 1960s and '70s [Binswanger (1974), Hayami and Ruttan (1985)].[3] It involved the development of high-yielding varieties (through genetic selection) of corn, wheat, and rice that were particularly responsive to nitrogen fertilizer. The incentive to develop and adopt these new varieties came in part from technological progress in the nitrogen fertilizer industry, which reduced the market price of nitrogen fertilizer. This combination of low-cost fertilizer with high-yielding varieties contributed to large crop yield improvements in developed agriculture, and to the success of the "green revolution" in developing countries.

Note that the period since the mid-1970s has seen higher prices for energy, fertilizers, and pesticides. There is empirical evidence suggesting that this period also saw some

[3] However, note that there is also empirical evidence suggesting some inconsistencies between the induced innovation hypothesis and technical change in agriculture [e.g., Chavas and Cox (1997a)]. This stresses the complexity of the process of technical change.

changes in U.S. agricultural technology toward becoming more "input-saving" for these inputs [Chavas and Cox (1997b)]. Again, being consistent with the induced innovation hypothesis, this illustrates that the nature of technical change appears to be sensitive to relative resource scarcity.

Over the last few decades, some agricultural technologies have been identified as contributing to pollution of the environment (e.g., groundwater pollution by nitrates) and degradation of the ecosystem (e.g., pesticide contamination). New technologies are currently being developed in an attempt to reduce these adverse effects of agriculture. They include the development of nitrogen-fixing corn and pest-resistant varieties. These emerging technologies offer new prospects to improve the current management of the ecosystem.

The process of technical change has been found to have large economic effects both within agriculture and within society [e.g., Griliches (1960), Schmitz and Seckler (1970), Huffman and Evenson (1993), OECD (1995)]. The current use of genetic engineering and biotechnology in both crop and animal production gives good prospects for continuing technical progress in agriculture. Typically, the adoption of a new technology is a slow diffusion process [e.g., Griliches (1957)]. At first, a few early adopters can benefit economically from the increased productivity it generates. Eventually, as a majority of producers adopt it, the new technology contributes to higher farm output and lower food prices. As a result, consumers gain significantly from technical progress. At the same time, the farms that are late adopters typically face difficult economic conditions: high production costs accompanied by lower food prices. This is Cochrane's (1958) "treadmill effect": in the presence of rapid technical progress, any farmer who does not quickly adopt new technology is threatened with declining profit. This puts considerable pressure on farm managers to remain informed about emerging technologies and their adaptation to local agro-climatic conditions. In general, the early adopters are likely to have good managerial skills. This means that technical change would tend to favor good managers. This "management bias" has important implications. For example, if specialization tends to be associated with superior management, then technical change would favor specialized production systems. This indicates that the distribution of the benefits from technical progress can vary greatly across firms within an industry.

Notably, most of the new agricultural technology did not originate from the farm. Rather, it typically came from some combinations of private and public institutions that made significant investments in agricultural research and development (R&D). Historically, the payoff from both private and public R&D investments in agriculture has been high. On average, their estimated rate of return has been in the range of 20 to 30 percent in the U.S. [e.g., Griliches (1960), Hayami and Ruttan (1985), Chavas and Cox (1992, 1997a), Huffman and Evenson (1993)]. For both private and public R&D, there is evidence of significant lags between the timing of investment and its effects on farm productivity, the lag varying between 10 and 30 years. The empirical evidence suggests that private R&D investments appear to generate their returns in the intermediate run (after about 8–15 years), while public R&D investments seem to pay off in the longer run (after 15–25 years) [e.g., Huffman and Evenson (1993), Chavas and Cox

(1992, 1997a)]. This is consistent with the 17-year legal patent protection, and the fact that private research tends to be more "applied". In contrast, public research tends to be more "basic", with longer-term and more uncertain payoff. However, the relative role of public versus private agricultural research is changing. In U.S. agriculture, investments in private research have increased faster than in public research. As a result, the share of public research has declined from 50 percent in 1981 to 45 percent in 1996 [Frisvold et al. (1998)]. This move toward the privatization of agricultural research is observed in many countries around the world [OECD (1995)]. With the current developments in biotechnology, it involves a redefinition of the relationships between private research and public research, as they promise to influence technical progress in agriculture in the twenty-first century.

It is worth emphasizing that the rate of technical progress has varied across industries and across regions. As discussed above, over the last few decades, most countries have exhibited large agricultural productivity growth [e.g., OECD (1995), Pardey et al. (1991), Craig et al. (1997)]. This is the main factor explaining the trend toward lower food prices. However, one significant concern relates to the current situation in Africa. Over the last three decades, sub-Saharan Africa has been in large part bypassed by the "green revolution". And current agricultural R&D investments indicate that it is not likely to benefit greatly from new biotechnology. This suggests that the prospects for large agricultural productivity growth in sub-Saharan Africa are not very good. This creates significant challenges to technology and economic development policies in this part of the world.

As discussed above, part of the increase in farm productivity over the last few decades has been associated with increased specialization. In many developed regions (e.g., Western Europe, U.S.A.), at the beginning of the twentieth century, most farm households were small and greatly diversified. Being strongly motivated by food self-sufficiency motives, they attempted to produce most of the household food consumption needs. This changed with the growth of agricultural markets, which facilitated the development of specialization in agriculture at the farm level, the regional level, as well as the national level. Greater specialization reduced the scope of activities and increased the need for market exchange for each farm and each region. It allowed farm managers to focus their skills on just a few enterprises, thus improving their production control and efficiency. It also allowed farm and food marketing firms to become better organized spatially, thus contributing to lower transportation and marketing costs. As a result, farms and regions evolved toward more specialized production systems that exploited their comparative advantage reflecting local agro-climatic conditions. As they became better integrated in the market economy, they received the benefits from market exchange and trade. This contributed to more efficient and more productive agriculture at the farm, regional, national, as well as world levels. This process is still in progress as regions and nations negotiate politically with each other over the distribution of the benefits from trade.

While the role of agricultural markets has for the most part been increasing over time, vertical coordination in some sectors has come to depend on contracts. This is particularly true for highly perishable products such as vegetables, where product quality and timing of economic decisions are closely linked. In those sectors, contractual relationships between producers and food processors typically exist, which stipulate the quality, quantity, and timing of production [Marion (1986)]. By improving product quality and timeliness, contracts can contribute to improving production and marketing efficiency in the food sector. Contractual relationships have also developed in some animal production. Starting in the 1950s, the broiler industry evolved quickly toward vertical integration. This was associated with production contracts, greater specialization, and rapid productivity gains [Lasley et al. (1988)]. A similar process is underway now in pork production, and to some extent in beef production.

Why is this move toward greater integration taking place in agriculture? At least three contributing factors have been proposed: efficiency gains, productivity gains, and the exercise of market power. First, efficiency gains would be obtained in the presence of economies of scope across the production systems being integrated. But, in his investigation of the U.S. pig sector, Azzam (1998) did not uncover evidence of vertical economies of scope between feeder-pig production and finishing. Second, it is often believed that integration can help stimulate productivity. The rapid productivity gains of the broiler industry under vertical integration is an illustrative example [Lasley et al. (1988)]. Third, the possible role of market power as a motivating force behind integration has generated both interest and concerns [e.g., Marion (1986), Azzam (1996), McCorriston et al. (1998)]. Azzam (1996) found some empirical support for the hypothesis that monopsony provided an (inefficient) incentive that contributed to the backward integration of the U.S. beef slaughter industry into the live cattle market.

In general, farmers approach their input and output markets as price takers. However, they can face marketing firms that are large and in a position to exercise market power. This raises questions about the effects of market concentration on the organization and performance of the food sector [Marion (1986), Huang and Sexton (1996), Cotterill (1997)]. Although a discussion of these issues is beyond the scope of this chapter, it seems appropriate here to mention the role of agricultural cooperatives. Cooperatives can be prevalent in particular sub-sectors (e.g., as in the case of the U.S. dairy subsector) [Marion (1986)]. Cooperatives can be interpreted as an institutional response to market imperfections. Often, a cooperative projects its member either forward or backward in a marketing channel. It can therefore accomplish many of the same purposes as vertical integration [Sexton (1986)]. Some of the motivations for cooperative formation include improving product quality and avoiding monopoly or monopsony situations [Marion (1986)]. In this context, cooperatives have an efficiency-enhancing role: they can help improve vertical coordination in the agricultural sector. Alternatively, cooperatives can be used as a means of increasing the bargaining power of farmers facing imperfectly competitive markets. When applied to agricultural marketing, cooperatives can generate significant price enhancements through their exercise of bargaining power. Under strong bargaining power, this would increase members' income, but can also lead to inefficient and non-competitive outcomes. However, under free entry, one may expect such inefficiencies to be unsustainable in the long term, unless some form of supply control is implemented.

4. Entry-exit decisions and resource mobility in agriculture

In our earlier discussion of economies of scale, we assumed free entry and exit, i.e., perfect resource mobility. We now examine the role of imperfect resource mobility in agriculture.

The typical family farm is heavily influenced by the life cycle of the farm household manager. Two phases of this life cycle are particularly important: the beginning of the cycle when a young manager decides to work on a farm; and the end of the cycle when an older manager decides to retire from farming. In between, with a few exceptions,[4] the continuation of the family farm is often not an issue. Thus, some of the most important decisions made by a farm household manager are long-term decisions that are not subject to frequent renegotiation. This suggests rather low mobility of farm labor in the short term. Similarly, land rights typically remain under the control of the same manager over extended periods of time. Finally, at least part of farm capital is usually "specialized", meaning that it has few alternative uses. An example is a milking parlor that cannot be moved easily and has no alternative use but the milking of cows. This indicates that agriculture is a sector characterized by restricted resource mobility, at least in the short run. In other words, the dynamic adjustments of land, capital, and agricultural labor tend to take place over many years [e.g., Schultz (1945), Brandow (1977)].

This reduced resource mobility can be traced in large part to special characteristics of agricultural production. Land and climate are specific to particular locations and cannot be moved. As a result, many agricultural adjustments involve spatial adjustments in other factors of production, in particular farm capital and farm labor. Yet agricultural investments in human and physical capital can also be location-specific. When there are significant costs of moving capital or labor over space, this generates a situation of "asset specificity" which affects the dynamic process of resource allocation in agriculture. This is the issue of "asset fixity" analyzed by Johnson and Quance (1972).

4.1. Capital mobility

A situation of asset fixity can be linked to the existence of sunk investment costs. An investment is sunk if the unit value of investment is higher than the unit value of disinvestment. This happens when the purchase price of capital is larger than its salvage value. For example, the salvage value of a milking parlor is typically close to zero, implying that the investment in a milking parlor is almost entirely sunk. The existence of

[4] A notable exception includes situations of foreclosure and bankruptcy, where large debt and severe financial stress can force the farm household manager out of agriculture.

sunk cost can be linked to transaction costs and/or market imperfections. In the case of a milking parlor, the lack of alternative uses and the high cost of moving are the main reason why its salvage value is so low. Sunk costs imply that an investment decision cannot be reversed costlessly. In general, there is an economic incentive for decision makers to avoid facing sunk costs. In situations of risk, this means that sunk costs provide an incentive to avoid reversing any decision, i.e., to keep capital in its current utilization. As analyzed by Dixit (1989), Chavas (1994), and Dixit and Pindyck (1994), this has three implications. First, under sunk costs, there is a zone of "asset fixity" where investments fail to respond to small changes in economic incentives [Johnson and Quance (1972)]. This can be interpreted as a "market failure", where changes in relative prices may not help guide the process of resource allocation at least in the short run. And it can lead to the segmentation of markets [e.g., Shiha and Chavas (1995)]. Second, asset fixity provides a disincentive to exit an activity. In the 1950s and 1960s, this generated a situation where agricultural resources were relatively slow to exit U.S. farming even in the face of persistently low return. Third, asset fixity interacts with uncertainty to provide a disincentive to invest. In other words, sunk costs and risk can create "barriers to entry". Vasavada and Chambers (1986) presented empirical evidence supporting a form of asset fixity and the presence of sluggish adjustments to price changes for labor and capital in U.S. agriculture. And the interaction of sunk costs and uncertainty can adversely affect market participation decisions and thus the functioning of markets [e.g., De Janvry et al. (1991), Goetz (1992)].

Advances in farm technology made capital highly productive and attracted capital into agriculture. In the longer term, capital investments have greatly stimulated labor productivity. High capital requirements have also made entry into farming more difficult. This has generated some concerns about the survival of the family farm [e.g., Gale (1993), Weiss (1998), Goetz and Debertin (1996), Allanson (1992)]. Weiss presents some Austrian evidence supporting an emerging bimodal structure of farm sizes: small part-time farmers and large farms surviving, with mid-size farms decreasing in relative number. The role of off-farm income in sustaining small farms has been documented [e.g., Hearn et al. (1996), Lianos and Parliarou (1986)]. It suggests that, in the absence of off-farm income, many prospective young farmers may find it economically unattractive to support a family on a mid-size farm. Finally, it is often suggested that government policies (e.g., government programs, tax policy) have contributed to increases in farm size [e.g., Lowenberg and Boehlje (1986), Goetz and Debertin (1996)]. There is evidence that the benefits from government farm programs are often not equitably distributed: the majority of the associated income transfers tend to go to large farms and relatively wealthy families [e.g., Sumner (1990)]. However, it is not clear how this affects the return per unit of land between small farms and large farms. Furthermore, distinguishing empirically between the effects of government policies and those of technical progress is difficult. As a result, the exact role of government policies in explaining the trend toward larger farms in developed countries remains somewhat unclear [e.g., Gardner and Pope (1978), Sumner (1990)].

4.2. Labor mobility

Individuals on farms have the option of choosing between farm work and non-farm employment. However, except when located near urban areas, choosing non-farm employment often requires moving to an urban area. As mentioned above, rural migration to cities has been an important aspect of structural change in agriculture through most of this century. Migration decisions depend on the nature of labor demand outside agriculture. For example, during the 1950s and 1960s, expanding industrial production created many urban job opportunities in developed countries. This was also a period when average household income was typically higher in urban areas. This stimulated rural migration. The persistence of this income gap over several decades points to "farm labor specificity". At least two factors contribute to this specificity: (1) investments in farm human capital are partially sunk whenever some farm skills have few alternative uses outside the farm sector; and (2) migration decisions involve significant information and transactions costs that are also sunk. This has generated a rather slow adjustment process in the farm labor market. However, over several decades, this process can still provide massive labor shifts across sectors (as observed in developed and newly industrialized countries).

In developed countries, the last two decades have seen most of the employment growth in the service sector. In the U.S., the income gap between farm versus urban households has been reduced (due in part to a leveling-off or a decline in real wages in urban areas). As a result, the income incentive to migrate from rural to urban areas is currently not as strong as it was in the 1950s or 1960s. This suggests that the decision to become a farmer versus working in the non-farm sector has become more complex over the last two decades. After decades of rural migrations to cities, the remaining active farm population is quite small. The fact that farm production increased in the face of such a sharp reduction in farm labor stresses the large labor productivity gains in agriculture. Given that in developed countries farming currently employs only a few percent of the active population, the prospects for important rural migration are now limited. As a result, there is a new focus on the role of non-agricultural activities in rural areas. Also, the concerns have shifted from exit issues to entry issues in agriculture [e.g., Gale (1993)]. What institutions are training and preparing the farmers of tomorrow? What is being done to reduce some of the adverse effects of risk and asset specificity in agriculture? With the rising importance of human capital, the structure of agriculture is slowly evolving toward units of production, stressing the role of technological and managerial skills.

4.3. Markets and trade

Over the last few decades, there has been a great increase in the role of agricultural markets in resource allocation. The 1980s and 1990s have seen an increased reliance on markets and a decreased role of government in agriculture. Structural adjustment policies advocated in the 1980s by the IMF and the World Bank have enhanced the role of agricultural markets in guiding the allocation of agricultural resources in many developing countries. Following decades of extensive involvement of government in the U.S. farm sector [e.g., Brandow (1977)], the Federal Agricultural Improvement and Reform (FAIR) Act of 1996 has set the stage for less government involvement in U.S. agriculture. And after decades of limited progress, GATT and WTO trade negotiations in the 1990s have contributed to reducing trade barriers in world agriculture.

The increased role of markets has been associated with increased resource mobility, especially for capital and finance. Over the last few decades, the international capital market has become very active, large, and fluid. It has significant implications for economic policy and trade. First, by arbitraging financial returns across countries, the international capital market has restricted the effectiveness of monetary policy conducted by any country. Second, exchange rates are now often more sensitive to international capital flows than they are to changes in the balance of trade. In this context, it is not clear that exchange rates always provide proper signals to evaluate the comparative advantage of production in a particular country. Also, the fluidity in the international capital market means a high volatility in exchange rates, which creates fluctuating import and export prices.

As discussed earlier, agricultural production faces significant price risk and production risk. Also, decrease in government involvement has contributed to increased price uncertainty for farmers. What can be done to reduce some of the adverse effects of sunk costs and risk? Good information about market conditions and superior technological and managerial skills seem crucial. Also, various risk management schemes are available. They can be interpreted as private and public safety nets designed to reduce exposure to downside risk. They include the use of insurance against production uncertainty, and of options and futures contracts to reduce price risk. But problems of asymmetric information (moral hazard and adverse selection) have hampered the development of insurance markets. Hedging using futures markets is an effective way to reduce the short-term effects of price risk. For example, traders commonly hedge on exchange rate futures to eliminate the price risk generated by fluctuating foreign currencies. However, the short maturity of most futures contracts means that their usefulness in managing long-term risk is limited. As a result, the use of futures and options markets cannot eliminate the adverse effects of price risk on long-term investments.

Various government schemes can also help. They include food aid to developing countries, price support programs that reduce the prospect of facing declining prices, government subsidy of insurance premium, and government disaster payments. All contribute to decreasing downside risk and thus reducing the negative effects of sunk costs and uncertainty on investment incentives. Finally, production and marketing contracts can also help when they redistribute risk and possibly mitigate the adverse influence of risk on resource allocation. However, the associated benefits may not be broadly shared since only the contracted parties receive them.

While new technologies are playing a significant role feeding a growing population, they are also raising new questions about food quality. This is illustrated by the current debate about "organic" food and bioengineered crops and livestock. The evaluation of food quality raises difficult issues both domestically and in international trade, especially when consumer perceptions differ from scientific opinions. The problem is that there is no universal evaluation of what constitutes "safe" food. There is a concern that food produced from new technologies may have some long-term adverse effects on human health (or on the environment), effects that are difficult to observe in the short term (e.g., the case of BST technology in the dairy sector). As a result, we are entering a new era where it is increasingly difficult to treat food items as standard products. This creates new opportunities for product differentiation in the food sector. It also generates significant challenges for developing marketing systems that respond effectively to consumer demand.

It seems that we are slowly evolving toward a marketing system of differentiated food products. The role of government is to provide minimum standards of food safety to protect human health against well-documented hazards, and enforce them in both domestic and international markets. Beyond that, market niches are developing for "higher quality" products that command some price premium. Even in the absence of strong scientific evidence, some consumers are willing to pay a premium for food products they perceive to be "safer". With appropriate information (e.g., labeling), consumers are in a position to choose among products of differing quality based on their own evaluation of relative food safety. Contracts can play an important role in establishing quality and product differentiation (e.g., in the case of "organic" food). They work best when producers and consumers are in close geographic proximity. This provides new economic opportunities for some farms to develop direct marketing schemes to reach local consumers. To the extent that large farms may find it more difficult to differentiate their products, this may give some economic advantage to smaller farms. More generally, product differentiation will require establishing vertically integrated marketing systems providing quality control and appropriate labeling throughout the marketing channel. Developing such systems remains a formidable task, with significant implications for the future organization and structure of the food system.

For international trade, the challenges are even more significant. The temptation is always strong to use food safety concerns to promote protectionism. Trade disputes over food quality will likely become more common. This involves the World Trade Organization (WTO) as well as national courts. WTO deals with global rules of trade between nations, interpreting trade agreements and commitments, and trying to settle trade disputes generated by countries' trade policies. And national courts are involved in settling private as well as public trade disputes. In a world of differentiated products, there is a need for institutional innovations to safeguard and improve the efficiency of international transactions [Casella (1992)]. Traders need to have access to a dispute resolution process acceptable to merchants of different national backgrounds. Judges in national courts are often unfamiliar with the "usage of trade" and the technicalities of specific transactions. This has stimulated international arbitration schemes (e.g., the International Chamber of Commerce in Paris). As a result, a body of law is developing through the published deliberations of arbitrators, deliberations taken as precedents in successive decisions. This can facilitate the process toward further international integration.

5. Concluding remarks

Rapid technological progress and expanding trade have been major factors influencing agriculture. National food security policies were common among many nations in the 1950s and 1960s. It meant only limited competition for many farmers around the world and limited benefits from specialization. The current liberalization of agricultural markets throughout the world means that farmers now face stiffer competition and stronger incentives to specialize. This can be difficult for many farmers who face economic and financial hardship. But this also provides new opportunities for farms, regions, and nations to identify their comparative advantage, exploit it to remain competitive, and contribute to increasing world food supply. A key issue is the nature of resource mobility and its variations across farms, regions, and nations. The farms, regions, or nations that face lower resource mobility will likely see depressed farm income. Alternatively, the ones with human capital, technological and managerial skills, and higher resource mobility will prosper. The challenge is to develop private institutions and government policies that can assist in the evolving production structure and adjustment process in agriculture.

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References

Allanson, P. (1992), "Farm size structure in England and Wales 1939–89", Journal of Agricultural Economics 43:137–148.

Azzam, A.M. (1996), "Testing the monopsony-inefficiency incentive for backward integration", American Journal of Agricultural Economics 78:585–590.

Azzam, A.M. (1998), "Testing for vertical economies of scope: An example from US pig production", Journal of Agricultural Economics 49:427–433.

Ball, V.E. (1985), "Output, input and productivity measurement in US agriculture, 1948–79", American Journal of Agricultural Economics 61:475–486.

Ball, V.E., J.-C. Bureau, R. Nehring and A. Somwaru (1997), "Agricultural productivity revisited", American Journal of Agricultural Economics 79:1045–1063.

Baumol, W.J., J.C. Panzar and R.D. Willig (1982), Contestable Markets and the Theory of Industry Structure (Harcourt B.J., New York).

Benjamin, D. (1992), "Household composition, labor markets and labor demand: Testing for separation in agricultural household models", Econometrica 60:287–322.

Berry, A., and W. Cline (1979), Agrarian Structure and Productivity in Developing Agriculture (Johns Hopkins University Press, Baltimore).

Binswanger, H.P. (1974), "The measurement of technical change biases with many factors of production", American Economic Review 64:964–976.

Binswanger, H.P. (1981), "Attitudes toward risk: Theoretical implications of an experiment in rural India", Economic Journal 91, 867–890.

Binswanger, H.P., and K. Deininger (1997), "Explaining agricultural and agrarian policies in developing countries", Journal of Economic Literature 35:1958–2005.

Binswanger, H.P., K. Deininger and G. Feder (1993), "Agricultural land relations in the developing world", American Journal of Agricultural Economics 75:1242–1248.

Boserup, E. (1965), The Conditions of Agricultural Growth (Allen and Unwin, London).

Brandow, G.E. (1977), "Policy for commercial agriculture, 1945–71", in: L. Martin, ed., Survey of Agricultural Economics Literature (University of Minnesota Press, Minneapolis).

Capalbo, S.M., and J.M. Antle (1988), Agricultural Productivity: Measurement and Explanation (Resources for the Future, Washington, DC).

Casella, A. (1992), "On market integration and the development of institutions: The case of international commercial arbitrage", European Economic Review 40:583–591.

Chavas, J.-P. (1993), "The Ricardian rent and the allocation of land under uncertainty", European Review of Agricultural Economics 20:451–469.

Chavas, J.-P. (1994), "On production and investment decisions under sunk cost and temporal uncertainty", American Journal of Agricultural Economics 76:114–127.

Chavas, J.-P., and M. Aliber (1993), "An analysis of economic efficiency in agriculture: A nonparametric approach", Journal of Agricultural and Resource Economics 18:1–16.

Chavas, J.-P., and T.L. Cox (1992), "A nonparametric analysis of the influence of research on agricultural productivity", American Journal of Agricultural Economics 74:583–591.

Chavas, J.-P., and T.L. Cox (1997a), "An analysis of the source and nature of technical change: The case of U.S. agriculture", Review of Economics and Statistics 79:482–492.

Chavas, J.-P., and T.L. Cox (1997b), "Production analysis: A nonparametric time series application to U.S. agriculture", Journal of Agricultural Economics 48:330–348.

Chavas, J.-P., and M.T. Holt (1996), "Economic behavior under uncertainty: A joint analysis of risk preferences and technology", Review of Economic and Statistics 78:329–335.

Chavas, J.-P., R.D. Pope and H. Leathers (1988), "Competitive industry equilibrium under uncertainty and free entry", Economic Inquiry 26:331–344.

Cochrane, W.W. (1958), Farm Prices: Myth and Reality (University of Minnesota Press, Minneapolis).

Cotterill, R.W. (1997), "The food distribution system of the future: Convergence toward the US or UK model?", Agribusiness 13:123–135.

Craig, B.J., P.G. Pardey and J. Roseboom (1997), "International productivity patterns: Accounting for input quality, infrastructure and research", American Journal of Agricultural Economics 79:1064–1076.

De Janvry, A. (1981), The Agrarian Question and Reformism in Latin America (Johns Hopkins University Press, Baltimore).

De Janvry, A., M. Fafchamps and E. Sadoulet (1991), "Peasant household behavior with missing markets: Some paradoxes explained", Economic Journal 101:1400–1417.

Dixit, A.K. (1989), "Entry and exit decisions under uncertainty", Journal of Political Economy 97:620–637.

Dixit, A.K., and R.S. Pindyck (1994), Investment under Uncertainty (Princeton University Press, Princeton).

Eswaran, M., and A. Kotwal (1986), "Access to capital and agrarian production organization", Economic Journal 96:482–498.

Fernandez-Cornejo, J., C.M. Gempesaw II, J.G. Elterich and S.E. Stefanou (1992), "Dynamic measures of scope and scale economies: An application to German agriculture", American Journal of Agricultural Economics 74:329–342.

Frisvold, G., K. Fuglie and C. Klotz-Ingram (1998), "Growth of private agricultural research", Choices, Second Quarter.

Gale, H.F. (1993), "Why did the number of young farm entrants decline?", American Journal of Agricultural Economics 75:138–146.

Garcia, R., S.T. Sonka and M.S. Yoo (1982), "Farm size, tenure, and economic efficiency in a sample of Illinois grain farms", American Journal of Agricultural Economics 64:119–123.

Gardner, B.D., and R.D. Pope (1978), "How is scale and structure determined in agriculture?", American Journal of Agricultural Economics 60:295–302.

Goetz, S.J. (1992), "A selectivity model of household food marketing behavior in sub-Saharan Africa", American Journal of Agricultural Economics 74:444–452.

Goetz, S.J., and D.L. Debertin (1996), "Rural population decline in the 1980s: Impacts of farm structure and federal farm programs", American Journal of Agricultural Economics 78:517–529.

Griliches, Z. (1957), "Hybrid corn: An exploration in the economics of technical change", Econometrica 25:501–522.

Griliches, Z. (1960), "Research costs and social returns: Hybrid corn and related innovations", Journal of Political Economy 42:1411–1427.

Hall, B.F., and E.P. Leveen (1978), "Farm size and economic efficiency: The case of California", American Journal of Agricultural Economics 60:589–600.

Hayami, Y., and V.W. Ruttan (1985), Agricultural Development: An International Perspective (Johns Hopkins University Press, Baltimore).

Hearn, D.H., K.T. McNamara and L. Gunter (1996), "Local economic structure and off-farm labour earning of farm operators and spouses", Journal of Agricultural Economics 47:28–36.

Huang, S.-Y., and R.J. Sexton (1996), "Measuring returns to an innovation in an imperfectly competitive market: Application to mechanical harvesting of processing tomatoes in Taiwan", American Journal of Agricultural Economics 78:558–571.

Huffman, W.E., and R.E. Evenson (1993), Science for Agriculture: A Long Term Perspective (Iowa State University Press, Ames, IA).

Innes, R.D., and G.C. Rausser (1989), "Incomplete markets and government agricultural policy", American Journal of Agricultural Policy 71:915–931.

Johnson, G.L., and L.C. Quance (1972), The Overproduction Trap in U.S. Agriculture (Johns Hopkins University Press, Baltimore).

Jorgenson, D.W., and F.M. Gollop (1992), "Productivity growth in U.S. agriculture: A postwar perspective", American Journal of Agricultural Economics 74:745–750.

Kalirajan, K. (1981), "The economic efficiency of farmers growing high-yielding, irrigated rice in India", American Journal of Agricultural Economics 63:566–570.

Kislev, Y., and W. Peterson (1996), "Economies of scale in agriculture: a reexamination of the evidence", in: J.M. Antle and D.A. Sumner, eds., Papers in Honor of D. Gale Johnson (University of Chicago Press, Chicago).

Lasley, F.A., H.B. Jones Jr., E.H. Easterking and L.A. Christensen (1988), "The U.S. broiler industry", ERS Agr. Econ. Rep. No. 591 (USDA, Washington, DC).

Lerman, Z. (1999), "Land reform and farm restructuring: What has been accomplished to date?", American Economic Review 89:271–275.

Lianos, T.P., and D. Parliarou (1986), "Farm size structure in Greek agriculture", European Review of Agricultural Economics 13:233–248.

Lin, W., G.W. Dean and C.V. Moore (1974), "An empirical test of utility vs. profit maximization in agriculture production", American Journal of Agricultural Economics 56:497–508.

Lopez, R.E. (1984), "Estimating labor supply and production decisions of self-employed farm producers", European Economic Review 24:61–82.

Lowenberg, D.J., and M. Boehlje (1986), "The impact of farmland price changes on farm size and financial structure", American Journal of Agricultural Economics 68:838–848.

Marion, B.W. (1986), The Organization and Performance of the U.S. Food System (Lexington Books, Lexington, MA).

Matulich, S.C. (1978), "Efficiencies in large-scale dairying: Incentives for further structural change", American Journal of Agricultural Economics 60:642–646.

McCorriston, S., C.W. Morgan and A.J. Rayner (1998), "Processing technology, market power and price transmission", Journal of Agricultural Economics 49:185–201.

Newbery, D.M.G., and J.E. Stiglitz (1981), The Theory of Commodity Price Stabilization: A Study in the Economics of Risk (Clarendon Press, Oxford).

OECD (1995), Technological Change and Structural Adjustments in OECD Agriculture, Paris.

Pardey, P.G., J. Roseboom and J.R. Anderson (1991), Agricultural Research Policy (Cambridge University Press, New York).

Pratt, J. (1964), "Risk aversion in the small and in the large", Econometrica 32:122–136.

Rao, V., and T. Chotigeat (1981), "The inverse relationship between size of land holding and agricultural productivity", American Journal of Agricultural Economics 63:571–574.

Schmitz, A., and D. Seckler (1970), "Mechanized agriculture and social welfare: The case of the tomato harvester", American Journal of Agricultural Economics 52:569–577.

Schultz, T.W. (1945), Agriculture in an Unstable Economy (McGraw-Hill, New York).

Sexton, R.J. (1986), "The formation of cooperatives: A game-theoretic approach with implications for cooperative finance, decision making and stability", American Journal of Agricultural Economics 68:214–225.

Shiha, A., and J.-P. Chavas (1995), "Capital market segmentation and U.S. farm real estate pricing", American Journal of Agricultural Economics 77:397–407.

Singh, I., L. Squire and J. Strauss (1986), Agricultural Household Models: Extensions, Applications and Policy (Johns Hopkins University Press, Baltimore).

Sumner, D.A. (1990), "Targeting and the distribution of program benefits", in: K. Allen, ed., Agricultural Policy in a New Decade (Resources for the Future, Washington, DC).

Sumner, D.A., and J.D. Leiby (1987), "An econometric analysis of the effects of human capital on size and growth among dairy farms", American Journal of Agricultural Economics 9:465–470.

Strauss, J. (1986), "Does better nutrition raise farm productivity?", Journal of Political Economy 94:297–320.

Vasavada, U., and R.G. Chambers (1986), "Investment in U.S. agriculture", American Journal of Agricultural Economics 68:950–960.

Weiss, C.R. (1998), "Size, growth and survival in the Upper Austrian farm sector", Small Business Economics 10:305–312.

Yotopoulos, P.A., and L.J. Lau (1973), "A test of relative economic efficiency: Some further results", American Economic Review 63:214–223.

Chapter 6

LAND INSTITUTIONS AND LAND MARKETS

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Contents

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Abstract

Assignment of land rights affects equity and efficiency, determining among other things households' ability to generate subsistence and income, their social and economic status, incentives to exert effort and make investments, and access to financial markets and consumption-smoothing mechanisms. The chapter discusses costs and benefits of the transition towards individualized land rights. It reviews how characteristics of the agricultural production process, credit access, portfolio risk, and transaction costs affect functioning of land sales and rental markets. Policy conclusions are drawn concerning the transition from communal to individualized land rights, award of formal titles, improved functioning of land sales and rental markets, and redistributive land reform.

JEL classification: Q15

1. Introduction

In agrarian societies land is not only the main means for generating a livelihood but often also for accumulating wealth and transferring it between generations. The way in which land rights are assigned therefore determines households' ability to produce their subsistence and generate marketable surplus, their social and economic status (and in many cases their collective identity), their incentive to exert non-observable effort and make investments, and in many cases also their ability to access financial markets or to arrange for smoothing of consumption and income.

Given this context, markets to exchange rights to land temporarily or permanently can provide a low-cost means to effect transactions that would bring this factor of production to its most productive use. The institutions governing the functioning of land markets will affect the transaction cost associated with such exchanges, the magnitude and distribution of the benefits generated by them, and the incentives for rational economic agents to undertake efficiency-enhancing transfers and land-improving investments. Furthermore, since land is one of the best collateral assets available, clear property rights and greater ease of their exchange are likely to affect the emergence and efficiency of financial markets. This implies that land markets have an essential role in the broader process of economic development.

In this chapter we first examine the way in which property rights in land evolve in an ideal and undistorted environment. We view the emergence of land rights as an endogenous response to increased scarcity of land and the associated incentives for land-related investment, and then discuss other factors – such as further increases in population density, better access to markets, or the introduction of improved technology to exploit the land – that would lead to increased productivity of agricultural cultivation, as well as endogenous technical change. We note that, historically, there have been few cases where such an uninterrupted evolution has been followed. We then briefly sketch the conditions required for as well as the deviations from this ideal path. With this in mind, we discuss factors affecting the costs and benefits of individualized land rights and examine empirical evidence for their magnitude. The implications of tenure security for investment incentives are highlighted.

Having clarified the concept of property rights in land, we turn to land sales and rental markets. We consider the main factors affecting participation in those markets, in particular characteristics of the agricultural production process, labor supervision cost, credit access, the risk characteristics of an individual's asset portfolio, and the transaction costs associated with market participation. These factors will affect land sales and rental markets differently; in particular, even if owner-operated farms are more productive than wage–labor-operated ones, the sales market will not necessarily shift land to them. This implies that, in environments where financial markets are imperfect, land market operation needs to be considered within a broader perspective focusing on access to other markets and the availability of alternative assets. We note that, in general, land rental markets would be less affected by these problems because renting out does not preclude the landlord from utilizing land as a collateral to access credit which could then be passed on to the tenant in an interlinked contract. Removing obstacles – often government regulations or imperfections in other markets – that prevent smooth functioning of land rental markets and taking measures that enhance potential tenants' endowments and bargaining power can considerably increase both the welfare of the poor and overall efficiency of resource allocation. There are also many instances where sales markets are regulated in a manner which hampers incentives for socially optimal behavior. In addition to reducing tenure insecurity, governments can in these situations improve the efficiency of resource use by avoiding interventions limiting rental and sales markets.

Finally, in a number of countries, a highly unequal land ownership distribution implies inefficient and inequitable resource use which the land sales or rental markets are not able to smoothly transform into a more efficient and equitable allocation. Based on these issues we draw policy conclusions concerning the transition from communal to individualized land rights and the award of titles, steps that might be used to improve the functioning of land sales and rental markets, and the scope for redistributive land reform.

2. Property rights in land

2.1. *The emergence of land rights*

The process of gradual individualization of property rights in land can be conceived as an induced institutional response to higher shadow prices of land to encourage longer-term investments in land, as in the pioneering analysis by Boserup.[1] At the earliest stages of development, even before the establishment of sedentary agriculture, tribes of hunters and gatherers assert control over certain locations where they collect food and engage in hunting. As population density increases, forest fallow systems, and then communal property right systems emerge. Under these arrangements, the general right to cultivation of a piece of land is an inseparable and in principle inalienable element of tribal membership. Cultivation rights are assigned to individuals on a temporary basis, normally as long as the cleared plot is cultivated. Once cultivation has ended (due to exhaustion of soil fertility), the plot falls back to the lineage and the family either selects a new plot (if land is abundant) or has a plot allocated by the chief of the tribe. The fact that land is held by the community or lineage rather than the individual facilitates periodic redistribution of at least part of the land among community members based on population growth, serving as a social safety net and preventing the emergence of a class of permanently landless individuals. Tenure security in a general sense is very high, i.e., individual members enjoy secure and inheritable general rights to cultivatable land which can be reactivated even after a period of absence.

[1] It is well understood that this idealized process has rarely been followed in actual history (Boserup herself devotes more than one chapter to the issue of coercion and the description of feudal systems). It is, nonetheless, useful to illustrate the main underlying factors.

As the relative scarcity of land increases, the pledging or intra-community rental of land emerges. This practice, whereby land that is not used can temporarily be pledged to another family, with the stipulation that it has to be returned upon request, facilitates the productive use of land in case the original owner is unable to undertake cultivation. It is distinctly different from permanent land transactions and is generally not allowed to involve people from outside the community.[2] It also does not uniformly apply to all land – unimproved land lying fallow at any given time continues to be at the free disposal of the community, for example, for grazing by domestic animals owned by any family with cultivation rights. Variations of such communal tenure systems, where parcels are re-allocated from time to time in order to accommodate population growth and grazing land is left for communal use, are common in many parts of the developing world, such as China, large parts of Africa, and Mexico.

What are the factors driving this process of successively increasing precision in the definition of property rights to land? The most frequent explanation is that a virtuous cycle of technical change and investment is set in motion by a combination of increasing population density, technical progress, commercial integration, and reduction of risk. Boserup was the first to point out the fact that, historically, higher population density was the driving force behind an endogenous process of better definition and enforcement of property rights, changing arrangements for the organization of production, and higher levels of investment.

The Boserupian framework of changes in the relative scarcity of land and the associated introduction of labor-saving technology can, for example, explain systematic changes in the strength of women's land rights [Platteau (1996)]. Under land abundance and predominance of shifting cultivation, agriculture tends to be female-dominated, polygyny is widespread, and women enjoy high status as workers as well as child-bearers. Marriage is accompanied by the transfer of bridewealth to the bride's family and, in case of the husband's death, women retain land rights either in their native or in their new village. With increased land scarcity and adoption of the plough, the importance of women in agricultural production tends to decline and bridewealth, as well as other customary safeguards to protect widowed and isolated women, disappears. Instead, women receive, upon marriage, pre-mortem inheritance, which – if it remains the property of the wife – establishes a threat point in intra-household bargaining and provides economic security in the case of divorce or death of the husband.

The diffusion of exogenous technical change and/or expansion of trade generally has an investment-increasing effect similar to the one caused by increased population density. By increasing the stream of incomes that can be derived from a unit of land, technical change and trade expansion increase incentives for better definition of property rights in land. Indeed, establishment of tree crops, and the associated heavy investment

[2] Indeed, the distinguishing characteristic of communal tenure systems is not a lack of general tenure security but the fact that property rights are not permanently linked to a specific plot, implying the existence of restrictions on the transferability of land rights (especially to individuals who are not members of the community).

in clearing and leveling of land, was generally undertaken only where institutional innovations had enhanced tenure security adequately so that individuals could be sure to reap the benefits from such investments. Similarly, the transportation revolution caused by the steamship in the late nineteenth century led not only to the incorporation of hitherto unexplored countries and states into global trade but also increased the demand for individualized ownership of land. For example the opening of Thailand to international rice trade through the Bowering treaty of 1826 induced a quantum increase in the demand for rice land in the Thailand plains, and brought about the introduction of a formal land registration system [Feeney (1988)].

Another important factor furthering the evolution of individual property rights to land is the reduction of risk to income and consumption. The three major avenues for this to come about are (i) the development of markets for output, capital, and insurance, (ii) technical progress that allows for diversification, reduction of the covariance of yields, and the probability of crop failure, and (iii) the emergence of access to non-covariate streams of off-farm income. It has long been noted that group ownership of land (or joint communal production) can be viewed as an "insurance policy" to eliminate the threat of permanent asset loss or to reduce vulnerability to idiosyncratic consumption shocks. However, the scope for using communal land ownership to insure against non-idiosyncratic shocks is limited by the weather-induced covariance of agricultural production. Especially when collective production on arable land is required to obtain these benefits,[3] households prefer individual ownership once alternative and less costly mechanisms to insure against covariate risks become available [see Key et al. (1998), for the case of Mexican farming communities].[4]

Because monitoring of effort in agricultural production is difficult and costly, collectives where individuals are not residual claimants to profits are highly inefficient forms of agricultural production [Deininger (1995)]. However, contrary to widespread misconceptions, communal tenure systems are generally *not* based on collective production. Instead, production on arable plots is normally undertaken by individuals who are residual claimants to output, implying that, on arable plots, incentives for effort supply by individual cultivators are likely to be appropriate. Inefficiencies may persist with regard to decisions concerning the use of communal areas such as forests and pasture, or the disincentive to invest, derived from the inability to claim ownership rights to specific plots. In an analysis of Mexican farming communities (ejidos), McCarthy et al. (1998) provide empirical evidence for the existence of collective action problems regarding the use of pasture and forest, but not of individually managed plots.

[3] Group ownership has often been prevalent where risk is high and where factors such as remoteness, environmental hazard, or presence of external enemies imply that superior insurance mechanisms are not available [Ellickson (1993)].

[4] The potential usefulness of communal land ownership as a device for consumption-smoothing is inversely related to the incidence of locally covariate climatic shocks. It is thus not surprising that, at comparable levels of population density, communal tenure systems have proven to be more durable in environments where such risks are lower.

Communal resource ownership is often motivated by the ability to provide benefits in the form of easier provision of public goods, arrangements to enhance equity, or the ability to take advantage of synergies that would be difficult to realize under fully individualized ownership. Examples include risk reduction through diversification in highly variable environments [Nugent and Sanchez (1993)], the utilization of economies of scale to break seasonal labor bottlenecks [Mearns (1996)], and investment in community-level infrastructure [Boserup (1965), Dong (1996)].[5] As long as effective means of governance and accountable institutions at the local level are available, these systems can be very effective – especially in situations where there is need for community-level investment. For example, under the medieval open field system, cultivation decisions were made collectively but monitoring-sensitive tasks were carried out on an individual basis. This allowed utilizing economies of scale in fencing, harvesting, shepherding, and risk diversification through strip-cropping without compromising the advantages of individual effort supply [McCloskey (1975, 1991), Townsend (1993), Blarel et al. (1992)].

The usufructuary rights given under communal tenure systems do not impose large losses as long as population density is low and land relatively abundant, payoffs for making long-term investments is low, and definition of individual property rights in land is costly. However, even though individuals have the right to cultivate specific plots (a measure that avoids the efficiency losses due to collective production), the lack of permanent rights that is implied by the periodic redistribution of plots may decrease incentives to make long-term land-related investments under communal arrangements. A similar effect comes through the limitation of land transfers to members of the community and the inability to utilize land as a collateral for credit.

Improved access to markets, infrastructure, and financial intermediation are alternative ways to provide the benefits – in terms of insurance, diversification, and access to funds for investment – associated with communal forms of land ownership. At the same time these exogenous factors increase the costs – in terms of investment disincentives and foregone land transactions with outsiders – associated with traditional land ownership systems. This implies that, with economic development, the relative attractiveness of communal systems will decrease and, at some point, it would be economically rational for a community to allocate permanent and fully tradable ownership rights to individuals [see Wilson and Thompson (1993) for Mexico], completing the transition from a communal to an individualized tenure system.

However, instead of following a smooth evolution along the lines outlined above, the transition to individual property rights historically has in the large majority of cases been affected by exogenous interventions. As population growth increases the relative

[5] An interesting case to illustrate this is made by Ellickson (1993) who compares different settlements (Jamestown, Plymouth, Salt Lake City, and the Bermudas) to suggest that, while many frontier settlements started out with group ownership and production to utilize economies of scale in defense and other activities, the length of time during which group ownership is maintained can be related to the riskiness of the environment, the frequency of social interaction, and the hierarchy structure of decision-making.

scarcity of land, one observes a general increase in boundary conflicts and social tension.[6] In the absence of strong and representative community-level institutions, this often leads to appropriation of property rights to the communal resources by powerful individuals, and abuses of power and land-grabbing by local chiefs and headmen.[7] These phenomena are often seen as a major cause of environmental degradation and increased social tension and inequality that leaves out the poor and vulnerable.

History demonstrates that regions with potential for agricultural or non-agricultural exports were generally characterized by the appropriation of large tracts of land through imperialist, colonial, or other overlords who either replaced local chiefs and elders, or tried to co-opt them to enforce their rule. These changes undermined traditional tenure systems, the associated structures of accountability, and thus the institutional underpinning of the organic evolution of such systems [Downs and Reyna (1993), Feder and Noronha (1987)].[8] Furthermore, once they realized that access to labor rather than land was the most limiting factor, overlords generally introduced distortions in other markets to reduce the reservation utility of independent farmers and to assure a supply of labor for export production in mines or for the newly established estates. In addition to reducing the reservation utility that cultivators could obtain from independent cultivation, such restrictions have contributed to widespread rural poverty and retarded development of competitive markets in rural areas, often laying the basis for continued rural–urban dualism.

In more recent times, governments have, through implicit and explicit taxation, drained the rural sector of resources that could have fueled a process of increased market integration and technology development, while at the same time higher rates of population growth vastly increased the need for new technology and better infrastructure [Schiff and Valdés (1995)]. The associated lack of markets and technological opportunities has, in a number of cases, contributed to a situation akin to the "involution" that had earlier been diagnosed for Asian systems [Geertz (1968)], with far-reaching implications for the structure of resource ownership rights. For example in Rwanda, with very high population density (787 persons per km^2), traditional systems of land allocation have become defunct and fail to provide even the most basic services they were designed for [Andre and Platteau (1996)]. As traditional limitations on land sales have been discarded, speculative land purchases by individuals with access to non-covariate

6 Zimmerman and Carter (1996a, 1996b) show that incorporating agent heterogeneity, risk, and subsistence constraints can facilitate a more differentiated assessment of the welfare impact and productivity impact of a given institutional innovation (e.g., the adoption of marketable land rights) on different groups of producers.

7 For example, despite extremely low levels of population density in Zambia, almost 50 percent of small producers feel that their security of tenure is insufficient and are willing to pay (a mean amount of US $ 40) for getting secure ownership rights [Deininger et al. (1998)]. Low-cost means of increasing tenure security and reducing encroachment from outside through better accountability and issuance of community titles could possibly increase welfare and tenure security.

8 This was independent of whether the intervention was associated with the elimination of traditional tenure systems in favor of individualized rights to the selected group, as in many parts of Central and Latin America, or the use of local chiefs and dignitaries as intermediaries for the central power, as in African countries.

off-farm income lead to a rapid disequalization of landholdings.[9] While costly land disputes consume productive energy, environmental degradation continues unabated and the return to an idealized notion of "communal property rights" is unlikely to be a feasible option. To judge, however, what alternative arrangements would be feasible, it is necessary to consider in more detail the costs and benefits associated with different tenurial arrangements.

Drawing together the evidence on costs and benefits associated with more secure and fuller property rights arrangements, three conclusions emerge. First, where population density is sufficiently high, increased tenure security – not necessarily equivalent to formal title – has an important impact on increased investment. Second, there is some evidence that a higher degree of transfer rights provides additional incentives for investments and for more efficient use of family labor. Finally, the ability to use land as collateral to increase access to medium- and long-term formal credit markets is of importance if foreclosure is feasible. Studies that compared the financial costs and economic benefits of titling programs suggest that high rates of return are possible but that, unless measures to reduce the transaction costs associated with administering credit to smallholders are undertaken, the benefits associated with titles may not accrue equally to all types of farmers.

2.2. Benefits and costs of individualized property rights

The main benefits from well-defined and secure individual property rights relate to (i) greater incentives for (and lower costs of) long-term resource conservation and the associated increased demand for investment; (ii) improving transferability (temporary or permanent) of land to cultivators who have the resources to make better use of it an issue that depends on the presence of economies of scale and the disincentives to rental; and (iii) the ability to use land as collateral in formal credit markets, a benefit that is more significant where formal title exists and land transactions are actually feasible. These benefits need to be weighed against two main types of costs: the administrative and logistical expense associated with definition of boundaries, enforcement of rights, and resolution of disputes among claimants, and the increased risk of losing a safety net provided by communal control of land.

2.2.1. Benefits from individual land rights

Improved tenure security brought about by individualized land rights will be associated with static and dynamic benefits. Even without having full long-term security of tenure, individual cultivation rights that entitle an individual to residual claimancy of profits

[9] It is of interest to note that about 65 percent of sales are classified as distress sales – the incidence of which is not restricted to the lowest landholding group – and an additional 17 percent of lands are sold to cover litigation expenses, often arising from land disputes.

generated on a plot mark the difference between collective and private forms of cultivation. The transition from collective to private cultivation has historically been associated with large increases in productivity, as for example in the case of China [McMillan et al. (1989), Lin (1992), Lin et al. (1994)]. However, equally important benefits from better-defined long-term property rights would come about in an intertemporal setting where higher security of tenure would increase the incentives for long-term investments, the incidence of productivity-enhancing transfers, and the supply of credit to make such investments. These aspects are elaborated upon below.

2.2.2. *Tenure security*

Conceptually, insecurity associated with the lack of well-defined property rights can be understood as a random probability of loss of future income due to conflicting challenges. Eliminating such a threat through informal institutions (customary tenure) or formal institutions (land titles) will clearly increase the subjective payoff from productivity-enhancing, long-term investments, and thus the owner's willingness to undertake them. While the theoretical expectation is straightforward and easily formalized [see, for example, Feder et al. (1986), Besley (1995)], the critical question, and much empirical debate, has focused on the magnitudes of such effects in different settings.

The analysis of different types of land rights in Africa is complicated by the need to take into account the potential endogeneity of investment [Besley (1995)]. The reason is that there may be certain types of investments – from marking of boundaries to planting of trees and hedges, and building of houses or sheds – that may be undertaken with the primary purpose of establishing implicit property rights to land rather than of increasing productivity [Brasselle et al. (1997)]. Depending on how such actions affect the probability of land loss and whether or not there are community rules to provide (partial) compensation for such investments when a plot reverts to the community, it is easy to construct scenarios where communal tenure systems may increase rather than decrease the amount of land-related investment undertaken [Sjaastad and Bromley (1997)].[10]

The key result from a number of studies that have investigated the investment-enhancing effect of tenure security is that, under formal as well as informal regimes, tenure security – as measured by the extent of rights possessed by the owner – significantly affects farmers' investment decisions. Especially where investments are labor-intensive but involve few cash outlays, the unambiguous conclusion is that higher levels

[10] Using comparative statics from a simple model it can be shown that communal as compared to individual tenure is more desirable from the individual's point of view as the discount rate increases; the productivity increase generated by investment is smaller compared to rent; the initial probability of eviction is low; and the probability of recovering investment even after eviction is high. A combination of these factors may cause individuals under indigenous tenure to commit resources to land improvement beyond what would be the case under individual resource ownership.

of tenure security – even if they are not associated with high levels of transferability and are defined only at an informal level – do indeed provide an important incentive for increased investment.[11]

Evidence from one of three study areas in Ghana indicates that greater tenure security at the plot level significantly increases the probability that individuals will plant trees and undertake a wide range of other investments such as draining, irrigating, and mulching [Besley (1995)]. The fact that field-specific rights but not mean household rights can be shown to be significant suggests that plot-level tenure security, rather than credit supply effects accruing to the household as a whole, is likely to be at the root of this relationship between tenure security and investment.

Results from China confirm the importance of tenure security for investment. Comparing plots planted with the same crop within the same household but under different tenure regimes, it is found that farmers tend to apply more manure and labor, and to obtain significantly higher yields, on plots that are privately owned and therefore more secure [Rozelle et al. (1996)]. This is the case even though the possible impact of greater tenure security on crop choice (e.g., shifting to orchards instead of growing maize) is not accounted for. Similarly, Yao (1996) finds that higher levels of tenure security in Chinese villages have a strong and very significant investment-enhancing impact (e.g., application of green manure).[12] Analysis of the impact of higher tenure security through land titling in the Brazilian Amazon yields similar results [Alston et al. (1995, 1996)] and there is considerable amount of more anecdotal evidence on a positive association between availability of title and farm output or investment [see Binswanger et al. (1995) for references].

On the other hand, in Niger, a more land-abundant setting, different degrees of tenure security between plots with full private ownership and plots held under usufruct do not give rise to statistically significant differences in application of manure, a medium-term yield-improving investment [Gavian and Fafchamps (1996)]. In this context, farmers apply significantly lower amounts of manure on rented as compared to owned plots, but there is no significant difference between parcels held under full private ownership and those held under "traditional" usufruct. The conclusion is that apparently tenure security on the latter is high enough for farmers to expect to be able to reap the benefits from their (medium-term) investment. At a more general level, it indicates that, in order to determine whether specific property rights arrangements are conducive to higher levels

[11] This does not necessarily imply that actions to increase tenure security are warranted or even needed [Platteau (1996)].

[12] At first glance this would seem to be at variance with the finding by Feder et al. (1992) where, for a similar sample from four Chinese provinces, neither short-term nor long-term tenure security (captured by farmers' perception about the possibility that their land may be reallocated before the expiration of the current 15-year contract) had any perceivable impact on investment. One can reconcile the two findings by noting that Feder et al.'s study considers non-attached investment (machinery, livestock, and construction) which should be made independently of individual plots' tenure security and affected more by access to working capital (which indeed emerged as an important determinant of investment).

of investment, more detailed study is necessary and generalizations are unlikely to be helpful. What is instead required is a more differentiated judgment that takes account of the time horizon of the investment, the opportunity cost of the resources used, and the size and distribution over time of the expected payoff associated with the investment.

2.2.3. *Transferability*

Land markets tend to be highly localized. As a consequence, the ability to transfer land between users may be of limited importance in early stages of development when there is little heterogeneity of skills across the population and non-agricultural opportunities are limited. However, the importance and value of being able to transfer use or ownership rights to land increase with economic development, specialization, and better development of other markets. In this case, the transfer of land from those who have lower productivity to those who are able to make more productive use of the land improves the overall resource allocation. The demand for such exchanges increases further as the rural economy becomes more integrated geographically, facilitating transactions between individuals who are not members of the same community. Such situations generally involve larger problems of asymmetric information and greater benefits from more formal systems of land ownership recording. If the ability to liquidate investments (through land transfers) increases the incentive to undertake such investments, higher levels of transfer rights, and the greater ability to affect transfers which is entailed in formal land rights systems, will not only improve resource allocation but will also be associated with higher levels of investment and labor use by individual cultivators.

The only data that allow testing of this hypothesis come from China, where one observes variability in systems of transfer rights in different communities [Carter and Yao (1998)]. Results suggest that higher levels of transfer rights increase investment (e.g., application of green manure). In addition, evidence from China indicates that higher levels of transfer rights also induce a better allocation of the household's labor endowments in response to, for example, outside employment opportunities. Households with higher levels of transfer rights apply less labor on their farm and devote more time to more remunerative off-farm activities [Yao (1996)], thereby contributing to equalization of factor ratios within a village and increasing overall efficiency. More indirect support for an important efficiency-increasing (but not investment-enhancing) impact of higher transfer rights is provided by Rozelle et al. (1996), who find that an increase in off-farm opportunities narrowed the difference between labor spent on (transferable) private and (non-transferable) communal plots.[13]

[13] Evidence is not uniform: for Ghana, the hypothesis that sales and rental rights do not have a significant impact on investment decisions can not be rejected [Besley (1995)]. This suggests that the prospect of being able to transfer land more easily through sales and rental markets in the future is, in this environment, not an important consideration in individuals' decision to effect land-related investment.

2.2.4. Credit access

In addition to inducing investment, secure land ownership is likely to increase the supply of credit from the formal credit system to undertake such investment. The reason is that, because of its immobility and virtual indestructibility, land with secure, clearly defined, and easily transferable ownership rights is an ideal collateral. The provision of a collateral – facilitated by possession of formal land title – is generally a necessary condition for participation in formal credit markets for medium- and long-term credit. In fact, there is evidence of titles facilitating access to informal (but impersonal) credit markets as well [Siamwalla et al. (1990)]. Existence of well-documented and transferable property rights and of institutional arrangements to facilitate the low-cost transfer of land is likely to make an important contribution to the development of financial markets.

However, while use of titled land as collateral can, under the condition that foreclosure is feasible, reduce a bank's default risk and thereby enhance credit supply, it will have little impact on the transaction costs associated with administering credit to small producers in rural areas. In environments where these costs are high, the improved creditworthiness brought about by possession of land title may therefore not be enough to facilitate access to formal credit by small farmers. Unless complementary measures to reduce transaction costs and ensure access to credit by this group are undertaken alongside with individualized property rights through titling, the benefits from titling programs may accrue only to medium and large landowners.

The importance of the credit supply effect associated with provision of land title is supported by evidence from Feder et al.'s (1986) study in Thailand, where farmers' opinions and econometric evidence point towards improved credit supply as the main benefit from titling. Land ownership titles induced higher investment in farming capital (attached investments and other capital);[14] titled land had significantly higher market values and higher productivity per unit. In three of the four provinces covered, households' credit supply had been significantly enhanced by the availability of title. By contrast, and in line with the above, title was found to have little impact on either investment or farm income where formal credit markets were not available [Atwood (1990), Carter and Wiebe (1990), Migot-Adholla et al. (1991), Pinckney and Kimuyu (1994)].[15]

Additional evidence from a study based on panel data from Paraguay indicates that titling had a positive income or productivity-enhancing effect through credit market benefits for at least some groups of farmers. Due to a strong impact of formal title on both

[14] Problems of endogeneity and self-selection are circumvented by drawing samples from squatter villages in areas nominally under public ownership (where titles could not be awarded) and private areas where all residents already had obtained titles.

[15] Pender and Kerr (1996) show that for India land ownership has little impact on credit supply, a fact that is attributed to severe non-price rationing. Nonetheless, land values for titled land are on average about 15 percent higher than for untitled land, suggesting that possession of formal title reduces the probability of land loss for potential buyers.

credit supply and investment demand, the benefits from title are relatively large (about 10 percent of farm income), and significantly higher than the cost of titling. However, the impact of awarding titles was strongly size-differentiated. Estimates indicate that producers with fewer than 20 hectares remained rationed out of the credit market and therefore did not benefit at all from the credit-supply effect of title [Carter and Olinto (1996)].

This differential impact suggests that, in environments where other markets (such as credit markets) entail distortions which put smaller and poorer farmers at a disadvantage, individual property rights on equity, and – in the medium to longer term – on the direction and nature of land transfers between different size classes of producers, could imply greater inequity. Whether, in the presence of heterogeneity in endowments, small producers will benefit from such policies depends critically on the ability to reduce, together with titling, transaction costs and policy-induced distortions that limit access to credit markets.

2.2.5. *Costs*

The most obvious cost associated with formal definition of property rights in land is the expenditure needed to physically demarcate and delineate plots, to establish and maintain accurate records of land ownership, and to enforce these rights and resolve whatever disputes might arise.[16] These costs are borne by individual land owners in situations (for example, frontier settlement) where public enforcement of property rights is absent and individuals make defensive investments such as guards, fences, and other demarcation devices to demonstrate the legitimacy of their claims to property and to defend such rights against possible intruders [Mueller (1997)]. It has been shown that the privately "optimal" amount of spending by individuals on means of protection will be inefficient from a social point of view [Feder and Feeney (1991), De Meza and Gould (1992)]. Furthermore, the defensive activities undertaken often have little social value and may generate negative externalities, an issue that has been emphasized with respect to the Brazilian Amazon where the need to demonstrate "productive" land use to establish ownership claims has been linked to increased deforestation [Binswanger and Elgin (1988), Southgate et al. (1991)]. Even where they are not associated with externalities, defensive activities that are often undertaken in speculative attempts to secure "ownership" of large tracts of land can lead to complete dissipation of the rents to be had [Allen (1991)].[17]

Given the undesirable impacts of private rights enforcement, public provision – in the form of land records, police, and a judiciary – would therefore be preferable in all

[16] Note that the number of disputes is itself endogenous, depending on the type of property rights system chosen.

[17] Spontaneous collective action to limit the dissipation of resource rents associated with individualized defense of property rights has been observed in a number of cases where group sizes were small [Umbeck (1977)].

situations except ones characterized by very low levels of population density [Malik and Schwab (1991)]. This is indeed observed throughout human history. The specific form in which land records are established will still depend on the relative costs and benefits from such an activity – something that depends partially on the technology and infrastructure available for record keeping.[18] At initial stages of human development, assignments of property rights appear to have been handled orally by the community (with community functionaries holding public sessions at the gate, for example).

However, the benefits from keeping written records seem to have been so great that, across a large number of cultures, officially validated land records were among the first documents to appear once a written language was developed. In addition to establishing unambiguous ownership rights, written records allow verification of ownership status of land at low cost, thus reducing the scope for asymmetric information about ownership and quality of land, and making land sales and rentals cheaper to implement. [19] This reduction of transaction costs increases the liquidity of the land market and can bring the number of efficiency-enhancing transactions closer to the optimum, i.e., helping to transfer more land from less productive to more productive individuals.

A second type of social cost associated with fully individualized property rights relates to the fact that, at low levels of development, communal land ownership may perform an important insurance function that would be eliminated by establishing fully individualized property rights in land.[20] Furthermore, it has long been known that in cases where other markets are highly incomplete, land sales markets may not automatically transfer land to more productive users. In such situations, individualization of land rights could be doubly disadvantageous [see Platteau (1996) for references]. On the one hand it could pave the way for the emergence of sales markets that deprive traditional communities of their source of livelihood (often without adequate compensation), thus generating social unrest and violence and eliminating an important form of insurance. On the other hand, where land rights are introduced in such an environment, productivity will not necessarily increase, as availability of land rights could induce concentration

[18] Ellickson (1993) notes that historically the establishment of formal land rights is closely related to the emergence and widespread use of written language; in many cultures records of land transactions were among the first texts to be officially recorded.

[19] See, for example, the Indian Arthsastra from the fourth century B.C., as well as references in the Bible relating to the period 600 B.C.

[20] Jodha (1990) provides evidence on the importance of access to the commons as a safety net for the poor. Based on panel data from China, Burgess (1997) finds that the equitable allocation of land use rights under communal tenure has an effect similar to a lump sum transfer that provides insurance against low nutritional outcomes in a way that is more incentive–compatible than an *ex post* redistribution. The fact that land ownership has a more significant impact on improving nutrition than on income can be explained by the fact that, with imperfect rural grain markets, considerable cash outlays would be required to achieve a similar effect through market purchases of grain. The presence of equity benefits from periodic redistribution of land rights in China would be consistent with peasants' strong support for the system of periodic redistribution [Kung (1995)].

of landholdings by a privileged minority of wealthy individuals who – for example by having access to non-covariate sources of income – are in a position to accumulate land for speculative purposes without making productive use of this asset.[21]

Historical evidence indeed suggests that, especially in situations where other markets are not well developed or where policy-induced distortions affect the functioning of land markets, increased transferability of land may deprive the poor of an important social safety net. The importance of the insurance aspect is confirmed by the fact that, even where societies have made the transition to individualized land rights, they have often maintained land-related social safety nets to provide insurance for the poor. One example of a mechanism to do so is to allow continuing uses of communal pastures and forest areas of low productive value as well as a universal right to collect leftovers after the harvest or to graze animals on harvested fields. Another example is the provision for periodic redistribution of at least part of the land available to the community.[22] Such redistribution of cultivation rights could decrease productive efficiency by attenuating incentive to make plot-specific investments. The fact that societies have been willing to incur these efficiency losses suggests that the subjective valuation of the benefits in terms of avoiding widespread landlessness, social destitution, and discontent, has been high. This implies that where land is an important asset for poor and marginal groups, both social and efficiency aspects associated with land rights need to be accounted for in assessing the potential benefits from individualizing land tenure arrangements.

3. Land markets: Functioning and efficiency implications

If there are differences in individuals' skills and endowments of different factors of production, markets should help in optimizing factor proportions employed and thus increase overall efficiency of resource allocation. This section aims to outline the main determinants that would affect participation in the land sales or the land rental market, and based on this to elaborate on links and differences between these two markets, in terms of their impact on equity and efficiency of resource allocation.

The productivity advantage of small farmers who rely predominantly on family labor rather than on less motivated hired workers who have to be supervised would imply that, in the absence of imperfections in other markets, a functioning land market should facilitate efficiency- and equity-enhancing transfers from large to small producers, or from ones with lower management skills to better operators. However, land sales transactions could be efficiency-decreasing if, for example due to policy-induced credit

[21] Note that this is historically well-founded, as the many examples in Binswanger et al. (1995) demonstrate.

[22] If incentive structures and enforcement mechanisms to ensure that such provisions are actually implemented at the local level are non-existent, the provision for regular redistribution can actually give way to arbitrary behavior and rent extraction by local leaders. For a theoretical and empirical discussion of these issues, see Turner et al. (1998).

market distortions, large owners' advantage in accessing credit would offset the productivity advantage of owner operators; or if, due to the inability to insure, significant land holdings are not part of poor people's optimal asset portfolio.[23] Thus, before actions to activate the land market are undertaken, careful empirical investigation of the functioning of financial markets and insurance mechanism, and possibly steps to improve their functioning, might be in order.

Even if imperfections in markets for credit and insurance reduce the scope for the land sales market to bring about improved land allocation through land transfers from large to small producers, such allocation should – in a frictionless world – be facilitated through the land rental market. One possibility would be an interlinked contract whereby the landlord uses the credit access provided by land ownership to provide the tenant with working capital as part of the rental contract. High transaction costs – part of them related to government regulation – reduce the extent of land rental transactions in a number of countries. Examining the implication of regulations in more detail would be of importance as removing unjustified interventions is likely to go a long way towards improving resource allocation in agricultural systems characterized by very unequal land distribution. Most rental markets in developing countries involve some form of share tenancy. While this arrangement does not lead to full efficiency, it is a second best solution given risk and imperfect capital markets. The sections below elaborate these points and review relevant evidence.

3.1. Key determinants of land market participation

The shadow price of land for different types of agents is determined by the agricultural production function, the households' inherent managerial ability, and by possible imperfections in labor, credit, and land markets that are common in rural areas. If credit and land rental markets were perfect, the supervision costs associated with the use of hired labor would make smaller farms more productive, and would lead households to lease in or lease out the amount of land required to maintain a uniform ratio of family labor endowment to operated area, irrespective of the land ownership distribution [Feder (1985)]. However, imperfections in other markets may change this, with implications for the functioning of land rental and sales markets. For example, in the presence of credit market imperfections, if supply of working capital depends on the amount of land owned, the optimal size of the operational holding will vary systematically with size of the owned holding even if land rental markets were perfect. While the magnitude (and direction) of this effect would depend on the elasticity of output with respect to effective labor and of labor effort with respect to supervision, it can overwhelm the productivity advantage of family farmers and give rise to a positive relationship between

[23] Indeed, there is descriptive evidence indicating that in environments with imperfect credit market access, e.g., in Africa, land sales markets result in an efficiency-reducing transfer of land from small to large producers [Collier (1989)].

owned farm size and productivity. In addition to this, capital and insurance market imperfections may also affect the production activities of poor producers – possibly leading them to pursue less risky but also less productive activities. Below we review the factors which affect the productivity of farmers, and thus determine their demand for land.

3.1.1. Economies of scale

The presence or absence of economies of scale would systematically affect the shadow price of land for different farm-size classes. Possible economies of scale could arise from the presence of indivisible factors of production or cost elements leading to an initial range of farm size where the average cost of production declines with farm size. In cases where other markets function reasonably well, optimal farm sizes tend not to exceed the scale at which family labor is fully occupied (utilizing seasonal hired labor for specific tasks).[24] There are few agricultural activities in which significant economies of scale in the production process exist.[25] Some economies of scale are associated with the processing and marketing of many agricultural products, but this does not have important implications for the unit cost of farming operations as long as competitive markets for outputs and inputs exist. Alternatively, access to such markets is sometimes arranged through cooperatives. Only for a few "plantation crops" such as sugarcane, bananas, or tea could the need for immediate large-scale processing or marketing transmit economies of scale from the processing stage to production. To reap the economies of scale associated with the former, production of these crops is generally organized on a scale that corresponds to the optimum scale of the processing factory.[26]

3.1.2. Labor supervision cost

Constant returns to scale would imply that the size of agricultural operations has little impact on productivity. However, the need to supervise hired labor would confer a productivity advantage on owner-operated farm units. The fundamental reason for this is the presence of agency costs [Jensen and Meckling (1976)], which result from the need to manage wage labor and enforce effort in large-scale operations. The lack of incentives for wage workers to exert effort, and the consequent need to supervise labor or to offer incentive contracts, has received considerable attention in industrial

[24] A large number of empirical studies [e.g., Olson-Lanjouw (1995) for India, Feder et al. (1989) and Burgess (1997) for China, Olinto (1995) for Paraguay] are indeed unable to reject the hypothesis of constant returns to scale in agricultural production.

[25] Exceptions are limited to cases of highly specialized machinery, specialized livestock production, or plantation crops where economies of scale are transmitted from the marketing to the production stage.

[26] However, the supervision advantages of owner–operators have in many cases motivated large processors to contract production out to smallholders under outgrower or contract farming schemes, often providing credit in kind as well as technical assistance [Glover (1990)].

organization literature [Jensen and Meckling (1976)], and is recognized to have profound implications for the organization of production and for the optimal size of the firm [Calvo and Wellisz (1978), Eswaran and Kotwal (1985a, 1985b)]. The cost of supervision is particularly large in agricultural production due to spatial dispersion of the production process and the need to constantly adjust to micro-variations of the natural environment. Family members are residual claimants to profits and thus have higher incentives to provide effort than hired labor.[27] They share in farm risk, and can be employed without incurring hiring or search costs. These attributes underlie the general superiority of family farming over large-scale wage operations, manifested empirically in an inverse relationship between farm size and productivity. A large number of studies based on aggregate, or cross-sectional, and panel data have confirmed the existence of the inverse farm-size productivity relationship for all but the smallest farm size classes [Berry and Cline (1979), Carter (1984), Benjamin (1995), Newell et al. (1997), Kutcher and Scandizzo (1981), Olinto (1995), Burgess (1998), Udry (1997)].[28] Thus, unless there are other countervailing forces, one would expect land markets to transfer land from large to small producers. We turn now to a discussion of these countervailing effects.

3.1.3. *Credit market access*

A reason for observing few land market transfers from large to small producers is that it is difficult for small farmers to obtain credit and insurance.[29] This has two implications. On the one hand, credit market imperfections that increase the shadow price of credit for small producers would reduce small farmers' competitiveness in the land sales market, possibly outweighing the supervision cost advantage they enjoy. Also, if there are individuals with non-agricultural income who value land for other than productive reasons, land prices will exceed the net present value of agricultural profits, making it difficult to acquire land in the sales market with the expectation of paying off the debt from agricultural profits alone without recourse to equity.

Asymmetric information and moral hazard lead generally to quantity rationing in credit markets [Stiglitz and Weiss (1981)]. Formal credit markets can overcome the problem of asymmetric information by utilizing a collateral requirement. However, the costs of and political impediments to foreclosure on smallholders' land are often quite significant. This is part of the generally high transaction costs associated with providing credit to small producers. In informal credit markets, close familiarity and social control

[27] Empirical evidence confirms that family labor is more productive than hired labor, and that the intensity of supervision by family members affects the performance of hired labor [Frisvold (1994)].

[28] Bhalla and Roy (1988) and Benjamin (1992) have shown that cross-section analyses [e.g., Berry and Cline (1979), Carter (1984), Newell et al. (1997), Kutcher and Scandizzo (1981)] tend to overestimate the productivity advantage of smaller farms if soil quality is not specifically accounted for.

[29] Due to the covariance of production risks, crop insurance is very difficult to obtain and forward markets to insure against price risk are often unavailable to small producers due to high transaction costs.

is used to select promising clients or projects. This is quite costly as the scope for effective supervision is limited. Furthermore, informal lenders have only limited scope to diversify covariate risks, and they typically do not provide much long-term credit. Interest rates on informal loans are thus high. Thus, both limited availability of credit and high cost of borrowing would prevent those who do not have accumulated savings from acquiring land. [30]

Credit market imperfections can thus offset small farmers' supervision cost advantage. For the case of Sudan, for example, yields for virtually all crops are lower for poor (small) farmers and higher for rich (large) farmers, thus turning the farm-size productivity relationship upside down. Furthermore, the land rental market leads to land transfers from poor and labor-abundant smallholders to rich and relatively labor-scarce households [Kevane (1996)]. The reason is that capital market imperfections combined with reasonably functioning land and labor markets and a technology that is not supervision-intensive make it more attractive for small credit-constrained households to rent out land and work for a wage than to engage in owner-cultivation without capital inputs. By contrast, in panel data from Burkina Faso an inverse farm size-productivity relationship was observed even though a positive presence of correlation between yields and cash inflows from non-agricultural employment suggests the presence of capital market imperfections [Udry (1996)]. The conclusion is that imperfections in land, labor, credit, and insurance markets have to be analyzed together. Efforts at land redistribution that do not simultaneously address credit market imperfections may be costly and ineffective.

3.1.4. *Portfolio composition*

Small producers' inability to access formal markets for credit and insurance often forces them to adopt costly insurance substitutes, one of which is the adjustment of crop and asset portfolios to a low return-low risk combination.[31] In order to ensure satisfaction of a minimum subsistence requirement during periods of distress, credit-constrained producers could hold a portfolio of less risky but also less productive assets than that of unconstrained producers. In particular, smallholders may demonstrate a lower demand for land than that which would seem to be justified by their potential productive advantage. Zimmerman and Carter (1996b) use parameters from Burkina Faso to show that, starting from an egalitarian distribution of land, production risk together with covariance of land prices leads to successive concentration of land via sales from more productive small producers to relatively less productive large farmers. This illustrates

[30] The difficulty of land acquisition through borrowing by would-be smallholders, in spite of their productivity advantage, has been highlighted by Binswanger and Elgin (1988) and Carter and Mesbah (1993). Furthermore, they point out that by exhausting access to credit for land acquisition, the ability to borrow for working capital is eliminated.

[31] Examples are provided by Rosenzweig and Wolpin (1993), Dercon (1996), Dercon and Krishnan (1996), and Rosenzweig and Binswanger (1993).

that improving the functioning of land sales markets will not necessarily lead to better resource allocation if other markets' distortions are not tackled.[32]

3.1.5. Transaction costs

A further factor that might prevent land markets from achieving a first-best allocation is the transaction cost associated specifically with land sales. It has often been observed [see, for example, Balcazar (1990), Carter and Zegarra (1995)] that, especially in countries with a dualistic distribution of land ownership, land *sales* markets are highly segmented in the sense that, despite a considerable frequency of land transactions within farm size groups, land sales across farm-size class-boundaries are virtually absent. One explanation is that transaction costs of subdividing large farms to many smallholders are high. Similarly, the fact that certain costs (e.g., formal registration) associated with land transactions are independent of the size of the purchase creates indivisibilities that would either discourage small land transactions or drive them into informality where such costs are not incurred.

While the discussion of costs associated with land *rentals* in the literature is less extensive, government regulations appear to have reduced the amount of land leasing below what would take place otherwise. Even in countries that avoided the imposition of explicit restrictions on tenancy (which, as discussed below, were associated with significant efficiency losses), the threat of expropriative land reform in many countries implied that renting out land to more productive smaller producers exposed the landlord to a considerable risk of losing ownership rights in the course of land reform. To prevent this from happening, many landlords appear to have evicted tenants altogether, resorting instead to mechanization, cattle ranching, or cultivation using a hired labor force [De Janvry and Sadoulet (1989)]. The implications for land rentals, although they have not been rigorously quantified in any of the cases, appear to have been considerable.

3.2. Land sales markets

The discussion of the previous section implies that non-agricultural uses of land as well as credit market imperfections tend to drive the equilibrium price of land above the capitalized value of the income stream from agricultural profits. This would imply that fully mortgage-based land acquisition by the poor will not be possible. In addition, policy distortions will tend to increase the wedge between the price of land and the capitalized value of the income from agricultural production. Use of land as an inflation hedge, as

[32] The fact that study of land markets cannot be divorced from the functioning of other markets has been emphasized by Basu (1986) in a model of "interim" land transactions that explicitly serve as a credit substitute. In this context, the supply of land for sale would increase with the probability of being able to buy back the land, the attractiveness of other (financial) assets as compared to land, and the need for liquidity. Sengupta (1997) draws out the implications of limited liability on contract choice within a more general set of contractual options.

well as credit subsidies and tax advantages that allow the use of agricultural activities as a tax shelter, are examples [Gunjal et al. (1996), Brandao and de Rezende (1992), Just and Miranowski (1989), Feldstein (1980)]. To the degree that such distortions confer disproportionate benefits to larger landholders (as in the case of tax advantages, which are generally of no relevance to the poor), this would further bias the operation of the land sales market against redistributing land to landless or marginal landowning households who could have a productivity advantage as family farmers.

Analysis of land market transactions and offer and asking prices in Paraguay indicates the presence of a large gap between willingness to sell and willingness to pay,[33] significant differences in such prices across farm sizes, and very distinct regional patterns of land market performance depending on whether or not other markets exist and how well they function.[34] A similar conclusion is implied by the observation that the degree to which financial markets were accessible to small producers was (together with the initial distribution of assets and the characteristics of the production system) one of the key factors that determined the response of land accumulation patterns to agro-export booms in Guatemala and Chile [Carter and Barham (1996)].

Exposure to undiversifiable residual risk causes farmers to resort to liquidation of their assets during periods of severe crisis, a phenomenon commonly referred to as distress sales. This implies that the covariance of weather risks for the farming population causes land prices to be low (due to insignificant effective demand and high supply) during bad crop years, with the consequence that individuals who had to sell off land during crises may not be able to repurchase land during subsequent periods of recovery [Bidinger et al. (1991)]. Distress sales have not only played a major role historically in shaping more concentrated land ownership patterns, but are also linked in the literature to the elimination of traditional mechanisms for coping with risk [Kranton and Swamy (1997), Brockett (1990)].[35]

The link between unmitigated production risk and distress sales is highlighted by Cain (1981) who examines the implications of different insurance mechanisms on distress sales and the land ownership distribution between 1960 to 1980 for predominantly agricultural villages in India and Bangladesh. These villages faced very high production risks but were characterized by distinct differences in mechanisms of risk insurance: In Maharashtra, India, an employment guarantee scheme operated throughout the period

[33] Willingness to sell was significantly higher than was willingness to pay to purchase land, but the gap decreased with farm size (from 50 percent for the smallest farms, to 20 percent for medium-sized units). This could be an indication of labor market imperfections, i.e., the value given to land as a source for self-employment, in addition to small farmers' unwillingness to be bought out.

[34] In Paraguay, land markets function reasonably well in traditionally settled zones in the country's interior, but not at the frontier where the labor cost advantage of family farms appears to be overshadowed by capital market imperfections [Carter and Zegarra (1996)]. This suggests that the productivity advantage of small farmers would manifest itself in the land purchase market only if land market reform were combined with improved access to capital markets.

[35] Distress sales have been important in China [Shih (1992)], in early Japan [Takekoshi (1967)], in the Indian Punjab [Hamid (1983)], and in Latin America following the abolition of communal tenure [Brockett (1990)].

and attained participation rates of up to 97 percent of all households during disasters. Such schemes were absent after the major flood episodes in Bangladesh. Thus, 60 percent of land sales in Bangladesh were undertaken to obtain food and medicine, undoubtedly due at least in part to the lack of other insurance mechanisms. About 60 percent of the currently landless lost their land since 1960, and the Gini coefficient of landownership distribution increased from 0.6 to almost 0.7. This contrasts sharply with the Indian villages, where land sales to finance consumption expenditures accounted for only 14 percent of sales and were incurred mainly by the rich to meet social obligations. On the other hand, 64 percent of land sales were undertaken in order to generate capital for productive investment (digging of wells, purchase of pump sets, and children's education), and the land sales market actually contributed to a slight equalization of the land-ownership distribution. This suggests that in this case the poor were able not only to avoid distress sales, but were able, through access to cash-generating employment, to acquire some land as rich households liquidated agricultural assets to be able to pursue non-agricultural investment. Survey data on land transactions from India indicate that purchases of land are almost all undertaken by individuals with access to sources of income which are not correlated with agricultural production, and that borrowing to finance agricultural land acquisition is virtually non-existent [Sarap (1990)].

3.3. *Land rental markets*

As the discussion above illustrates, land sales markets will not necessarily lead to an optimal allocation of land in the presence of credit and insurance market imperfections. However, improved resource allocation can be achieved through land tenancy contracts even when other markets are incomplete. Analysis shows clearly that land rental markets serve an important function in equalizing returns to non-tradable factors of production such as family labor and bullocks [Skoufias (1991)].[36] Given the huge diversity of tenancy arrangements, we need first to explain the wide range of tenancy contracts that is empirically observed in developing countries. This gives rise to the second issue, namely, the implications of these contracts for the efficiency of resource allocation.

Assume a constant returns to scale production function $Q = \theta F(e, h)$, where Q is output, e is effort, h is number of tenants, and θ is a stochastic element. Then the range of contracts can be summarized as follows. The landlord's income is $y = h[(1-\alpha)Q - \beta]$, and the representative tenant's income is $Y = \alpha Q + \beta$. The fixed rent contract is given by $\{\alpha = 1, \beta < 0\}$, the pure wage contract is represented

[36] Land rental transactions to circumvent imperfections in credit markets have been important in West Africa in the past [Robertson (1982)], and continue to be observed in a number of developing countries where credit markets are absent or credit is highly rationed. Usufruct mortgage is still reported to be common in Bangladesh [Cain (1981)], Java [Morooka and Hayami (1989)], and Thailand [Fujimoto (1988)]. In the Philippines, tenancy transactions emerged as a credit substitute in response to limitations on the transferability of land [Nagarajan et al. (1991)].

by $\{\alpha = 0, \beta > 0\}$; and the share contract is given by $\{0 < \alpha < 1\}$, with the sign and magnitude of β a function of the landlord's choice of α and the tenant's reservation utility level [Otsuka et al. (1992)].

Under conditions of certainty and the assumption that tenants' effort can be monitored and enforced, the specific choice of contract type does not matter as all contracts lead to equivalent outcomes [Cheung (1969)]. If the assumption of perfect effort enforceability is dropped, and agents are assumed to be risk neutral, only the fixed rent contract is optimal. The reason is that in all other cases tenants receive only a fraction of their marginal product, something that would induce them to exert less than the optimal amount of effort (where the marginal disutility is equal to the full marginal benefit from this action). Any type of contract other than fixed rent would result in undersupply of effort by the producer (tenant or worker), which would lower total production.

Indeed, fixed-rent tenancy is widespread in all developed countries, such as the U.S. and Canada, where about one-third of the agricultural land is cultivated by tenants. The fact that virtually all of this land is rented under fixed-term contracts suggests that such an arrangement would be a relatively efficient way of achieving optimal operational holding sizes in economies with well-functioning credit, risk, and labor markets. However, where markets for credit and insurance are highly incomplete and where the rural landless class is large, as is the case in most developing countries, adoption of a fixed rent contract where rent is paid up-front (i.e., independent of the output from production) may not be feasible or optimal from the perspective of all parties to the transaction.

In such a situation, two main reasons, risk-sharing and limited tenant wealth, could mitigate against adoption of the fixed rent contract and in favor of a sharecropping contract.[37] Although it would reduce the incentive to exert effort, a share contract provides the possibility of partly insuring a risk-averse tenant against fluctuations in output. Where, in risky environments, a risk-averse tenant faces significant uninsured risk, a share contract may well provide the tenant with higher expected utility and thus be adopted despite the lower aggregate productivity involved. In fact, it can be shown that in this case, the Pareto optimal outcome will always require a trade-off between the risk-reducing properties of the fixed-wage contract, under which the tenant's residual risk is zero, and the incentive effects of the fixed-rent contract, which would result in optimal effort supply but no insurance [Otsuka et al. (1992)]. Given risk aversion and incomplete intertemporal markets, a one-period contract is a second-best solution. Part of this shortcoming can be eliminated by state-contingent side payments in the context of a repeated game.[38]

[37] There is a third rationale for adoption of the share contract, namely that imperfect information on tenants' unobservable characteristics, such as ability, causes landlords to use sharecropping contracts as a screening device where the tenants' acceptance of certain types of contracts provides a signal for their productive ability [Newbery and Stiglitz (1979)]. Data from India indicate that landlords observe tenants' ability quite well [Olson-Lanjouw (1995)], suggesting that such signaling may not be the main reason for the adoption of sharecropping.

[38] Sadoulet et al. (1997, 1994) observe that close kinship relations provide sufficient assurance to landlords to provide implicit insurance to their tenants, thereby avoiding the inefficiency of the share contract.

Limited tenant wealth increases the landlord's risk when a fixed-rent contract does not involve a front-end payment. In case of a disaster (such as a bad climatic shock), tenants with insufficient wealth are likely to default on the rent payment, implying that landlords will tend to enter into fixed-rent contracts only with tenants who are wealthy enough to pay the rent under all possible output realizations. If tenants are poor, it will be optimal for the landlord to choose a share, rather than a fixed-rent contract [Shetty (1988)]. In a one-period game this would imply that landlords would rank tenants by wealth, choosing to enter into contracts only with the wealthiest tenants. Empirical evidence reported by Quibria and Rashid (1984) confirms such behavior. By implication, the efficiency of any particular tenancy contract is increasing in tenant wealth, and the overall efficiency of the tenancy market would depend on the initial wealth distribution of potential tenants, generating a direct mapping between the distribution of wealth and economic efficiency [Bardhan et al. (1997)]. In a repeated game, landlords would allow all but the least wealthy tenants to earn positive profits in equilibrium, thus using the threat of contract termination (or eviction) as a device to elicit effort supply.

An extension of this argument is provided by Mookherjee (1997), who shows that in the context of bargaining on the terms of an interlinked tenancy contract between landlord and tenant, the efficiency of the contract – i.e., the amount of effort exerted – will always be higher under operator-ownership of the land than under a tenant-landlord relationship.[39] This would imply that redistribution of land from the landlord to the tenant – or any other measure (e.g., increased off-farm opportunities) that would increase the tenant's reservation utility – would be associated with an increase in aggregate productivity. Still, while such a redistribution could increase the aggregate utility of both parties (thus making compensation of the landlord a theoretical possibility), a voluntary market-based transfer of land from the landlord to the farmer is not feasible. The intuition is simple – since a credit-based land purchase does not enhance the tenants' wealth, the limited liability constraint will still be applicable and the debt overhang incurred by the cultivator to purchase the land will reduce the incentive to apply effort instead of just defaulting on the loan. However, a non-market transfer of land from landlords to farmers could be associated with an increase in overall productivity as well as aggregate welfare.

Insights on the relationship between liquid assets and contractual parameters are provided by Laffont and Matoussi (1995) in a study of Tunisian sharecroppers. Their results suggest that differences in the contracting parties' working capital endowments can account for the coexistence of a variety of contracts, even in the same environment and among parties with similar risk aversion characteristics.[40] The positive relationship

[39] The scope for other benefits from a more egalitarian distribution of land ownership that are not directly related to agricultural productivity is illustrated by Banerjee et al. (1997).

[40] If risk were a major factor in choosing the optimal type of contract, one would observe significant variation in crop shares according to the riskiness of the crops grown on particular plots. This, however, is not observed empirically.

between the crop share and the tenant's working capital endowment that would be predicted by theory, even with perfect monitoring of effort, is indeed confirmed by the data. Output is shown to increase significantly with tenants' wealth for all contract types as well as for share contracts, but tenant wealth has no effect if only fixed rent contracts are considered. Similarly, the wealth of the landlord has, as expected, a negative effect on the tenant's share and a positive effect on production under the share contract, but none in other forms of contractual arrangements. Working capital thus appears to be a significant explanation of the type of contract chosen and the production gains achieved on a given plot.

The importance of potential tenants' asset endowment is also emphasized by evidence from India which indicates that, due to wealth constraints, a large number of potential tenants are actually rationed out of the tenancy market [Shaban (1991)]. In this context, both the smallest and the largest landholders rent their land to middle farmers who are neither capital-constrained nor suffering from the disadvantage associated with the need to supervise hired labor. This illustrates that the ability of the land rental market to bring about efficiency-enhancing transfers is constrained by potential tenants' endowment of assets and other means of production.

Thus, while land rental markets improve the allocation of resources in the presence of factor market distortions by bringing land to imperfectly or non-tradable factors of production (experience, family labor, animal power), the gains are constrained by endowments of potential transactors. In addition, there is evidence that fixed transaction costs preclude some poor households that desire only relatively minor adjustments from entering the tenancy market. Similarly, data from India suggest the prevalence of imperfect adjustment whereby, on average, farmers realize only about 75 percent of the desired level of land transactions [Skoufias (1995)]. The latter study also indicates that the adjustment effected by the land rental market is asymmetric for net in-renters and out-renters; consistent with the view that market power depends on relative scarcity of factors, in this environment of land scarcity, it is easier to rent out than to rent in.

What, then, is the magnitude of the productivity effects that are brought about by the operation of land rental markets? To obtain credible estimates of the loss due to the second-best nature of sharecropping, one needs to control for unobserved household specific fixed effects, e.g., by comparing input use, productivity, and investment, between sharecropped and owned (or cash-rented) plots for the same household. Bell (1977) was the first to conduct such an analysis in a static context, finding that farmers indeed exert less effort on tenanted plots. Applying the same methodology, Shaban (1987) found that, on average, tenancy was associated with a 32 percent lower output; but the difference was only 16 percent once adjustments were made for differences in land quality. Inputs of family labor and draft animals were significantly lower on sharecropped plots than on owned parcels. No statistically significant differences in productivity were found between owned plots and plots rented on a fixed-rent basis, confirming that fixed-rent contracts induce higher productivity. Other studies yield results that point in the same direction [Sen (1981)].

The productivity loss entailed in sharecropping can be reduced through close social relationships, as confirmed by Sadoulet et al. (1997). Their study compared the attributes of contracts with kin and non-kin, finding that non-kin sharecroppers use significantly fewer inputs and obtain less output. However, for sharecropping among close kin, there is neither a disincentive effect nor a reduction in output. This suggests that embedding contractual arrangements in a long-term personal relationship offers considerable potential to attenuate the disincentives and productivity losses that are otherwise associated with sharecropping contracts. This evidence is in line with the comprehensive review of the literature by Otsuka et al. (1992), who found a large number of studies about equally split between efficiency and inefficiency of sharecropping contracts. Studies that did not find a disincentive effect of sharecropping were generally conducted in environments where such a contract was embedded in enduring family and patron-client relationships or where effort was easily monitored.

Even within households, imperfections in land and labor markets, together with the inability to commit, may prevent individuals from achieving an optimal allocation of productive factors. For plot-level panel data from Burkina Faso, Udry (1995) finds that reallocation of factors from male- to female-controlled plots within the same household could increase output by 6 percent – less than half of the estimated output loss from imperfect allocation of productive factors at the village level (13 percent), but still significant. One interpretation is that, by "renting" out land to their husband, women would risk losing these rights. In the absence of other assets that could be transferred from the husband to the wife to provide assurance, they fail to do so, despite the productivity increases that doing so might entail.

All this implies that, although they cannot completely eliminate structural impediments and bring about a fully efficient allocation of land in an economy, land rental markets can go a long way in bringing the operational distribution of holdings closer to the optimum. However, in quite a few countries, the extent of land rental markets has been greatly diminished by large landowners' reluctance to engage tenants due to concern for potential challenges to their property rights. Furthermore, rental markets' potential to increase overall welfare was not well understood by governments. Consequently, the static productivity loss entailed in sharecropping tended to induce interventions that have limited the extent of rental transactions, thus causing a larger inefficiency in resource allocation. We turn now to discuss these and other policy issues related to land markets.

4. Policy issues

This section reviews the main policy implications of the earlier discussion, focusing on clarification and adjudication of property rights, ways to improve the functioning of land sales and rental markets, and redistributive land reform. These three steps form a rough sequence, in the sense that it is difficult to improve the functioning land sales or rental markets without clarification of land use and ownership rights, or to conduct non-expropriative land reform in an environment where land markets are absent. This implies that government activity should be focused on eliminating distortions and taking measures to reduce market imperfections rather than on attempting to compensate for imperfections and distortions in other markets.

4.1. Clarification and adjudication of property rights

A coherent system of property rights that guarantees security of tenure to cultivators, facilitates access to land by the poor, and encourages investment to increase sustainability and productivity can be of overriding policy importance in two types of settings. In countries making the transition from communal to more individualized forms of land ownership, it is important to have a flexible, stepwise, and decentralized approach that acknowledges differences in demand for tenure security based on diversity across regions and agro-climatic conditions. This requires a legal framework that permits evolution of land rights towards individualized tenure as the need emerges with commercialization and land scarcity. Second, in situations where land tenure arrangements have been severely disrupted by civil strife and war, collectivist land reform, or land-grabbing of influential individuals (e.g., Bolivia, Honduras, Nicaragua, Cuba, Vietnam, Ethiopia, Uganda, Tanzania, and the former Soviet Union), an approach that adjudicates among overlapping claims and establishes clear ownership rights to land at minimum cost is needed.

The evidence reviewed in preceding sections provides support for the view that secure land rights are necessary for longer-term investment nd the associated productivity increases. Land registration and titling systems are often perceived as an important element in policy seeking to promote tenure security and to facilitate more effective land markets. This is because official documentation provides better protection of an owner's property rights, and eliminates the asymmetric information that curtails land markets transactions. However, experience with titling programs indicates that in sparsely populated areas the cost of introducing formal titling systems may outweigh the benefits and that the administrative infrastructure needed to effectively implement such rights is not available. Similarly, formal documentation is not crucial where customary tenure systems provide sufficient security to facilitate the level of investments and land transactions that are relevant for the prevailing economic environment, and where credit markets are not yet developed to the point where collateral use is necessary.

Past interventions have often underestimated the cost and administrative requirements of providing tenure security through formal title and have given little thought to the scope for alternative means to provide such security. Community-based approaches whereby a whole area is demarcated and internal administration of land rights (including provision of documentation by local authorities) is left to the community may in many cases provide a cheaper alternative to formal titles [Platteau (1996)]. However, the critical precondition for such an approach to work is that consistent implementation of this arrangement is feasible, that decentralized institutions are accountable and effective, and that the certificates awarded by such authorities are legally recognized, entailing a possibility of converting them into more formal titles at a later stage.

The 1992 modification of the Mexican Constitution, and similar arrangements in a number of other countries (e.g., Bolivia, Colombia, Côte d'Ivoire, and Nicaragua), allow indigenous and non-indigenous communities to administer property rights internally. In the case of Mexico this also includes communities' right to decide, subject to established rules of accountability, on the partial or formal transformation of their land rights into individual freehold title [Gordillo et al. (1997)]. In principle, such an arrangement would allow the utilization of informational advantages available at the community level in tailoring property rights to the specific situation at hand. However, little is known about the transaction costs incurred and the degree to which outcomes have been equitable and conducive to improved efficiency. Evaluation of these experiences within a consistent framework would be very desirable and could provide valuable insights to fine-tune the approach and make the experience useful for other countries.

The benefits associated with individuals' ability to use title to gain access to formal credit have been discussed above. Experience indicates that titling programs are most effective in areas where tenure insecurity already affects incentives, where there is an incipient formal credit market where title can be used as a collateral because foreclosure of collateral is enforceable, and where an effective legal system operates.[41] It is important to include safeguards against the grabbing of land (and in particular of hitherto common land) by powerful and wealthy individuals, who are typically better informed on the procedures entailed in more formal systems [Feder and Nishio (1996)].

Past experience also suggests that land titling should be systematic and area-based rather than "on demand".[42] An area-based program with complete coverage can utilize economies of scale in measurement, adjudication, and a speedy process for conflict resolution. This would reduce the cost of program implementation. Experience in Thailand, El Salvador, Peru, and Bolivia, along with other countries, demonstrates that this can be accomplished by introducing titling in combination with a mechanism for dispute resolution on location (within the community) and a comprehensive publicity campaign.[43] In contrast, "on demand titling" is not only costly, but is often inequitable. It provides opportunities for land-grabbing to individuals with good political connections and may preclude poor smallholders from participation due to the high cost of land registration.

[41] The example of Kenya, where banks could not foreclose on the land that had been given to them as collateral because of social and ethnic factors, illustrates that – even where there is a demand for formal credit and the use of land as collateral – it is only the ability to effectively foreclose on defaulters that will persuade banks to accept land as a collateral for loans [Ensminger (1988)].

[42] Given the fixed cost element entailed in "on demand" titling (which is based on individual initiative) and the lack of economies of scale, this format of titling will tend to be more accessible to the wealthier landowner.

[43] This would be of particular importance in the case of Africa where resistance against titling is fueled more by the fact that generally individualization of land tenure has been associated with extreme land-grabbing by powerful individuals – much more than the activation of a land sales market that would disempower smallholders [Bruce (1988)].

4.2. *Improving the functioning of land sales and rental markets*

Land taxation. A moderate land tax levied and collected by local governments has been advocated as a contribution to effective decentralization. There are two reasons why a land tax is theoretically attractive. On the one hand, taxation of land is one of the few cases of a lump-sum tax where, using asset rather than production values, the effective tax rate on income decreases with the income generated from the land, thus encouraging more productive resource use. On the other hand, a land tax is one of the few taxes that can provide revenues for the local governments, and that – through the capitalization of local amenities in land values – establishes a direct relationship between tax level and the benefits received by taxpayers [Glaeser (1995)].

Several countries have attempted to implement progressive land taxes, where the tax rate would increase with land area or value, as a means to make land speculation less attractive and to induce large landowners to use their land more intensively, or to break up large estates. Experience with this instrument has not been very positive, as implementation and collection of progressive land taxes have been frustrated by political difficulties and resistance in countries as diverse as Argentina, Bangladesh, Brazil, Colombia, and Jamaica [Strasma et al. (1987), Bird (1974)]. Carter and Mesbah (1993) use simulations to show that a progressive land tax by itself is unlikely to be effective even if it is enforceable. Effectively collecting a uniform land tax may be a more realistic goal. However, if environmental risk is high, introduction of a land tax (which has to be paid even if output is low) may not be desirable for equity reasons, and a mix of land tax and output tax (contingent on realized output) Pareto-dominates either tax in isolation [Hoff (1991)]. To avoid negative equity consequences that might be associated with a land tax, a number of developing countries exempt small producers below a certain size from the need to pay land taxes.

Land sales markets. The fear of the undesirable consequences associated with land market operation in an environment characterized by market imperfections seems to have in the past motivated policymakers to impose restrictions on the operation of such markets. Administrative restrictions on land sales, however, have often been costly to enforce and ineffective in preventing inequitable outcomes.

Administrative restrictions on land sales typically take the forms of limits on tradability of land and ownership ceilings. In many cases beneficiaries of land reform or settlers on state-owned land are not allowed to sell or mortgage their land. This deprives them of access to credit, often in the establishment phase when credit would be most needed. It has been shown that, in the presence of such restrictions, smallholders are forced to resort to less efficient arrangements (e.g., usufruct-mortgaging and the associated use of wage labor contracts) to gain access to credit [Hayami and Otsuka (1993)]. The goal of preventing land owners from selling out in response to temporary shocks would be better served by adequate safety nets, technical assistance, and access to complementary finance. Permanently precluding land reform beneficiaries from rental or sales is likely to reduce efficiency – all over the world such restrictions have resulted in large tracts of land being less than optimally utilized. Allowing for some adjustments in response to differential settler ability may be preferable to the losses imposed by this measure.

Another restriction intended to facilitate the breakup of large farms and the associated sales of land to small producers has been the imposition of land ownership ceilings, often together with land taxes. In addition to being largely ineffective,[44] such restrictions appear to have imposed extra cost on all parties. Landowners often took measures to avoid them, and the bureaucracy had to decide on exceptions to allow for the utilization of economies of scale in plantation crops – a process conducive to red tape and corruption. Even in the most favorable case such ceilings would constitute a temporary second-best measure to allow government to deal with the problem in a more thorough way. In many cases the reason for land concentration is not in a relative inefficiency of small farms but rather imperfections and policy-induced distortions in product and financial markets and the limitations on small farmers' ability to self-insure. If this is the case, it would be more effective for government to focus on the root of the problem, e.g., by designing safety nets and helping improve the functioning of other markets, rather than trying to deal with the symptoms. The interpretation that dis-equalization of land ownership is driven by imperfections in other markets is supported by the fact that in Central Uganda, in an area with good non-farm employment opportunities and well-functioning factor markets, land *sales* markets contributed to a pronounced equalization of land ownership [Baland et al. (1999)].[45] This implies that concerns about potential adverse equity impacts of land sales should be addressed by helping small farmers to compete, taking measures to improve the functioning of financial markets, and providing relief to avoid distress sales in cases of disaster.

Land rental markets. For a number of reasons, and especially in the presence of other market imperfections that would affect land prices, land rental markets may be more effective than sales markets in moving the distribution of operational holdings closer to the optimum. Rather than recognizing the potential of land rental markets to improve agricultural productivity and augment the welfare of landless poor people, governments have often focused efforts on restricting tenancy markets through bans on share tenancy and limits on cash rental fees.

Such measures had very undesirable equity consequences in Latin America where they resulted in tenant evictions and the resumption of large-scale mechanized farming. Even in India, the country where tenancy reforms are generally believed to have had success, benefits to the poor have been limited. Tenant evictions associated with the threat of tenancy reforms caused the rural poor to lose access to about 30 percent of

[44] In India, for example, 35 years of implementing ceilings laws have, in all except three states, led to the distribution of less than one percent of the operated area to the target group [Appu (1996)].

[45] The lack of land rental market transactions in this environment may be attributable to relatively insecure ownership rights, which might lead the landowner to lose the land in case of rental.

the total operated area and, by threatening landowners who lease out with the loss of their land, undermined land access through rental markets [Appu (1996)]. If feasible, the transfer of property rights implicit in such tenancy protections should improve static efficiency, as is confirmed by district-level data from West Bengal. In this case, tenancy laws yielded productivity gains of about 40 percent – slightly larger than the static loss estimated by Shaban [Banerjee et al. (1998)]. However, even in this case tenancy reform required intensive bureaucratic involvement and often created overlapping property rights to the same plot, thereby undermining investment incentives and reducing the scope for land (rental and sales) markets after the reform.

Even in countries where tenancy reform has historically constituted a major policy instrument, there is now growing recognition that there is little scope for further tenancy reform and that, even in those cases where it is possible to implement, it provides at best a temporary measure that has to be complemented by market-based mechanisms in the longer term. Tenancy reform is not an option in countries where large-scale owner-cultivation or wage labor is the predominant mode of cultivation. In all of these cases, the critical issue is to reduce remaining obstacles to land transactions without jeopardizing equity objectives. Land rental markets would appear to provide an ideal instrument to achieve this objective.

4.3. *Redistributive land reform*

As discussed earlier, unmitigated operation of land markets alone would not necessarily produce an optimal land allocation. In the land sales market, credit constraints would restrict the ability of the poor to acquire land (or any other indivisible asset), a phenomenon that has, in a more general context, been shown to be associated with intergenerational persistence of poverty [Banerjee and Newman (1991)].[46] Transactions in the land rental market are easier to accomplish, but may be associated with a more limited impact on investment and productivity as well as tenant welfare. Efficiency-enhancing rental transactions might not come about either because of high transaction costs (especially in an unclear legal environment) or because of government restrictions that threaten rented properties with expropriation. In situations characterized by pervasive inequality in the ownership distribution of land or assets more generally, government involvement in redistributive land reform, aiming to improve efficiency and equity and at the same time remove impediments to the functioning of factor markets, could be justified.

However, historically the experience with government-initiated land reform policies has been mixed, not only because reforms involving significant asset transfers are politically difficult and could be speedily implemented only where they were imposed by

[46] This idea has been formalized in theoretical models where lack of collateral keeps individuals in "poverty traps" unable to undertake indivisible investments which would be highly profitable [Galor and Zeira (1993), Eckstein and Zilcha (1994), Jalan and Ravallion (1997), Fafchamps and Pender (1997)]. In such a situation, a one-off asset distribution could be more effective than continuing redistributive efforts with the associated disincentive effects [Banerjee and Newman (1993)].

an outside power or a revolutionary change of regime.[47] In the case of *landlord estates* where tenants already cultivated the land and all that was required was a reassignment of property rights, land reform was generally easy: The organization of production retained the same family farm system, where beneficiaries already had the skills and implements necessary to cultivate their fields. The administrative requirements associated with this type of land reform were minimal, and considerable efficiency gains have often been realized by improving incentives to work and invest by former tenants.[48] The magnitude of such gains was affected by the difference in (long- and short-term) incentives between the before- and after-reform situation. Productivity gains from such reforms were generally more modest if before the reform (i) security of tenure and incentives to invest had already been high, (ii) cash-rent–rather than share-rent–contracts had prevailed, and (iii) landlords had provided tenants with access to credit inputs, and outputs.[49]

In contrast to the generally successful experience in landlord estates, land reform in *hacienda* systems – i.e., systems where tenants have a small house-plot for subsistence but work most of their time on the landlord's home farm – has been very difficult to accomplish. Thus some have argued that the "game of Latin American Land Reform" has been lost [De Janvry and Sadoulet (1989)]. In the large majority of these systems, large landowners responded to the threat of land reform by either evicting tenants who could have made claims to land ownership under a possible reform program, or converting them into wage laborers. In the case of eviction, landlords reduced reliance on hired workers either by resuming extensive livestock production and ranching or – aided by significant credit subsidies – by embarking on highly mechanized self-cultivation [Binswanger et al. (1995)]. This not only reduced tenant welfare but also depopulated farms and created further difficulties for redistributive land reform. A number of further difficulties of effective land reform in hacienda systems are associated with policy distortions, limitations on the functioning of the land market, and inability to provide the necessary complementary elements for land reform beneficiaries to start successful small farm enterprises.

First, the costs of carrying out land reform were often increased by the continued existence of implicit and explicit policy distortions (e.g., agricultural protection and

[47] The marked difference in the success of land reform between Korea, Taiwan, and Japan on the one side, and Nicaragua, Cuba, and Vietnam on the other, suggests that the ability to redistribute large amounts of land is not a sufficient condition for land reform to be successful.

[48] Indeed, since the end of World War II, landlord estates in Bolivia, Eastern India, Ethiopia, Iran, Japan, Korea, and Taiwan have been transferred to tenants in the course of successful land reforms. While evidence on the productivity impact of such reforms is much less than what would be desirable, they have generally been associated with significant increases in output and/or productivity [King (1977), Lieten (1996), Besley and Burgess (1998)].

[49] The degree to which land reform improved productivity and cultivator welfare increased with the profitability of existing investment opportunities [Callison (1983), Koo (1968), King (1977)], the degree to which land ownership enabled the new owners to access markets for credit and insurance that had previously been beyond their reach [Dorner and Thiesenhusen (1990)], and the availability of new technology that could be readily adopted [Otsuka (1991)].

selective credit subsidies) that drove land prices above the capitalized value of agricultural profits and often disproportionately benefited large producers. Such distortions increased the fiscal cost of land reform policies and reduced their sustainability by making it profitable for land reform beneficiaries to sell their newly acquired land back to large farmers. Indeed, despite attempts to limit beneficiary desertion through imposition of legal restrictions and the threat of punishment in case of contravention, there is considerable anecdotal evidence on land sales by reform beneficiaries in Nicaragua, Colombia, and El Salvador. In a recent census of Brazilian land reform settlements, only about 60 percent of recently established land reform beneficiaries were actually found tilling their land.

Second, many countries aimed to implement land reform by eliminating or restricting other forms of (rental and sales) market transactions. This completely eliminated price and other market signals, making it more difficult to select beneficiaries and land, and further increased the costs of land reform implementation. It also tilted the balance in favor of a highly centralized mode of land reform implementation that has, in a number of countries, led to the domination of land reform processes by formidable (and often corrupt) centralized bureaucracies. In addition, and probably most important, this virtually eliminated beneficiaries' access to credit markets, despite the evidence that without access to such markets, it is difficult for them to sustain themselves. In Ireland, for example, a large-scale experiment in "negotiated" land reform early in the twentieth century did not have the expected effect for two reasons. On the one hand it did little to alter the structure of production or to improve tenants' rights. More important, however, it actually *worsened* access to credit, by limiting the ability of new landowners to mortgage land, while at the same time cutting off informal credit they had earlier obtained from the landlord [Guinnane and Miller (1997)].[50]

Third, transforming a large farm into a viable smallholder enterprise requires a change in the pattern of production, subdivision of the farm, and construction of infrastructure. As the productivity advantage of land reform hinges on increased incentives by owner-operators and adoption of labor-intensive crops, attention to complementary investments and awareness by beneficiaries is critical. Generally beneficiaries, even if they are workers of the former farm, are not accustomed to making independent entrepreneurial decisions, implying that training and human capital formation is therefore an essential component of the land reform process. Realizing the productivity benefits from land reform requires shifting the focus from political to productivity- and poverty-related objectives.[51]

[50] Severely restricted access to credit, together with insecure property rights, has also led to widespread selling of land by former land reform beneficiaries in Nicaragua – often at prices way below the productive value of the land [Joakin (1996)].

[51] The effect of political motivation on beneficiary selection and the stop-and-go cycle of land reform in response to political crises rather than opportunities for productivity increases and poverty reduction are well documented [Barraclough (1970)]. A model of land reform as a piecemeal strategy by the rich to avoid the imminent threat of revolt – with backtracking as soon as the threat weakens [Horowitz (1993)] – would be consistent with such a view.

Due to these difficulties, and the fact that land reform is a highly politicized topic, many of the land reforms that have been undertaken since the 1960s have not achieved their stated objectives. Evidence on the longer-term impact of land reform on poverty and productivity is more limited than desirable.[52] However, measures of macroeconomic adjustment such as elimination of trade protection and credit subsidies have resulted in a considerable reduction of land prices and the importance of land in a large number of developing countries.

This has led a number of countries (e.g., Brazil, Colombia, South Africa) to begin implementing a new model of "negotiated" land reform that aims to replace a centralist and often expropriative approach with provision of a grant that would enable poor people to acquire land through the market. Key elements of this approach are (i) an emphasis on sustainable poverty reduction through elaboration of integrated farm projects by the poor (which are then supported by a land purchase grant), (ii) decentralized execution and integration into development objectives at the local level with an overarching emphasis on beneficiary training and human capital formation, and (iii) private sector involvement in project development, financing, and implementation. Obviously, mere adoption of a "negotiated" mode is not immunity against the shortcomings that have plagued earlier land reform attempts.[53] Initial evidence from pilot programs that have aimed to integrate land reform into a more comprehensive package of support does, however, suggest that the new approach is perceived to be significantly different from earlier land reform attempts [Deininger (1998)]. To what degree this potential can be realized remains to be seen.

5. Conclnsion: Areas for further research

While research on land markets and land institutions has been extensive, there are a number of areas where additional or more conclusive knowledge would be of great value. Below we highlight a number of key areas that merit further study.

5.1. Security of land rights

There is broad agreement in the literature that secure individual land rights will increase incentives to undertake productivity-enhancing land-related investments. If there is scope for agricultural intensification, and these rights can be enforced at low cost,

[52] One example of such economic analysis is the study by Scott et al. (1976) for Kenya. While it illustrates that land reform can have a positive social rate of return, it is based on data gathered in the immediate aftermath of the reforms, after which data collection was discontinued.

[53] Due to a lack of poverty targeting, an exclusive focus on land purchases but not complementary investments, and a high (75 percent) level of subsidy, a "negotiated" program of land reform that was carried out in Italy during the period 1948–70 had only a limited impact on poverty reduction and was characterized by relatively high costs [Shearer and Barbero (1993)].

and secondary rights to land by other stakeholders are not eliminated in the process, then establishment of such rights would constitute a clear Pareto improvement. However, in many cases, traditional systems are associated with a wide range of equity benefits, not all of which normally can be preserved in a system characterized by private land ownership. Research aiming to understand not only the existence and magnitude of productivity benefits arising from the transition from traditional to private property rights, but also the types of welfare benefits provided by different forms of communal arrangements, their magnitude, and possible alternative mechanisms to generate similar effects, would be very useful. It could facilitate better identification of the point at which a transition from traditional to individualized tenure arrangements might be socially optimal and allow adoption of mechanisms that would ensure tenure security with minimal social disruption. Evaluation of country cases where innovative ways to make this transition have been explored recently could be a starting point for such an endeavor.

5.2. *Improving the functioning of land markets*

While there has been significant research on the static inefficiency of tenancy contracts, the welfare consequences and the impact of tenancy on farmers' investment behavior have received less attention. Assessment of the welfare aspects of tenancy – i.e., the impact of land ownership as compared to mere usufructuary rights on household well-being – would be of relevance to help policymakers determine specific steps for comprehensive land market development. Such analysis should consider the impact of access to land under different systems on productivity and welfare (e.g., through choice of livelihood strategies, higher or smoother consumption, access to credit, ability to accumulate wealth, etc.).

A large body of literature on land price formation and the relationship between land sales and rental prices for developed countries already exists. However, much less is known on this issue for developing countries, in particular how recent dramatic changes in macroeconomic policy have affected land values and the relationship between land prices and agricultural profits. Elimination of credit subsidies and tax privileges, changes in relative prices of different types of agricultural products, and increased attractiveness of non-land financial assets that have been associated with these policies would have important implications not only for land prices but also for the operation of land (sales and rental) markets. This would also affect the type of economic agents who would be able to use these markets to gain access to land and the type of complementary policies (e.g., in the area of credit) that would affect their ability to do so.

Notwithstanding the fact that markets are an important avenue for individuals to gain access to land, non-market transactions such as inheritance, allocation by village chiefs, and informal rentals among kin continue to have a far-reaching impact on a large part of the population and the structure of land ownership and land use in many parts of the world. A large descriptive literature discusses advantages and disadvantages of non-market mechanisms. However, quantitative evidence on the efficiency and equity impact of non-market transactions and the way in which policies that aim to change decision-makers' incentive affect the extent and modalities of such transactions is still limited. Given that informal systems tend to be characterized by lower transaction costs and can provide land access for the poorest segments of the population who may not be able to utilize land rental and sales markets, better understanding of the potential and shortcomings of non-market mechanisms would be of great interest. There is also little doubt that in situations where, either traditionally or due to male out-migration, a significant part of agricultural production activities is carried out by women, the nature of women's land rights – many of which are defined informally – will have far-reaching implications for agricultural productivity and investment. However, much remains to be learned about the interaction between legal prescriptions, social norms, and intra-household bargaining in determining the nature of women's rights to land, and the scope for specific policy interventions to bring about efficiency increases by strengthening these rights.

Over and above the market imperfections characteristic of rural areas, functioning of land rental and sales markets has in the past often been constrained by government interventions – in many cases with the aim to promote equity or overcome market imperfections. While the effectiveness of such policies was often limited, they generally left an institutional legacy that is difficult to dismantle. Research on the links between land and other markets could do much to identify such "second generation reforms" and to facilitate their implementation in an environment characterized by multiple market imperfections.

5.3. Land redistribution

Compared to the volume of resources that has been spent since the 1960s on land reform programs, the effort invested in monitoring their performance and in assessing their impact on poverty reduction and agricultural productivity has been minuscule. As a consequence, evidence on promising models of land reform in hacienda systems and the long-term impact associated with them is extremely limited. Little or no guidance exists on how to compare the effectiveness of different approaches to land reform in (i) reaching specific target groups, (ii) helping these groups to complement land ownership with other investments and thereby increase agricultural productivity, and (iii) enabling them to convert the one-time transfer of land into a sustained improvement in their livelihood. Such evidence will be critical in assessing whether these new approaches to market-assisted land reform are fiscally, socially, and economically sustainable.

Given the recent emphasis in the theoretical literature on asset ownership as a means for sustainable poverty reduction, it would be of great interest to carefully monitor innovative land reform efforts with a view toward drawing the necessary policy conclusions. Issues to be explored include the volume and price of land (sales and rental) transactions, characteristics of participants, and the productivity change associated with land transactions within and outside a specific land reform program. Complementing this with longitudinal information on changes in welfare of specific beneficiaries and the population at large would provide an opportunity to assess the equity impact of land reform and ultimately compare this type of intervention to other policies aimed at the same goal.

References

Allen, D.W. (1991), "Homesteading and property rights; Or, 'how the west was really won", Journal of Law and Economic 34:1–23.

Alston, L.J., G.D. Libecap and R. Schneider (1995), "Property rights and the preconditions for markets: The case of the Amazon Frontier", Journal of Institutional and Theoretical Economics 151(1):89–111.

Alston, L.J., G.D. Libecap and R. Schneider (1996), "The determinants and impact of property rights: Land titles on the Brazilian Frontier", Journal of Law, Economics & Organization 12(1):25–61.

Andre, C., and J.-P. Platteau (1996), "Land relations under unbearable stress: Rwanda caught in the Malthusian trap" (Centre de Recherche en Economie du Development (CRED), Namur, Belgium).

Appu, P.S. (1996), Land Reforms in India. A Survey of Policy, Legislation and Implementation (Vikas Publishing House, New Delhi).

Atwood, D.A. (1990), "Land registration in Africa: The impact on agricultural production", World Development 18:659–671.

Auty, R.M. (1997), "Natural resource endowment, the state and development strategy", Journal of International Development 9:651–663.

Baland, J.-M., F. Gaspart, F. Place and J.-P. Platteau (1999), "Poverty, tenure security and access to land in Central Uganda: The role of market and non-market processes", mimeo (CRED Dept. of Economics, University of Namur).

Baland, J.-M., and J.-P. Platteau (1996), Halting Degradation of Natural Resources: Is There a Role for Rural Communities? (Oxford University Press, Clarendon Press).

Baland, J.-M., and J.-P. Platteau (1997a), "Coordination problems in local-level resource management", Journal of Development Economics 53(1):197–210.

Baland, J.-M., and J.-P. Platteau (1997b), "Wealth inequality and efficiency in the commons, Part I: The unregulated case", Oxford Economic Papers 49:451–482.

Baland, J.-M., and J.-P. Platteau (1998), "Wealth inequality and efficiency in the commons, Part II: The regulated case", Oxford Economic Papers 50(1):1–22.

Balcazar, A. (1990), "Tanaño de finca, dinamica tecnologia y rendimientos agricolas", Coyuntura Agropecuaria 7(3):107–125.

Banerjee, A., P. Gertler and M. Ghatak (1998), "Empowerment and efficiency: The economics of agrarian reform", mimeo (Dept. of Economics, Massachusetts Institute of Technology).

Banerjee, A.V., and A.F. Newman (1991), "Risk-bearing and the theory of income distribution", Review of Economic Studies 58:211–235.

Banerjee, A.V., and A.F. Newman (1993), "Occupational choice and the process of development", Journal of Political Economy 101(2):274–298.

Banerjee, A., D. Mookherjee, K. Munshi and D. Ray (1997), "Inequality, control rights and rent seeking a theoretical and empirical analysis of sugar cooperatives in Maharashtra", mimeo (Boston University).

Bardhan, P., S. Bowles and H. Gintis (1997), Wealth Inequality, Wealth Constraints and Economic Performance (University of Massachusetts, Amherst).

Barham, B.L., S. Boucher and M.R. Carter (1996), "Credit constraints, credit unions, and small-scale producers in Guatemala", World Development 24(5):793–806.

Barham, B.L., M.R. Carter and W. Sigelko (1995), "Agro-export production and peasant land access: Examining the dynamic between adoption and accumulation", Journal of Development Economics 46:85–107.

Barraclough, S.L. (1970), "Agricultural policy and land reform", Journal of Political Economy 906–947.

Barrett, C.B. (1996), "On price risk and the inverse farm size – productivity relationship", Journal of Development Economics 51:194–215.

Baruah, S. (1990), "The end of the road in land reform? Limits to redistribution in West Bengal", Development and Change 21:119–146.
Basu, K. (1986), "Market for land: An analysis of interim transactions", Journal of Development Economics 20:163–177.
Bell, C. (1977), "Alternative theories of sharecropping: Some tests using evidence from Northeast India", Journal of Development Studies 13:317–346.
Benjamin, D. (1992), "Household composition, labor markets, and labor demand: Testing for separability in agricultural household models", Econometrica 60:287–322.
Benjamin, D. (1995), "Can unobserved land quality explain the inverse productivity relationship?", Journal of Development Economics 46:51–84.
Berry, R.A., and W.R. Cline (1979), "Agrarian structure and productivity in developing countries" (International Labor Organization, Geneva).
Besley, T. (1995), "Property rights and investment incentives: Theory and evidence from Ghana", Journal of Political Economy 103(5):903–937.
Besley, T., and R. Burgess (1998), "Land reform, poverty reduction, and growth: Evidence from India", mimeo, LSE.
Bhalla, S.S., and P. Roy (1988), "Mis-specification in farm productivity analysis: The role of land quality", Oxford Economic Papers 40:55–73.
Bidinger, P.D., T.S. Walker, B. Sarkar, A.R. Murty and P. Babu (1991), "Consequences of mid-1980s drought: Longitudinal evidence from Mahbubnagar", Economic and Political Weekly 26:A105–A114.
Binswanger, H.P., and K. Deininger (1997), "Explaining agricultural and agrarian policies in developing countries", Journal of Economic Literature 35(4):1958–2005.
Binswanger, H.P., K. Deininger and G. Feder (1995), "Power, distortions, revolt and reform in agricultural land relations", in: J. Behrman and T.N. Srinivasan, eds., Handbook of Development Economics, Vol. III.
Binswanger, H.P., and M. Elgin (1988), "What are the prospects for land reform", in: A. Maunder and A. Valdés, eds., Agriculture and Governments in an Interdependent World, Proceedings of the Twentieth International Conference of Agricultural Economists 1988.
Binswanger, H.P., and M.R. Rosenzweig (1986), "Behavioral and material determinants of production relations in agriculture", Journal of Development Studies 22:503–539.
Bird, R. (1974), Taxing Agricultural Land in Developing Countries (Harvard University Press, Cambridge, MA).
Birdsall, N., and J.L. Londoño (1997), "Asset inequality matters: An assessment of the world bank's approach to poverty reduction", American Economic Review 87(2):32–37.
Blarel, B., P. Hazell, F. Place and J. Quiggin (1992), "The economics of farm fragmentation: Evidence from Ghana and Rwanda", World Bank Economic Review 6:233–254.
Boserup, E. (1965), Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure (Aldine, New York).
Bowles, S., and H. Gintis (1994), "Escaping the efficiency-equity tradeoff: Productivity enhancing asset redistributions", in: Macroeconomic Policy after the Conservative Era: Research on Investment, Savings, and Finance (Cambridge University Press, Cambridge).
Brandao, A.S.P., and G.C. de Rezende (1992), "Credit subsidies, inflation and the land market in Brazil: A theoretical and empirical analysis", mimeo (World Bank, Washington).
Brasselle, A.-S., G. Frederic and J.-P. Platteau (1997), "Land tenure security and investment incentives: Some further puzzling evidence from Burkina Faso" (CRED, Namur, Belgium).
Brockett, C.D. (1990), Land, Power, and Poverty. Agrarian Transformation and Political Conflict in Central America (Unwin Hyman, Boston).
Brooks, K., and Z. Lerman (1994), "Land reform and farm restructuring in Russia", World Bank Discussion Paper 233 (Washington, DC).
Bruce, J.W. (1988), "A perspective on indigenous land tenure systems and land concentration", in: R.W. Downs and S.P. Reyna, eds., Land and Society in Contemporary Africa (For University of New Hampshire by University Press of New England, Hanover and London).

Bruce, J.W., and S. Migot-Adholla (1994), Searching for Land Tenure Security in Africa (Kendall Hunt Publishing Company, Dubuque, IA).

Burgess, R. (1998), "Land, welfare and efficiency in Rural China", mimeo (London School of Economics).

Cain, M. (1981), "Risk and insurance: Perspectives on fertility and agrarian change in India and Bangladesh", Population and Development Review 7:435–474.

Callison, C.S. (1983), Land to the Tiller in the Mekong Delta: Economic, Social and Political Land Reform in Four Villages of South Vietnam (University Press of America, Bloomington, IN).

Calvo, G.A., and S. Wellisz (1978), "Supervision, loss of control, and the optimum size of the firm", Journal of Political Economy 86:943–952.

Carter, M.R. (1984), "Identification of the inverse relationship between farm size and productivity: An empirical analysis of peasant agricultural production", Oxford Economic Papers 36:131–145.

Carter, M.R., and B.L. Barham (1996), "Level playing fields and laissez faire: Postliberal development strategy in inegalitarian agrarian economies", World Development 24(0):1–17.

Carter, M.R., and D. Mesbah (1993), "Can land market reform mitigate the exclusionary aspects of rapid agro-export growth?", World Development 21(7):1085–1100.

Carter, M.R., and P. Olinto (1996), "Does land titling activate a productivity–promoting land market? Econometric evidence from rural Paraguay" (University of Wisconsin-Madison).

Carter, M.R., L. Shouying, M. Roth and Y. Yao (1996), "An induced institutional innovation perspective on the evolution of property rights in post-reform rural China", mimeo (University of Wisconsin-Madison).

Carter, M.R., and K.D. Wiebe (1990), "Access to capital and its impact on agrarian structure and productivity in Kenya", American Journal of Agricultural Economics 72:1146–1150.

Carter, M.R., and E. Zegarra (1995), "Reshaping class competitiveness and the trajectory of agrarian growth with well-sequenced policy reform", Agricultural Economics Staff Paper Series No. 379 (University of Wisconsin-Madison).

Cheung, N.S. (1969), The Theory of Share Tenancy (University of Chicago Press, Chicago).

Collier, P. (1989), "Contractual constraints on labour exchange in rural Kenya", International Labour Review 128:745–768.

Cramb, R.A. (1993), "The evolution of property rights to land in Sarawak: An institutionalist perspective", Review of Marketing and Agricultural Economics 61(2):289–300.

De Alessi, L. (1980), "The economics of property rights: A review of the evidence", Research in Law and Economics 2:1–47.

De Janvry, A., and E. Sadoulet (1989), "A study in resistance to institutional change: The lost game of Latin American land reform", World Development 17:1397–1407.

De Meza, D., and J. R. Gould (1992), "The social efficiency of private decisions to enforce property rights", Journal of Political Economy 100:561–580.

Deininger, K. (1995), "Collective agricultural production: A solution for transition economies?", World Development 23(8):1317–1334.

Deininger, K. (1998), "Making negotiated land reform work: Initial experience from Brazil, Colombia, and South Africa", World Development, forthcoming.

Deininger, K., P. Olinto, M. Wamulume and D. Chiwele (1998), "Agricultural sector performance in a post-reform environment: Implications for second-generation reforms in Zambia", mimeo (World Bank, Washington, DC).

Dercon, S. (1996), "Risk, crop choice, and savings: Evidence from Tanzania", Economic Development and Cultural Change 44(3):485–513.

Dercon, S., and P. Krishnan (1996), "Income portfolios in rural Ethiopia and Tanzania: Choices and constraints", The Journal of Development Studies 32(6):850–875.

Dong, X.-Y. (1996), "Two-tier land tenure system and sustained economic growth in post-1978 rural China", World Development 24(5):915–928.

Dorner, P., and W.C. Thiesenhusen (1990), "Selected land reforms in East and Southeast Asia: Their origins and impacts", Asian Pacific Economic Literature 4:69–95.

Downs, R.W., and S.P. Reyna, eds. (1993), Land and Society in Contemporary Africa (For University of New Hampshire by University Press of New England, Hanover and London).
Dujon, V. (1997), "Communal property and land markets: Agricultural development policy in St. Lucia", World Development 25(9):1529–1540.
Eckstein, Z., and I. Zilcha (1994), "The effects of compulsory schooling on growth income distribution and welfare", Journal of Public Economics 54:339–359.
Ellickson, R.C. (1993), "Property in land", Yale Law Journal 102(6):1315–1400.
Ensminger, J. (1997), "Changing property rights: Reconciling formal and informal rights to land in Africa", in: J.N. Drobak and J.V.C. Nye, eds., The Frontiers of the New Institutional Economics (Academic Press, San Diego, Harcourt Brace).
Eswaran, M., and A. Kotwal (1985a), "A theory of two-tier labor markets in agrarian economies", American Economic Review 75:162–177.
Eswaran, M., and A. Kotwal (1985b), "A theory of contractual structure in agriculture", American Economic Review 75:352–367.
Eswaran, M., and A. Kotwal (1986), "Access to capital and agrarian production organization", Economic Journal 96:482–498.
Fafchamps, M., and J. Pender (1997), "Precautionary saving, credit constraints, and irreversible investment: Theory and evidence from semi-arid India", Journal of Business and Economic Statistics 15(2):180–194.
Feder, G. (1985), "The relation between farm size and farm productivity: The role of family labor, supervision, and credit constraints", Journal of Development Economics 18:297–313.
Feder, G., et al. (1989), "Agricultural credit and farm performance in China", Journal of Comparative Economics 13(4):508–526.
Feder, G., and D. Feeney (1991), "Land tenure and property rights: Theory and implications for development policy", World Bank Economic Review 5:135–155.
Feder, G., and A. Nishio (1996), "The benefits of land registration and titling: Economic and social perspectives" (The World Bank).
Feder, G., T. Onchan, Y. Chalamwong and C. Hangladoran (1986), Land Policies and Farm Productivity in Thailand (Johns Hopkins University Press, Baltimore, MD).
Feder, G., and N. Raymond (1987), "Land rights systems and agricultural development in Sub-Saharan Africa agriculture and rural development", Dept. RU Paper 64 (Washington, DC).
Feeney, D. (1988), "The development of property rights in land: A comparative study", in: R.H. Bates, ed., Toward a Political Economy of Development: A Rational Choice Perspective (University of California Press, Berkeley).
Feldstein, M. (1980), "Inflation, portfolio choice, and the prices of land and corporate stock", American Journal of Agricultural Economics 62:910–916.
Foster, A.D., and M.R. Rosenzweig (1996), "Comparative advantage, information and the allocation of workers to tasks: Evidence from an agricultural labor market" (University of Pennsylvania).
Frisvold, G.B. (1994), "Does supervision matter? Some hypothesis tests using Indian farm-level data", Journal of Development Economics 43:217–238.
Fujimoto, A. (1988), "The economics of land tenure and rice production in a double-cropping village in Southern Thailand", Developing Economies 26:189–211.
Galor, O., and J. Zeira (1993), "Income distribution and macroeconomics", Review of Economic Studies 60:35–52.
Gavian, S., and M. Fafchamps (1996), "Land tenure and allocative efficiency in Niger", American Journal of Agricultural Economics 78:460–471.
Geertz, C. (1968), "Agricultural involution: The process of ecological change in Indonesia" (For the Association of Asian Studies by University of California Press, Berkeley).
Glaeser, E.L. (1996), "The incentive effects of property taxes on local governments", Public-Choice 89(1–2):93–111.
Glover, D. (1990), "Contract farming and outgrower schemes in East and Southern Africa", Journal of Agricultural Economics 41:303–315.

Gordillo, G., A. de Janvry and E. Sadoulet (1997), "Mexico's second agrarian reform: Household and community responses. 1990–1994" (La Jolla, Calif. Center for U.S.–Mexican Studies, University of California, San Diego).

Guinnane, T.W., and R.l. Miller (1997), "The limits to land reform: The land acts in Ireland, 1870–1909", Economic Development and Cultural Change 45(3):591–612.

Gunjal, K., S. Williams and R. Romain (1996), "Agricultural credit subsidies and farmland values in Canada", Canadian Journal of Agricultural Economics 44(1):39–52.

Hayami, Y., L.S. Adriano, Y. Quisumbing and M.A.R. Quisumbing (1990), Toward an Alternative Land Reform Paradigm, A Philippine Perspective (Ateneo de Manila University Press, Manila).

Hayami, Y., and K. Otsuka (1993), The Economics of Contract Choice: An Agrarian Perspective (Oxford University Press, Clarendon Press, Oxford, New York).

Hoff, K. (1991), "Land taxes, output taxes, and sharecropping: Was Henry George right?", World Bank Economic Review 5:93–111.

Horowitz, A.W. (1993), "Time paths of land reform: A theoretical model of reform dynamics", The American Economic Review 83(4):1003–1010.

Jalan, J., and M. Ravallion (1997), "Are the poor less well insured? Evidence on vulnerability to income risk in rural China", mimeo (The World Bank).

Jensen, M.C., and W.H. Meckling (1976), "Theory of the firm: Managerial behavior, agency costs, and ownership structure", Journal of Financiai Economics 3:305–360.

Joakin, J. (1996), "The impact of structural adjustment and property rights conflicts on Nicaraguan agrarian reform beneficiaries", World Development 24(7):1179–1191.

Jodha, N.S. (1990), "Rural common property resources: Contributions and crisis", Economic and Political Weekly 25:A65–A78.

Just, R.E., and J.A. Miranowski (1989), "U.S. land prices: Trends and determinants", in: A. Maunder and A. Vaidés, eds., Agriculture and Governments in an Interdependent World, Proceedings of the Twentieth Internationai Conference of Agricultural Economists 1988.

Kevane, M. (1996), "Agrarian structure and agricultural practice: Typology and application to Western Sudan", American Journai of Agricultural Economics 78(1):236–245.

Kevane, M., and B. Wydick (1998), "Social norms and the time ailocation of women's labor in Burkina Faso", mimeo.

Key, N., C. Muñoz-Piña, A. de Janvry and E. Sadoulet (1998), "Social and environmental consequences of the Mexican reforms: Common pool resources in the Ejido sector" (Department of Agricultural and Resource Economics, University of California-Berkeley).

King, R. (1977), Land Reform: A World Survey (G. Bell and Sons, London).

Koo, A.Y.C. (1968), Land Reform and Economic Development: A Case Study of Taiwan (Praeger, New York).

Kranton, R.E., and A.V. Swamy (1997), "The hazards of piecemeal reform: British civil courts and the redit market in colonial India" (World Bank, Washington, DC).

Kung, J.K. (1995), "Equal entitlement versus tenure security under a regime of collective property rights: Peasants' preference for institutions in post-reform Chinese agriculture", Journai of Comparative Economics 21:82–111.

Kutcher, G.P., and P.L. Scandizzo (1981), "The agricultural economy of northeast Brazil" (World Bank, Washington, DC).

Laffont, J.-J., and M.-S. Matoussi (1995), "Moral hazard, financial constraints and sharecropping in El Oulja", Review of Economic Studies 62(3):381–399.

Lastarria-Cornhiel, S. (1997), "Impact of privatization on gender and property rights in Africa", World Development 25(8):1317–1333.

Lieten, G.K. (1996), "Land reforms at centre stage: The evidence on West Bengal", Development and Change 27:111–130.

Lin, J.Y. (1992), "Rural reforms and agriculturai growth in China", American Economic Review 82:34–51.

Lin, J.Y., F. Cai and Z. Li (1994), "Why China's economic reforms have been successful: Its implications for other reforming economies" (Peking University and the Chinese Academy of Social Sciences).

Liu, S., and M.R. Carter (1996), "Dimensions and diversity of property rights in rural China: Dilemmas on the road to further reform", World Development 26(10):1789–1806.

Malik, A., and R.M. Schwab (1991), "Optimal investments to establish property rights in land", Journal of Urban Economics 29:295–309.

McCarthy, N., A. de Janvry and E. Sadoulet (1998), "Land allocation under dual individual-collective use in Mexico", Journal of Development Economics 56:239–264.

McCloskey, D.N. (1975), "The persistence of English common fields", in: W. Parker and E. Jones, eds., European Peasants and their Markets (Princeton University Press, Princeton, NJ).

McCloskey, D.N. (1991), "The prudent peasant: New findings on open fields", Journal of Economic History 51(2):343–355.

McMillan, J., J. Whalley and L. Zhu (1989), "The impact of China's economic reforms on agricultural productivity growth", Journal of Political Economy 97:781–807.

Mearns, R. (1996), "Community, collective action and common grazing: The case of post-socialist Mongolia", Journal of Development Studies 32(3):297–339.

Migot-Adholla, S., et al. (1991), "Indigenous land rights systems in Sub-Saharan Africa: A constraint on productivity?", World Bank Economic Review (International) 5:155–175.

Moene, K.O. (1992), "Poverty and landownership", American Economic Review 82:52–64.

Mookherjee, D. (1997), "Informational rents and property rights in land", in: J. Roemer, ed., Property Rights, Incentives & Welfare (Macmillan Press).

Morooka, Y., and Y. Hayami (1989), "Contract choice and enforcement in an agrarian community: Agricultural tenancy in Upland Java", Journal of Development Studies 26(1):28–42.

Mueller, B. (1997), "Property rights and the evolution of a frontier", Land Economics 73(1):42–57.

Nagarajan, G., M.A. Quisumbing and K. Otsuka (1991), "Land pawning in the Philippines: An exploration into the consequences of land reform regulations", Developing Economies 29:125–144.

Newbery, D.M.G., and J.E. Stiglitz (1979), "Sharecropping, risk sharing and the importance of imperfect information", in: J.A. Roumasset et al., eds., Risk, Uncertainty, and Agricultural Development (Agricultural Development Council).

Newell, A., P. Kiran and S. James (1997), "Farm size and the intensity of land use in Gujarat", Oxford Economic Papers 49:307–315.

Nugent, J., and N. Sanchez (1993), "Tribes, chiefs, and transhumance: A comparative institutional analysis", Economic Development and Cultural Change 42(1):87–113.

Olinto, P.V. (1995), "Land quality and the inverse relationship between farm size and productivity: A panel data analysis of Paraguayan farm households" (Department of Agricultural Economics, University of Wisconsin-Madison).

Olson-Lanjouw, J. (1995), "Information and the operation of markets: Tests based on a general equilibrium model of land leasing in India", Economic Growth Center Discussion Paper No. 727 (Yale University).

Otsuka, K. (1991), "Determinants and consequences of land reform implementation in the Philippines", Journal of Development Economics 35:339–355.

Otsuka, K., H. Chuma and Y. Hayami (1992), "Land and labor contracts in agrarian economies: Theories and facts", Journal of Economic Literature 30(4):1965–2018.

Otsuka, K., C. Hiroyuki and Y. Hayami (1993), "Permanent labour and land tenancy contracts in agrarian economies: An integrated analysis", Economica 60(237):57–77.

Pender, J.L. and J.M. Kerr (1996), "The effect of transferable land rights on credit, land investment and use: Evidence from South India", mimeo.

Pinckney, T.C., and P.K. Kimuyu (1994), "Land tenure reform in East Africa: Good, bad or unimportant?", Journal of African Economies 3(1):1–28.

Platteau, J.-P. (1996), "The evolutionary theory of land rights as applied to Sub-Saharan Africa: A critical assessment", Development and Change 27:29–86.

Platteau J.-P. (1999), "Intra-family exclusionary processes in access to land–with special reference to Europe and Sub-Saharan Africa", in: A. de Janvry, E. Sadoulet and J.-P. Platteau, eds., Land Reform Revisited: Access to Land, Rural Poverty, and Public Action (Oxford University Press) forthcoming.

Quibria, M.G., and S. Rashid (1984), "The puzzle of sharecropping: A survey of theories", World Development 12:103–114.

Reid, J.D. (1976), "Sharecropping and agricultural uncertainty", Economic Development and Cultural Change 24:549–576.

Robertson, A.F. (1982), "Abusa: The structural history of an economic contract", Journal of Development Studies 18(4):447–478.

Rosenzweig, M.R., and H.P. Binswanger (1993), "Wealth, weather risk and the composition and profitability of agricultural investments", Economic Journal 103:56–58.

Rosenzweig, M.R., and K.I. Wolpin (1993), "Credit market constraints, consumption smoothing and the accumulation of durable production assets in low-income countries: Investments in bullocks in India", Journal of Political Economy 101:223–244.

Rozelle, S., L. Guo and L. Brandt (1996), "Land tenure, property rights, and productivity in China's agricultural sector" (Food Research Institute, Stanford University).

Sadoulet, E., A. de Janvry and S. Fukui (1997), "The meaning of kinship in sharecropping contracts", American Journal of Agricultural Economics 79:394–406.

Sadoulet, E., S. Fukui and A. de Janvry (1994), "Efficient share tenancy contracts under risk: The case of two rice-growing villages in Thailand", Journal of Development Economics 42:243–269.

Sarap, K. (1990), "Factors affecting small farmers access to institutional credit in rural Orissa, India", Development and Change 21:281–307.

Schiff, M., and A. Valdés (1995), "The plundering of agriculture in developing countries", Finance and Development 32(1):44–47.

Scott, M.F., J.D. MacArthur and D.M.G. Newbery (1976), Project Appraisal in Practice: The Little-Mirrlees Method Applied in Kenya (Heinemann Educational Books, London).

Sen, A.K. (1981), "Market failure and control of labour power: Towards an explanation of structure and change in Indian agriculture, Parts 1 and 2", Cambridge Journal of Economics 5(3):201–228, Part 1; 5(4):327–350, Part 2.

Sengupta, K. (1997), "Limited liability, moral hazard and share tenancy", Journal of Development Economics 52:393–407.

Shaban, R.A. (1987), "Testing between competing models of sharecropping", Journal of Political Economy 95:893–920.

Shaban, R.A. (1991), "Does the land tenancy market equalize holdings?", Working Paper (University of Pennsylvania).

Shearer, E.B., and B. Giuseppe (1993), "Public policy for the promotion of family farms in Italy" (The World Bank).

Shetty, S. (1988), "Limited liability, wealth differences and tenancy contracts in agrarian economics", Journal of Development Economics 29:1–22.

Siamwalla, A. et al. (1990), "The Thai rural credit system: public subsidies, private information, and segmented markets", World Bank Economic Review 4:271–295.

Sjaastad, E., and D. Bromley (1997), "Indigenous land rights in Sub-Saharan Africa: Appropriation, security and investment demand", World Development 25(4):549–562.

Skoufias, E. (1991), "Land tenancy and rural factor market imperfections revisited", Journal of Economic Development 16:37–55.

Skoufias, E. (1995), "Household resources, transaction costs, and adjustment through land tenancy", Land Economics 71(1):42–56.

Southgate, E., R. Sierra, and L. Brown (1991), "The causes of tropical deforestation in Ecuador: A statistical analysis", World Development 19:1145–1151.

Stiglitz, J.E., and A. Weiss (1981), "Credit rationing in markets with imperfect information", American Economic Review 71:393–409.

Strasma, J., J. Alsm, E. Shearer and A. Woldstein (1987), "Impact of agricultural land revenue systems on agricultural land usage", mimeo (Land Tenure Center, Madison, WI).

Townsend, R.M. (1993), The Medieval Village Economy: A Study of the Pareto Mapping in General Equilibrium Models (Princeton University Press, Princeton, NJ).

Townsend, R.M. (1994), "Risk and insurance in village India", Econometrica 62(3):539–591.

Townsend, R.M. (1995), "Consumption insurance: An evaluation of risk-bearing systems in low-income economies", Journal of Economic Perspectives 9(3):83–102.

Turner, M.A., L. Brandt and S. Rozelle (1998), "Property rights formation and the organization of exchange and production in rural China", mimeo.

Udry, C. (1995), "Recent advances in empirical microeconomic research in poor countries" (Northwestern University).

Udry, C. (1996), "Gender, agricultural production, and the theory of the household", Journal of Political Economy 104(5):1010–1046.

Umbeck, J. (1977), "The California gold rush: A study of emerging property rights", Explorations in Economic History 14(3):197–226.

Wilson, P.N., and G.D. Thompson (1993), "Common property and uncertainty: compensating coalitions by Mexico's Pastoral Ejidatarios", Economic Development and Cultural Change 41(2):299–318.

Yao, Y. (1996), "Three essays on the implications of imperfect markets in rural China", Ph.D. (University of Wisconsin).

Zimmerman, F., and M.R. Carter (1996a), "Dynamic portfolio management under risk subsistence constraints in developing countries" (Food Research Institute, Stanford University).

Zimmerman, F., and M.R. Carter (1996b), "Rethinking the demand for institutional innovation: Land rights and markets in the West African Sahel" (Stanford University).

Chapter 7

HUMAN CAPITAL: EDUCATION AND AGRICULTURE

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Contents

Handbook of Agricultural Economics, Volume 1, Edited by B. Gardner and G. Rausser

Abstract

This chapter presents a review and synthesis of effects of education in agriculture, summarizes major contributions, and suggests major research gaps in the literature. Although growth in knowledge enables skill acquisition and specialization of labor, which generally raises labor productivity, and technical change, the dominant effect on agriculture has been technical change. A puzzle remains why schooling does not have broader direct impacts in agriculture. Furthermore, as we proxy education or general intellectual achievement by schooling in our empirical research, this has led to biased interpretations of impacts when general intellectual achievement of school graduates changes over time and perhaps in nonlinear ways.

Keywords

education, schooling, agriculture, human capital, impact analysis

JEL classification: Q12

Education is widely considered to be the most important form of human capital [Becker (1993, pp. 1–13)]. A major part of formal education or general intellectual achievement is obtained in elementary and secondary schools and in colleges/universities. Although there are differences in exactly what these institutions teach in different parts of the world, common components are skills, knowledge, and a method of analyzing problems [Schultz (1963, pp. 1–19), Becker (1993, pp. 1–13), Bishop (1989)]. Investments of students' and teachers' time and other inputs are used in the schooling process, and schooling of an individual beyond the permanent literary level, which is generally three to four years of formal schooling, has lifetime impacts on almost all of his or her activities. These are widely accepted to include labor productivity and wage rates, but also include choices of occupation, geographical location, information acquisition, and technology. In agriculture, the returns to schooling seem to increase substantially as a country goes from traditional agriculture to modernizing, which creates a dynamic technical and economic environment requiring information acquisition, technology evaluation, and adjustments to change [Schultz (1964), Schultz (1975), Becker (1993, pp. 1–13)].

The objective of this paper is to present a review and synthesis of the broad effects of education on agriculture and to summarize where major contributions lie and where major gaps exist in the literature. The first section presents a conceptual framework for education's contribution. The second section reviews and synthesizes the empirical evidence which is organized around the topics of (1) choices about where to work, (2) technology adoption and information acquisition, (3) agricultural production, (4) agricultural productivity decomposition, and (5) household income. The third section presents a summary of major contributions and research gaps in the literature.

1. A conceptnal framework

1.1. Overview

Growth in knowledge seems to be 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, pp. 71–87)]. Hence, the returns to labor's specialization arise through workers taking on narrower and more specialized tasks, but to get output produced, this means that a group of workers having different skills must cooperate together. "Team production" within or across firms raises special incentive problems [Gibbons (1998), Becker and Murphy (1993)]. As the degree of specialization of labor and tasks increases, the number of different tasks and specialists that must be coordinated increases. For the continuation of this growth process emphasizing knowledge accumulation and specialization, an economy must find new ways to reduce team-labor coordinating costs. Economies that have high coordination/ transaction costs because of a weak economic exchange system (i.e., absence of private property, weak contracts, suppressed prices and markets) reduce the incentives 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, pp. 88–107), Huffman and Evenson (1993)] occur. These innovations are frequently adopted in manufacturing, agriculture, and other sectors. Considerable evidence exists for the United States that unskilled labor and capital services are substitutes in manufacturing, but skilled labor and capital services are complements [see Orazem et al. (1997), Griliches (1969, 1970)]. More generally, capital services and labor become less substitutable as the skills of labor increase, and labor and capital services eventually become complements, especially for college trained labor. This means that as knowledge and technology advance, the demand for skilled (more highly educated) labor grows relative to the demand for less skilled (less educated) labor, and the potential exists for a rise in the real (and relative) wage of skilled labor.

Production on farms is one of biological processes, but major differences exist between crop and livestock production. 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. 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.

Because plants occupy fixed land area as they grow, machines suitable for mechanization of crop production must be mobile and move across the fields or through plant materials that are fixed in location. Furthermore, machines must be small relative to plot or field sizes. Thus, a special type of mechanization is required for crops. This contrasts with industrial (and livestock) production where the production plant is fixed and materials move through it. The latter type of production permits workers to become specialized in one phase of the total production process and this has aided labor productivity in the industrial sector of developed countries. It is difficult for workers in crop production to be fully employed and to specialize in any phase of production.

Livestock production 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 during the growing and finishing phases. Production can be organized in sequential phases where all phases from birth to finishing occur on one farm or where different farms specialize in different phases. Advances in animal health products, animal feeding, housing and equipment, and management have made it technically possible to speed up the growing and finishing phases by using large confined animal production systems which greatly increase animal densities and populations. To further reduce disease problems in large animal confined systems, animals of different ages can be segregated and raised apart in "all-in, all-out" systems. With the growing and finishing of animals and birds in a facility in phased groups, livestock production becomes similar to production of industrial goods where workers have the opportunity to specialize in a particular phase of production.

When firms are heterogeneous within a sector or have some 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 the available technologies, and adopt only the new ones that are expected to make them better off. Considerable evidence exists that schooling of entrepreneurs becomes 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)].[1]

1.2. Agricultural household models

The behavior of agricultural households has been modeled from different perspectives depending on the central issue researchers are considering. If 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 multi-period household utility maximization with human capital production or innovation have provided a useful guide to empirical models. If household members have obtained their human capital, e.g., formal education, and the impact of this human capital on other outcomes – e.g., occupational choice, hours of work, purchased input use, wage rates, income – is the central focus, one-period static agricultural household models have provided a useful guide to researchers about which variables are expected to affect behavior or outcomes and how they might be related. In particular, behavioral models provide one useful guide to researchers for deciding which variables should be treated as endogenous, e.g., choices, and which are exogenous or causal variables.

In the following two subsections, two representative agricultural household models are outlined. One is a multi-period dynamic agricultural household model, and the other is a single-period static agricultural household model.

[1] Average schooling completion levels of the adult population differ greatly across countries. Barro and Lee (1993) have recently constructed good estimates of schooling completion levels for a set of 125 countries for the period 1960–1985. They report summaries for regional groups of countries. In 1985, sub-Saharan Africa and South Asia had the lowest average schooling completion levels for adults, 2.67 and 2.81 years, respectively. In the Middle East and North Africa, the average schooling completion level was 3.51 years, and in Latin America and the Caribbean the average was 4.47 years. In other regions, the average schooling completion level for adults was higher, 5.19 years for East Asia and the Pacific, 8.88 years for the OECD countries, and 9.17 years for centrally planned economies (excluding China). No similar international data exists on schooling completion of the farm population.

1.2.1. A three-period model with human capital production and investment

Building on the multiperiod household decision model of Ghez and Beeker (1975), the human capital (e.g., education) investment model of Ben-Porath (1967) and Mincer (1974, pp. 14–15), and the one-period agricultural household models of Singh et al. (1986) and Huffman (1991b), a multiperiod agricultural household focused on consumption, human capital production, farm production, and human capital service allocation is presented. To capture the main economic issues in human capital investment decisions and yet to keep the model simple enough that many of its implications are easily interpretable, I assume that the household is risk-neutral and has a three-period planning horizon or lifetime.

In each period, the farm household is assumed to consume human capital services, i.e., leisure, L_{1j}, $j = t, t+1, t+2$, and goods X_{1j}, and to have a well-behaved intertemporal utility function:

$$U = U(L_{1t}, X_{1t}, L_{1t+1}, X_{1t+1}, L_{1t+2}, X_{2t+2}). \tag{1}$$

The household faces technology constraints on the production of human capital and farm output. First, the production of the human capital in each period, i.e., the investment, is assumed to use two variable inputs: human capital services L_{2j} from an individual's initial human capital endowment or past human capital investment, a purchased input X_{2j}, and a fixed individual or household-specific genetic or innate ability factor A_2:

$$Z_{2j} = F_2(L_{2j}, X_{2j}, A_2), \quad F_2(0, X_{2j}, A_2) = 0, \quad F_2(L_{2j}, 0, A_2) \geqslant 0. \tag{2}$$

$F_2(\cdot)$ exhibits decreasing returns to scale in L_2 and X_2. Hence, when the input prices of L_{2j} and X_{2j} are fixed to the household, the assumption of decreasing returns implies that marginal cost is rising with added Z_{2j}. For schooling, this assumption reflects the upper limit on mental capacity of an individual to learn in each period.

Second, the production of farm output is assumed to use two variable inputs and one fixed input. The variable inputs are human capital services of household members L_{3j} and purchase inputs X_{3j}, and the fixed input is technology and agro-climatic conditions A_3:

$$Z_{3j} = F_3(L_{3j}, X_{3j}, A_3). \tag{3}$$

The farm production function is assumed to exhibit decreasing return to scale in L_3 and X_3 in the region of an optimal solution, e.g., due to natural limitations placed on the production process by agro-climatic conditions.[2]

[2] If an active rental or asset market in farmland does not exist, then farmland is part of A_3.

To facilitate the modeling, human capital investments are assumed to change the quantity of human capital services available, but they do not affect the wage rate per unit of human capital service. Hence, this is a model where human capital investments augment the effective number of units of human time that are available each period rather than raising the wage per unit of actual time worked. The latter approach is the one taken by the hedonic wage literature, e.g., Mincer (1974) and Willis (1986).

The household has an initial human capital endowment K_t^0; human capital is permitted to depreciate over time at a rate δ, $0 \leqslant \delta < 1$, due to obsolescence or wearing out, and the human capital services available to the household in each period are:

$$L_j = \alpha K_j = \alpha \sum_{j=t}^{t+2} \left[(1-\delta)^{j-t} K_t^0 + \gamma (1-\delta)^{j-t-1} Z_{2j-1} \right], \tag{4}$$

where α (> 0) is the time invariant rate of conversion of human capital stock to services, and γ equals 1, adjusting human capital investment (a flow) to a stock. The available human capital services are allocated among four activities: leisure L_{1j}, human capital production L_{2j}, farm production L_{3j}, and wage work L_j^w:

$$L_j = L_{1j} + L_{2j} + L_{3j} + L_j^w, \quad L_{2j}, L_{3j}, L_j^w \geqslant 0. \tag{5}$$

Because human capital services allocated in any period j to human capital production, farm productions, and wage work can be zero, a non-negativity constraint is imposed on these choices.

The household faces a multiperiod cash budget constraint:

$$\sum_{j=t}^{t+2} \frac{P_{3j}^* Z_{3j} + W_j L_j^w}{(1+r)^{t-j}} = \sum_{i=1}^{3} \sum_{j=t}^{t+2} \frac{P_{ij} X_{ij} + C_j}{(1+r)^{j-t}}, \tag{6}$$

where P_{3j}^* is the (expected) price of farm output and P_{ij} is the (expected) price of the purchased consumption goods, inputs into human capital production, or inputs into farm production, respectively. The (expected) wage rate per unit of human capital services is W_j; $C_j \geqslant 0$ is any fixed cost associated with the household's production or consumption activities, e.g., on licenses or fees; and r is a fixed discount rate.

If Equation (3) is substituted into Equation (6), then the farm production and multiperiod budget constraints are combined into one constraint:

$$\sum_{j=t}^{t+2} \frac{P_{3j}^* F_3(L_{3j}, X_{3j}, A_3) + W_j L_j^w}{(1+r)^{j-t}} = \sum_{i=1}^{3} \sum_{j=t}^{t+2} \frac{P_{ij} X_{ij} + C_j}{(1+r)^{j-t}}. \tag{7}$$

The household can now be viewed as making multiperiod consumption, human capital production, farm production, and labor supply decisions by maximizing Equation (1) subject to Equations (7), (2), (4), and (5), including nonnegativity constraints. The Kuhn–Tucker first-order conditions are

$$\frac{\partial \Phi}{\partial L_{1j}} = \frac{\partial U}{\partial L_{1j}} - \frac{\lambda_j}{(1+r)^{j-t}} = 0, \quad j = t, t+1, t+2, \tag{8}$$

$$\frac{\partial \Phi}{\partial X_{1j}} = \frac{\partial U}{\partial X_{1j}} - \frac{P_{1j}}{(1+r)^{j-t}} = 0, \tag{9}$$

$$\frac{\partial \Phi}{\partial L_{2t}} = \zeta \big(PV^t_{Z_{2t}} MP^{Z_2}_{L_{2t}} - \lambda_t\big) \leqslant 0, \quad L_{2t} \geqslant 0, \quad L_{2t}\big(PV^t_{Z_{2t}} MP^{Z_2}_{L_{2t}} - \lambda_t\big) = 0, \tag{10}$$

where

$$PV^t_{Z_{2t}} = \frac{P^*_{3t+1}}{(1+r)} \frac{\partial Z_{3t+1}}{\partial L_{3t+1}} \frac{\partial L_{3t+1}}{\partial Z_{2t}} + \frac{P^*_{3t+2}}{(1+r)^2} \frac{\partial Z_{3t+2}}{\partial L_{3t+2}} \frac{\partial L_{3t+2}}{\partial Z_{2t}} + \frac{W_t \alpha}{(1+r)} + \frac{W_{t+1}\alpha(1-\delta)}{(1+r)^2},$$

and

$$MP^{Z_2}_{L_{2t}} = \frac{\partial Z_{2t}}{\partial L_{2t}}, \qquad MP^{Z_2}_{x_{2t}} = \frac{\partial Z_{2t}}{\partial X_{2t}};$$

$$\frac{\partial \Phi}{\partial X_{2t}} = \zeta \big(PV^t_{Z_{2t}} MP^{Z_2}_{X_{2t}} - P_{2t}\big) \leqslant 0, \quad X_{2t} \geqslant 0,$$

$$X_{2t}\big(PV^t_{Z_{2t}} MP^{Z_2}_{X_{2t}} - P_{2t}\big) = 0, \tag{11}$$

$$\frac{\partial \Phi}{\partial L_{2t+1}} = \zeta \left(PV^t_{Z_{2t+1}} MP^{Z_2}_{L_{2t+1}} - \frac{\lambda_{t+1}}{1+r}\right) \leqslant 0, \quad L_{2t+1} \geqslant 0,$$

$$L_{2t+1}\left(PV^t_{Zt+1} MP^{Z_2}_{L_{2t+1}} - \frac{\lambda_{t+1}}{1+r}\right) = 0, \tag{12}$$

where

$$PV^t_{Z_{2t+1}} = \frac{P^*_{3t+2}}{(1+r)^2} \frac{\partial Z_{3t+2}}{\partial L_{3t+2}} \frac{\partial L_{3t+1}}{\partial Z_{2t+1}};$$

$$\frac{\partial \Phi}{\partial X_{2t+1}} = \zeta \left(PV^t_{Z_{2t+1}} MP^{Z_2}_{X_{2t+1}} - \frac{P_{2t+1}}{1+r}\right) \leqslant 0, \quad Z_{2t+1} \geqslant 0,$$

$$X_{2t+1}\left(PV^t_{Z_{2t+1}} MP^{Z_2}_{X_{2t+1}} - \frac{P_{2t+1}}{1+r}\right) = 0, \tag{13}$$

$$\frac{\partial \Phi}{\partial L_{3j}} = \zeta P^*_{3j} MP^{Z_3}_{L_{3j}} - \frac{\lambda_j}{(1+r)^{j-t}} \leqslant 0, \quad L_{3j} \geqslant 0,$$

$$L_{3j}\left(\zeta P^*_{3j} MP^{Z_3}_{L_{3j}} - \frac{\lambda_j}{(1+r)^{j-t}}\right) = 0, \tag{14}$$

$$\frac{\partial \Phi}{\partial X_{3j}} = \zeta P_{3j}^{*} MP_{X_{3j}}^{Z_3} - \frac{P_{ij}}{(1+r)^{j-t}} = 0, \tag{15}$$

$$\frac{\partial \Phi}{\partial L_j^w} = \frac{(-\lambda_j + W_j)}{(1+r)^{j-t}} \leqslant 0, \quad L_j^w \geqslant 0, \quad L_j^W(-\lambda_j + W_j) = 0, \tag{16}$$

plus Equations (7), (2), (4), and (5), where $\lambda_j/(1+r)^{j-t}$ is the marginal utility of human capital services in period j, and ζ is the marginal utility of discounted cash income.

A little interpretation of the first-order conditions is enlightening. Equations (8) and (9) imply the standard condition for optimal mix of consumption goods in each period. The ratios of the marginal utilities of the two goods should equal the ratio of their respective marginal cost or shadow price, i.e., $MU_{L_{1j}}/MU_{X_{1j}} = \lambda_j/P_{ij}$. Equations (10)–(12), and (13) imply that the production of human capital (investment) in each period occurs at minimum cost, i.e.,

$$\frac{MP_{L_{2t}}}{MP_{X_{2t}}} = \frac{\lambda_t}{P_{2t}}, \qquad \frac{MP_{L_{2t+1}}}{MP_{X_{2t+1}}} = \frac{\lambda_{t+t}}{P_{2t+1}}.$$

Equations (14) and (15) imply that the production of farm output is at minimum cost in each period,

$$\frac{MP_{L_{3j}}}{MP_{X_{3j}}} = \frac{\lambda_j}{P_{3j}}.$$

Because of the human capital focus of this chapter, Equations (10) through (14) have special meaning. First, they provide the information about 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 of Z_2 equals the present value of the marginal cost. For period t this implies

$$PV_{Z_{2t}}^t = MC_{Z_{2t}} = \frac{\lambda_t}{MP_{L_{2t}}^{Z_2}} = \frac{P_{2t}}{MP_{X_{2t}}^{Z_2}}.$$

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 for Z_2. 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 in 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 non-farm 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, perhaps zero, 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. This outcome might be expected in countries where skills are rewarded in the nonfarm labor market but where new technologies for agriculture are being developed slowly. Alternatively, wage rates in the nonfarm labor might be unaffected by skill, e.g., due to the physically demanding nature of the work or institutional factors, but agriculture might be receiving a steady stream of new technologies that require skill to use them effectively. In this scenario, an increment of schooling will not affect an individual's nonfarm wage but will raise his marginal product at farm work. Hence, if an investment in an increment of human capital is optimal, an agricultural household will increase the share of its employed human capital services that is allocated to farm work. In this case, investing in schooling for farm people would not necessarily be expected to cause an exit of schooled individuals from farms to the cities for 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 period $t+2$ because there is cost but no return.

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 reduced 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.

At an interior solution, except $L_{2t+2} = X_{2t+2} = 0$, the model implies that human capital services are allocated in t and $t+1$ such that at the margin

$$\frac{MU_{L_{1j}}}{\zeta} = PV_{Z_{2j}^t} MP_{L_{2j}} = P_{3j}^* MP_{L_{3j}}^{Z_3} = W_j.$$

Given the finite planning horizon, the optimal allocation of human capital services in $t+2$ is such that at the margin

$$\frac{MU_{L_{1j}}}{\zeta} = P_{3j}^* MP_{L_{3j}}^{Z_3} = W_j.$$

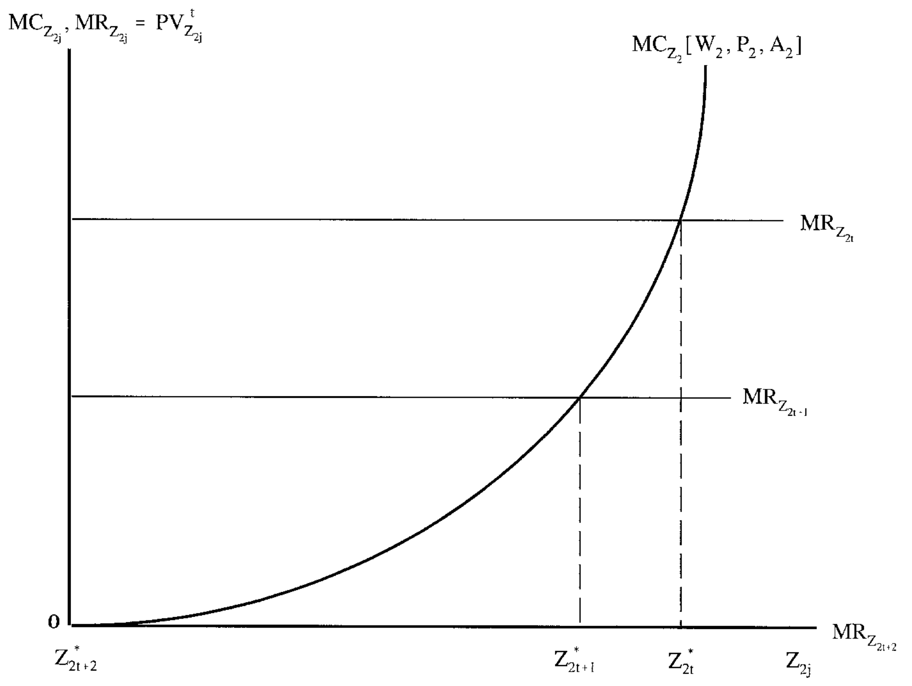

Figure 1. Optimal production of human capital.

In these two scenarios, farm production decisions are separable from household consumption, human capital production, and labor supply decisions, i.e., farm input/output decisions are static profit-maximizing decisions with W_j as the price of L_{3j}. Furthermore, given that life is finite and that investment in human capital early in life increases the total available human capital services available for allocating later in life, a likely scenario in the initial period t is that optimal $L_t^w = L_{3t} = 0$, i.e., none of an individual's human capital services is to farm and nonfarm work, and available human capital services are allocated to consumption and human capital production. In this case, the opportunity cost of human capital services used in human capital production (consumption) is its marginal value in foregone leisure (future labor productivity increases).

As a guide to empirical researchers and research, this model has as endogenous or choice variables in each period the following: the quantity of goods for consumption, leisure, and purchased inputs; inputs for human capital production (investment); human capital services, and purchased inputs; inputs for farm production, human capital services and purchased inputs; and supply of labor (human capital services) to the nonfarm labor market. An upper limit to the set of relevant exogenous variables is the following list:

$$W_t, W_{t+1}, W_{t+2}, P_{1t}, P_{1t+1}, P_{1t+2}, P_{2t}, P_{2t+1}, P_{2t+2}, P^*_{3t}, P^*_{3t+1}, P^*_{3t+2}, P_{3t}, P_{3t+1}, P_{3t+2}, C_t, C_{t+1}, C_{t+2}, A_2, A_3, \alpha, \delta, \text{ and } r.$$

1.2.2. A one-period static model

Drawing upon the agricultural household models of Singh et al. (1986) and Huffman (1991b, 1996b), the farm household is assumed to make resource allocation decisions for any production cycle by maximizing utility subject to resource and technology constraints. The farm household is assumed to derive utility from a home-produced good Y_1 and from leisure L:

$$U = U(Y_1, L). \tag{17}$$

First, the household faces a technology constraint from the farm-household production or transformation function:

$$F(Y_1, Y_2, Y_3, H, X, A, E) = 0, \quad Y_3 \geqslant 0, \; X \geqslant 0, \tag{18}$$

where Y_1 is output of the home good, and Y_2 and Y_3 are outputs produced for sale. Output Y_3 may or may not be produced, so a non-negativity constraint is imposed. H is hours of farm-household work by members, and X is purchased variable inputs, which might not be used, so a non-negativity constraint is imposed. A is technology and agro-climatic conditions, and E is an education index of household decision makers. The production function permits adopting new inputs (and discarding old ones) and expanding or reducing the number of outputs produced. It also accommodates substitute or complement relationships between variable inputs, and schooling of the decision maker(s) can enhance technical efficiency. For model development, an asymmetric form of the transformation function is used:

$$Y_2 = f(Y_1, Y_3, H, X, A, E), \quad Y_3 \geqslant 0, \; X \geqslant 0. \tag{19}$$

Second, the household faces a human time constraint:

$$T = L + H + H_m, \quad H_m \geqslant 0, \tag{20}$$

where total available time per production cycle T is allocated among leisure L, farm-household work H, and off-farm wage work H_m. A non-negativity constraint is imposed on H_m because it may be zero.

Third, the household faces a cash income constraint:

$$I = P_2Y_2 + P_3Y_3 + W_mH_m + V = W_XX, \tag{21}$$

where P_2 and P_3 are the market prices of Y_2 and Y_3, W_m is the market wage rate for off-farm work, V is household nonfarm-nonlabor income net of any fixed costs associated with farm-household production, and W_X is the market price of X. All prices are assumed to be given to households, but the off-farm wage rate depends on human capital E and local economic conditions Φ, i.e., $W_m = W(E, \Phi)$.

If Equation (19) is substituted for Y_2 in Equation (21), then two of the three constraints facing the household are combined:

$$P_2 f(Y_1, Y_3, H, X, A, E) + P_3 Y_3 + W_m H_m + V = W_X X. \tag{22}$$

The household can now be viewed as making consumption, production, and labor supply decisions (i.e., choice set C: Y_1, L, Y_3, H, X, and H_m) by maximizing Equation (17) subject to Equations (22) and (20), including the non-negativity constraints. The Kuhn–Tucker first-order conditions are:

$$\frac{\partial U}{\partial Y_1} = -\lambda_1 P_2 \frac{\partial Y_2}{\partial Y_1}, \tag{23}$$

$$\frac{\partial U}{\partial L} = \lambda_2, \tag{24}$$

$$\lambda_1\left(P_2 \frac{\partial Y_2}{\partial Y_3} + P_3\right) \leqslant 0, \quad Y_3 \geqslant 0, \quad Y_3\left(P_2 \frac{\partial Y_2}{\partial Y_3} + P_3\right) = 0, \tag{25}$$

$$\lambda_1 P_2 \frac{\partial Y_2}{\partial H} - \lambda_2 = 0, \tag{26}$$

$$\lambda_1\left(P_2 \frac{\partial Y_2}{\partial X} - W_x\right) \leqslant 0, \quad X \geqslant 0, \quad X\left(P_2 \frac{\partial Y_2}{\partial X} - W_x\right) = 0, \tag{27}$$

$$\lambda_1 W_m - \lambda_2 \leqslant 0, \quad H_m \geqslant 0, \quad H_m(\lambda_1 W_m - \lambda_2) = 0, \tag{28}$$

plus Equations (22) and (20) where λ_1 is the marginal utility of cash income and λ_2 is the marginal utility of human time. With an interior solution, Equations (23), (24), and (28) imply optimal marginal rate of substitution between home goods Y_1 and leisure L of

$$\frac{\partial U/\partial Y_1}{\partial U/\partial L} = -\frac{P_2 \partial Y_2/\partial Y_1}{W_m},$$

or the ratio of their opportunity costs ($\partial Y_2/\partial Y_1 < 0$). If production of Y_3 is to occur, the value of the marginal reduction of Y_2 to produce Y_3 must equal the price of Y_3 (i.e., $-P_2 \partial Y_2/\partial Y_3 = P_3$). At an interior solution, family labor and purchased inputs are to be used such that the value of the marginal product of an input equals its respective price (Equations (26) and (27)).

As a guide to empirical research and researchers, this static model has a slightly different configuration of endogenous and exogenous variables than the three-period model. The endogenous or choice variables are home-produced goods Y_1 and leisure L, production of Y_1, Y_2, and Y_3, purchase of variable inputs X, and hours of on-farm and off-farm work by household members. The upper limit to set of exogenous variables driving these decisions includes P_1, P_2, P_3, W_X, W_m, V, A, and E. In particular, at an interior solution, the farm production decisions can be separated from the household consumption and labor supply decisions. Farm input decisions are then profit-maximizing decisions where the price of family labor is the off-farm wage. Furthermore, if the household has a "garden" rather than a farm, the agricultural household model is applicable to most rural and some urban households.

1.3. More about agriculture

Schooling and experience 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 to 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 (1996a)]. Although agriculture can in some cases compete with the nonfarm sector on rate of technical change, the opportunities for raising labor productivity in agriculture through task specialization and coordination or teamwork may be modest compared to the nonfarm sector, i.e., the skilled individual may face a more inelastic demand for his services on a farm than in a large nonfarm business. Also, the agricultural sector may in some cases face small market size and high coordination costs that put it at a disadvantage.

Formal schooling is part skill creation, part local culturalization, and part screening. The composition differs across countries and through the grade levels within a country. Skill creation generally receives most of the attention in economics, and skill creation fits neatly into a human capital framework. Primary schooling, which emphasizes literacy, numeracy, and problem- solving skills for its graduates, creates basic skills that are generally productive to farm people and provide a foundation for secondary and higher education. Secondary schooling encompasses a range of skills, sometimes being mainly college preparatory and at the other extreme being quite utilitarian. In the U.S. before 1890, high schools were primarily college preparatory, located in cities, and were not teaching skills generally useful to farm people. Starting about 1900, secondary schools in America were transformed into a new and generally useful institution for the masses, including farm people [Goldin (1998), Goldin and Katz (1999a, 1999b)]. The new high schools had a new curriculum centered around English, geometry, algebra, accounting, and typing, that could serve as a useful terminal degree providing skills for life's work or as college preparation. These schools were "open", admitting all students who had completed the requirements of public elementary schools. From 1910 to 1940, U.S. high school enrollment and graduation rates grew rapidly, especially in the Great Plains, West, and Midwest where agriculture was relatively important. Higher education becomes potentially useful to farm people when successful decision making in agriculture requires depth of understanding of science and business or when farm people need to prepare for an occupation outside of agriculture.

In some agricultural environments, experience rather than schooling may be a more important form of human capital, while in other environments, schooling has a major advantage over experience [Schultz (1964), Becker (1993, pp. 1–13), Huffman (1991a, 1985)]. In a static (political, economic, technical) environment, accumulated experience seems to be a better investment than schooling. Information accumulated through experience in farming or working in the household does not depreciate when the environment is unchanging. Work experience is a relatively valuable form of training, e.g., farmers can learn much that is useful for decision making from their own and others' experiences. 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 have an advantage over on-the-job training. Most new agricultural technologies are geo-climatic 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 valuable. Hence, a changing agricultural environment is expected to increase the expected returns to formal schooling and possibly to reduce the opportunity cost of schooling for farm male youth (reduce the expected payoff to farm-specific human capital) [Foster and Rosenzweig (1996)]. These are all arguments for allocative efficiency effects of human capital. Schooling and experience may also enhance the technical efficiency at agricultural production activities, but for enhancing technical efficiency, experience seems likely to be a more important form of human capital in both static and dynamic environments.

For farmers to have access to new technologies, they must have either a successful national research and development (R&D) system or access to international technologies. In all cases, some special attention must be given to adaptive research to meet local agricultural conditions. Farmers in developed countries have access to locally, nationally, and internationally developed technologies, but the technologies available in developed countries are frequently limited to the output of the national public agricultural research system and possibly the international agricultural research centers.

2. Empirical evidence

2.1. Choices about where to work

Worldwide about one-half of the labor force works in agriculture [The World Bank (1997, pp. 220–221)]. 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 generally has a local component and a migratory component [see Emerson (1984)].

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 [Johnson (1997), OECD (1995)]. 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 have significantly less education. For example, in the United States, hired farm workers have about 50 percent as much schooling as farm operators [Huffman (1996b)], and in 1990, 53 percent of seasonal crop workers had less than 8 years of schooling [Gabbard and Mines (1995)]. In this latter group, about 60 percent were foreign born and 40 percent undocumented.[3] This subsection examines the impact of schooling on individuals' choices of where to work in a free society.

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 percent of the world's population, and in other low income countries, about 65 percent of the labor force in 1990 was employed in agriculture. In Western Europe, less than 10 percent of the labor force was employed in agriculture, and in the United States the share was only 3 percent. In noncentrally planned countries, individuals make a choice of an occupation/industry for work.

Orazem and Mattila (1991) have examined occupational choices for U.S. high school graduates. Graduates are assumed to choose the occupation that maximizes their expected lifetime utility, where indirect utility depends primarily on the mean and variance of earnings and income independent of occupational choice. Their model is similar to the three-period conceptual model presented in the previous section, and goes beyond and is superior to the (lifetime) earnings maximization models [e.g., Ben-Porath (1967)]. Schooling is also permitted to produce different amounts of occupation-specific human capital, i.e., schooling is not equally productive across occupations. This occupation-specific human capital is a function of the intensity with which a student invests in school (attendance rate) and school (teacher) quality.

Orazem and Mattila (1991) then use the model to examine the choices of Maryland high school graduates (1951–69) among eight activities: six occupations (including farming, fishing, and mining) and two college options. They found that increasing the mean of the earnings distribution (or reducing the variance) for an occupation/activity i increases the probability that activity i is selected by high school graduates. The quality of secondary schooling is shown to affect graduates' activity choices differentially, suggesting that schooling has an activity-specific and a general training component. In particular, increasing schooling quality reduces the proportion of high school graduates going into farming, fishing, or mining relative to other occupations, or continuing with college. Hence, parameters of occupational-earnings distributions and school quality seem to affect occupational choices of rural youth in free societies, but there is considerable potential here for future research on occupational choice involving agriculture.

[3] See Martin et al. (1995) for an extensive review of the use of foreign, including undocumented, workers in U.S. agriculture and an examination of the impacts on U.S. agriculture of the Immigration Reform and Control Act of 1986.

Perloff (1991) has examined wage workers' industrial choice of work (in agriculture versus nonagriculture) and wages by industry for U.S. low-educated nonurban workers. Workers are assumed to choose the industry that gives them the largest total current benefit, i.e., wage adjusted for the monetary value of the (dis)utility of work. The probability of wage-work in agriculture is then a function of individual, family, and regional attributes. Wage equations by industry are then a function of workers' attributes and regional/state location of work.

To focus on the population for which working in agriculture seemed most relevant, Perloff limited his sample to nonurban male wage workers who were age 16 or older, had 9 years or fewer of schooling, and were working 15 or more hours per week. The sample is from the 1988 U.S. Current Population Survey. The results showed that a year of additional schooling increased the probability of working in agriculture for workers having less than 5 years of schooling, but reduced the probability for those having more than 5 years. An additional year of post-schooling experience increased the probability of choosing agriculture only for workers having more than 32 years of experience. A worker being Mexican, non-Mexican Hispanic, or black increased his probability of choosing agriculture.

Using a hedonic wage equation, Perloff found significant differences in the agriculture and nonagriculture wage structures. An additional year of schooling had a (small) positive effect on the wage in agriculture up to 5 years, but no significant effect on the nonagriculture wage. An added year of post-schooling experience had no significant effect on the wage in agriculture but a (small) positive effect on the nonagricultural wage up to 33 years. In agriculture, Mexicans, other Hispanics, and blacks earned significantly more than whites, but in nonagriculture, the blacks earned 15 percent less than whites, and Mexican and other Hispanics had wage rates that were not significantly different from whites' (with the same education and experience). Controlling for demographic differences, the agriculture wage differed significantly across regions and states, but for nonagriculture, no difference across regions and states existed, except in California, where wages were higher. Perloff then fitted a structural participation equation using the predicted agricultural–nonagricultural wage differentials adjusted for selectivity, and found strong positive effects of the agriculture-nonagriculture wage differential on the probability of working in agriculture. He concluded that low-education nonurban male wage workers are quite responsive to the agriculture-nonagriculture wage differential.[4]

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

[4] Perloff also concluded that if the supply of undocumented workers to U.S. agriculture was to end, the wage rate in agriculture would rise relatively, and significant positive supply response would arise from low-educated nonurban U.S. workers.

individuals are acting on anticipated wage rate differences rather than the ex post values. Schooling has been hypothesized to play a significant role in these adjustments or reallocations because of its effect on both the costs and returns to migration.

Migratory agricultural workers incur moving costs in exchange for a higher expected wage in a new location. Emerson (1989) examines the earnings structure for migratory and nonmigratory work and the probability of migration for 559 domestic males in a survey of Florida farm workers. A migrant, an individual who has earnings in two or more states during the survey year, is hypothesized to have a different earnings structure for nonmigratory work. He finds that the expected earnings difference between migratory and nonmigratory work increases significantly as the probability of a worker being migratory increases. For these workers, the mean schooling completion level was 6.5 years, and a worker's schooling had a positive but not significantly different from zero (5 percent) effect on being migratory.

Perloff et al. (1998) examine the migratory responsiveness of seasonal agricultural service labor to geographical wage differences using the National Agricultural Workers Surveys 1989–1991. They define migration as a worker traveling at least 75 miles for perishable crop work during a survey year. They test and confirm the hypothesis that workers who have the largest expected gain to migration are the ones who actually migrate for work. In a probit equation explaining the probability of a worker migrating, they find the worker's amount of schooling has no significant effect. However, a worker's U.S. farm labor market experience and a worker being female had significant negative effects on the probability of migration.

Taylor (1986, 1987) examined the decisions of rural Mexican households to allocate adult labor to work in Mexico or to work as undocumented labor in the United States. Mexican households are assumed to employ adults so as to maximize expected (source) household income. If the adult migrates as an undocumented worker, his or her contribution to Mexican source household income is expected remittances net of migration costs, and the probability of successful undocumented migration is assumed to be a function of individual and family attributes. Net remittances and Mexican income from work are each assumed to be a function of individual and source household attributes.

Taylor (1987) fits his model to data for randomly chosen households in a rural Mexican village 2,000 kilometers from the U.S.–Mexican border. In a (reduced-form) equation explaining the probability of undocumented Mexico–U.S. migration, he found that an adult's age has a significantly positive effect up to 36 years for men and 32 years for women, one added year of experience as an undocumented Mexico–U.S. migrant has a significantly positive effect up to 9 years, but an added year of worker schooling has a significantly negative effect. The latter result arises because more educated rural Mexican adults have relatively better labor market opportunities in Mexican cities than in the United States. A Mexican household having a migration kinship network, i.e., family contacts in the United States, has a significantly positive effect on the probability of undocumented Mexico–U.S. migration. The reason put forth in the network reduces the costs to a potential immigrant of crossing the border and finding a job. Hence, Taylor presents evidence which many researchers would find counterintuitive: an individual's schooling reduces rather than increases his or her likelihood to migrate internationally. Migration kinship networks seem to be highly substitutable for educators in understanding Mexico–U.S. migration. Finding collaborative evidence in other parts of the world would seem to be a useful activity.

Taylor (1987) also reports results for fitted income equations, one for Mexico–U.S. migrant remittances and one for income contribution by working in Mexico. He found that a worker's education has a positive and significant effect on his or her Mexican income but no significant effect on remittances to Mexico. U.S. experience as an undocumented migrant has a significantly positive effect on remittances and on Mexican income, but Mexican experience as a migrant in Mexico has a positive effect only on Mexican income. Thus, U.S. work experience seems to produce a type of general human capital, but work experience in Mexico seems to produce country-specific skills.

Taylor (1987) then fits a structural probit to explain Mexican–U.S. undocumented migration. He uses the fitted remittance and Mexican worker income equation, corrected for selection, to estimate for each worker the difference between his or her predicted migrant remittance and predicted Mexican worker income. This difference in income is then shown to contribute positively to the probability of undocumented Mexico–U.S. migration while leaving the effects of a migrant's U.S. experience, migration kinship network, and age largely unchanged from the reduced-form equation.

Barkley (1990) presents economic evidence on the determinants of net migration of labor out of U.S. production agriculture, 1940–1985. This is an especially interesting period because employment in U.S. agriculture declined about 300 percent. He hypothesized and found that labor was responding to a significant decline in the expected payoff to working in agriculture relative to other industries. A higher return to labor in nonfarm work relative to farm work increased the net exit rate from agriculture. Higher real land prices, which raises the wealth position of farm labor that owns land, however, tended to reduce the migration of labor out of agriculture. Government program payments which clearly affect farm income did not affect migration, except perhaps through the land prices or returns to farm labor. Being a farmer creates location-specific information about the land, climate, and input supplies, and Huffman and Feridhanusetyawan (2001) have shown that being self-employed or a farmer causes a significant reduction in the likelihood of an adult male experiencing interstate migration. But formal schooling which creates general skills was shown to have a strong positive effect on the likelihood of migrating.

Huang, Orazem and Wohlgemuth (2001) applied a human capital model, similar to the three-period model, in their examination of the underlying causes of growth and decline in U.S. rural county populations by decade, 1950–90. They examined population growth rates for 306 southern and midwestern counties and tested for human capital and labor market opportunity effects. They found that rural counties that had a higher average adult schooling level at the beginning of a decade had a higher rate of loss of population over the following decade. When a county was farther from a large city, had more concentrated employment by industry, had a larger share of population on farms or share of population who were black, it had a larger rate of population loss over the following decade. Over their study period, schooling yielded higher returns in urban than rural areas. Hence, in rural U.S. counties that invested more in schooling of children, the rate of net export of human capital to other counties was larger. Because of positive, expected geographical spillover effects of rural schooling, a significant part of the cost should be borne by areas that are expected to benefit – e.g., state and federal sources [Olson (1969, 1986)].

In contrast to the human capital approach taken by Huang and Orazem to modeling annual county population growth rates, Goetz and Debertin (1996) rejected a human capital approach. They employed a rather *naive* empirical economic model for explaining rural county population growth rates over 1980–90. It placed all the emphasis on *actual* characteristics of counties at the beginning of the period, e.g., average characteristics of farms, average earnings in farming and other occupations, and total employment across industries, and the net birth rate from 1980 to 1990. The authors argued that individual characteristics, e.g., education and age, are unimportant, and ignored information about the expected commuting distance to work and earning prospects elsewhere. Also, they apparently considered birth rates to be an uneconomic decision. Another deficiency is their use of actual characteristics of counties in 1980 to explain population growth: Individuals presumably use as information for migration decisions anticipated rather than actual characteristics, although past values do represent naive expectations formation.

Off-farm work. Although farmers or cultivators 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 [Bryant (1986)], and the real nonfarm wage has generally increased. Faced with needing to make adjustments in labor allocation, farm households in the 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., see Hallberg et al. (1991)].

Most empirical studies of off-farm work participation of farm household members have used an agricultural household model similar to the static conceptual model presented in the previous section. In this framework, an individual's schooling has been an important determinant of off-farm work participation in middle- and high-income countries. In all the published econometric studies of off-farm work participation of farm operators in the U.S., Canada, and Israel, the operator's schooling has been shown to have a positive and statistically significant effect on his probability of off-farm work (see Table 1). Fewer studies have examined off-farm work decisions of farm wives, but a farm wife's schooling has a positive and significant effect on her probability of off-farm work too [see Huffman and Lange (1989), Gould and Saupe (1989), Tokle and Huffman (1991), Lass and Gempesaw (1992), Kimhi (1994), and Abdulai and Delgado (1999)]. Cross-person schooling effects between spouses are mixed in sign and generally statistical significance. Where wage equations have been part of these econometric

Table 1
Summary of econometric evidence: probability of participation in off-farm work.

Off-farm participation	Location	Dependent data type	Operator's variable	Marginal effect on probability of male operators' off-farm work: Operator's schooling	Spouse's schooling	Age	Age^2	Nonfarm asset income
Huffman (1980)	U.S. (Iowa, N.C., Okla.)	1964 census ct. aggre. avg.	Log (odds of off-farm work)	+[a]	+[a]	+	–	+
Sumner (1982)	U.S. (Ill.)	1971 farm level	Probit (1,0)	+	–	+[a]	–[a]	–[a]
Huffman/Lange (1989)	U.S. (Iowa)	1977 farm level	Probit (1,0)	+[a]	–[a]	–	–	–
Jensen/Salant (1985)	U.S. (Miss., Tenn.)	1981 farm level	Probit (1,0)	+[a]	–	+[a]	–[a]	–[a]
Bollman (1979)	Canada	1971 census 1971 census	Probit (1,0)	+[a]	+[a]	–[a]		–[a]
Gould/Saupe (1989)	U.S. (Wis.)	1986 farm level	Probit (1,0)	+	+	+[a]	–[a]	–
Lass, Findeis, and Hallberg (1989)								
Tokle/Huffman (1991)	U.S.	1978–82 household level	Probit (1,0)	+	–[a]	+[a]	+[a]	–[a]
Lass/Gempesaw (1992)	U.S. (Pa.)	1985 farm level	Probit (1,0)	+	+[a]	+[a]	–[a]	–[a]
Kimhi (1994)	Israel (1981 census)	1981 farm level	Probit (1,0)	+[a]	–[a]	+[a]	–[a]	excluded

[a] Computed from a coefficient that is significantly different from zero at 5 percent level.

studies, an individual's schooling always has a positive and significant effect on his or her off-farm wage, and an individual's experience also has been a significant predictor of the wage.

Overall, the review of the literature has shown that the quantity and quality of an individual's schooling affects his or her choice of where to work. In the U.S., higher secondary school quality seems to reduce the likelihood of an individual choosing an occupation in agriculture. For less-educated wage workers, say less than 5 years, added schooling increases the likelihood of working in agriculture. 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.

2.2. *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 returns are distributed over time. Furthermore, only a small share of the new technologies that become available will be profitable for any given farmer 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, a model similar to the three-period model of the previous section provides a useful guide to the empirical literature. Also, see Besley and Case (1993) for examples of particular choice-based empirical models of farmers' technology adoption.

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.

Huffman and Mercier (1991) examined the adoption of microcomputers and/or purchased computer services by a 1982–84 sample of Iowa farmers. Farmers' schooling has a positive and statistically significant effect on the probability of adopting a microcomputer, adopting purchased computer services, and adopting both a microcomputer and computer services. As farmers become older, they have fewer years to capture returns from changing, and farmers' age has a negative and significant effect on adopting all combinations of computer technologies. Although arguments can be made for off-farm work releasing credit constraints and giving exposure to computer use and usefulness, a higher probability of off-farm work by these farmers reduces (significantly) the probability of adopting a microcomputer, and tends to reduce adoption of purchased computer services.

Putler and Zilberman (1988) examined computer use by a 1986 sample of (Tulare County) California farmers who had relatively high schooling completion levels. Forty-six percent of these farmers had completed a college bachelor's (4-year) degree, and of them 11 percent had also completed a graduate degree. The authors found that farmers who were college graduates, i.e., individuals who had completed bachelor's and graduate degrees, had higher probabilities of computer adoption than farmers who completed only elementary or high school. However, individuals who completed some college but did not receive at least a four-year degree had adoption probabilities that were similar to individuals who had completed only elementary or high school. Thus, the effective use of a computer in California agriculture seems to require high levels of education. The authors also found that farm size has a positive and significant effect on computer adoption. Farmers' age had a quadratic effect on computer adoption, peaking in the 36–40 age range. The authors' evidence on type of software owned is generally weaker than for computer adoption, but they concluded that it is influenced primarily by the type of farm products produced, the size of the farming operation, ownership of a farm-related business, and education of the farm operator.

Wozniak (1984) examined the adoption of two interrelated cattle feeding technologies – one new and the other mature (available for several years) – for a 1976 sample of Iowa farmers. The new technology was the use of Rumensin which enhances natural microbial activity in rumens, and it became available to farmers about one year before the survey. The mature technology was implanting growth hormones, which is a technology that had been available for several years. Wozniak found that farmers' schooling and frequent contact with agricultural extension information sources had positive and statistically significant effects on the probability of adopting the new technology (Rumensin) but no effect on the probability of adopting the mature technology (implanting). He also found a positive and statistically significant effect of scale/size of the cattle feeding operation on the probability of adopting both feeding technologies. These results suggest that education and extension are important to assessing new innovations and explaining early adoption but not for diffusion or use of mature technologies. Also, the results imply that if an innovation is compatible with current technology, it is more likely to be adopted than if it displaces it.

Rahm and Huffman (1984) examined the adoption of reduced tillage for row crop (corn) seedbed preparation and the efficiency of the adoption decision for a 1976 sample of Iowa farms. Reduced tillage technology refers to seedbed preparation without the aid of a moldboard plow, e.g., chisel plows, field cultivators, primary tillage disks, or no-till planting. Reduced tillage significantly reduces field preparation time and retains crop residue on the soil surface, which has the potential to decrease soil loss from wind and water erosion. It also lowers springtime soil temperatures and decreases evaporation. The profitability of reduced tillage over moldboard plow technology depends on soil characteristics, annual precipitation, cropping system, and other management practices, and it is not profitable for all cropland. The authors found that the probability of a farm operator adopting reduced tillage was not related significantly to his schooling. A large corn enterprise size (acres of corn planted) had a positive and significant effect on a farmer's adoption of reduced tillage, and the cropping system of the farm and soil association of the farmland significantly affected the probability of adoption.

But Rahm and Huffman (1984) also examined the efficiency of a farmer's adoption decision, which is defined as the absolute difference between actual and predicted adoption behavior. Here, farmers who had more education (years of formal schooling) had greater efficiency of reduced tillage adoption. Also, if the farm operator used media sources of information published or marketed by the private sector or if the farm operator or spouse attended short courses, conferences, or meetings at Iowa State University, the efficiency of a reduced tillage adoption was increased. However, a farm operator's active years of experience farming or participation in meetings, field days, or demonstrations sponsored by the extension service did not have a significant effect on the efficiency of reduced tillage adoption.

Soule et al. (1999) have extended the Rahm and Huffman model of adoption of conservation practices. They develop a multiperiod model of the adoption decision, focusing on possible differences that might be associated with different land tenure arrangements, and fit a probit specification of the adoption decision to data from the 1996 Agricultural Resource Management Study survey. They find that if a farm operator has some college education he is more likely to adopt (short-term) conservation tillage practices than if he has less schooling. However, they found no significant effect of the farm operator having some college education on the probability of adopting medium-term practices, e.g., contour farming, strip cropping, establishing grassed waterways.

We turn next to some adoption evidence for developing and transition economies. New high yield wheat and rice varieties became available in the mid-1960s. Foster and Rosenzweig (1996) consider the probability that a sample of Indian farm households had ever adopted high yielding seed varieties by 1971. Schooling completion is low in these households; only 49 percent of households had someone who had completed primary school and 21 percent had someone who had completed secondary schooling. Foster and Rosenzweig found that farm households containing at least one adult who had completed primary schooling were significantly more likely to have adopted the new seeds by 1970–71 than households having no adult who was a primary schooling graduate. Schooling beyond the primary level tended to not significantly affect adoption of high yield varieties (HYV). Households that had more acres of owned land and were located in villages with an agricultural extension program were also more likely to use HYV seeds.

In another study, Foster and Rosenzweig (1995) examined the adoption of high-yielding seed varieties in a national panel sample of Indian rural households pertaining to the crop years 1968–69, 1969–70, and 1970–71. Here they focused on the importance of prior experience with HYV on current rate of use. They found that farmers who had more prior experience with HYV seed had a significantly higher current rate of use of the new seed. They also found that farmers in villages that had more prior experience with HYV also tended to have higher current rates of use of HYV seed.

Their results suggest positive learning-by-doing (or own experience effects) and positive learning-from-neighbors (or experience spillover effects) occur. Because of the fixed-effects specification of their econometric model, farmers' schooling, which does not change over time, does not have an identifiable effect on HYV adoption.

Lin (1991) examined the adoption of high-yielding rice varieties for a 1988 sample of Chinese farmers (Hunan Province). Although China did not have a market economy, a new household-based (rather than collective-based) farming system was introduced to the study area in 1981–82. The average years of formal schooling completed by the household head was 5.5 years, and 93 percent had less than 10 years of schooling. Hybrid rice seeds were released to farmers in 1976, but the price of the seed was set relatively high (10 times conventional seed), although the seeding rate was one-third to one-fourth of conventional rice's seeding rate. Controlling for 16 other variables, Lin found that schooling of the head of the farm household had a positive and significant effect on the probability of adopting middle or late hybrid rice seed. Increasing the land area cultivated by a household also increased the probability of hybrid rice variety adoption. Household head's experience in farming had a positive effect on adoption (at the 10 percent significance level).

Strauss et al. (1991) examined the adoption of cultural practices by upland rice and soybean farmers from survey information collected from 161 central-west Brazilian farms in 1985–86. Both soybeans and upland rice technologies began to be introduced in the region after 1980. The educational distribution of the farmers in the survey is as follows: fewer than 4 years, 56.8 percent; 4–8 years, 29.0 percent; and more than 8 years, 14.2 percent. The authors found that better-educated farmers were more likely to do soil analysis and use fertilizer on both rice and soybean plots, but farmers' education did not significantly affect the probability of using treated soybean seeds, certified rice seeds, or rice blast control. Farmers in areas with more experienced extension agents were more likely to use treated soybean seeds and certified rice seeds, but extension did not have a significant effect on adoption of other practices. Clearly these are a mixed set of results.

Pitt and Sumodiningrat (1991) examined the determinants of rice seed variety choice (HYV vs. traditional variety (TV)) for a 1980 national sample of Indonesian farm households. High-yielding varieties first became available at least a decade earlier. They found that farmers' schooling had a positive but statistically insignificant effect on HYV adoption, holding relative profitability of HYV to traditional varieties constant. Higher expected profitability of HYV and higher quality irrigation for a farm household also had positive and significant effects on the probability of HYV adoption.[5]

Although successful adoption of innovations clearly requires information, few studies have considered the important joint decisions of information acquisition and new

[5] See Feder, Just and Zilberman (1985) for a survey of other economic factors affecting adoption of technologies in developing countries. See Birkhaeuser, Evenson and Feder (1991) for a review of impacts of agricultural extension on adoption.

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 (Rumensin) and one mature (implanting) – and four channels of information – one active and one passive information channel 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 of 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 information providers 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.

In addition, Wozniak (1993) found that scale has a positive and significant effect on adoption of new and mature technologies and on the likelihood of acquiring information from extension actively or passively, but no significant effect on likelihood of acquiring information from private sector firms. Farm operators who had larger off-farm wage income had a lower probability of adopting the new technology and lower probability of talking with private sector information providers. He concluded that off-farm work seems to impact adoption not by easing credit restraints but by reallocating operators' time away from farm-related activities of early technology adoption and gathering technical information.

Klotz et al. (1995) examine California dairy farmers' awareness of recombinant bovine somatotropin (rbST) and its adoption using survey data over a four-year period, 1987–1990. They argue that information acquisition costs per cow decline as the size of a cow herd increases, leading to scale bias to large producers. Empirically they fit a bivariate probit model to explain awareness and adoption of rbST. They find that farmers' schooling has a positive and significant effect on both the probability of awareness and adoption. In addition, they find that as the size of the dairy herd increases, the probability of a farmer's awareness and adoption increases.

Bindlish and Evenson (1997) have undertaken an extensive study of information acquisition and its impacts on agriculture in two poor African countries. They use econometric techniques to examine whether the Training and Visit (T&V) system of extension led to earlier and greater awareness, testing, and adoption of improved farming practices in Burkina Faso and Kenya than would have occurred otherwise. They pay particular attention to the effects of endogenous T&V participation by farmers in their analysis. They found that farmers having more schooling had a high probability of participating as T&V contact farmers or members of contact groups. Holding the probability of T&V participation constant, additional T&V extension had a positive and significant effect on farmers' testing 10 of 12 recommended practices and on adoption of 9 of them. The authors also found positive externalities or spillover effects of T&V participating farmers on the probability that other farmers would test and adopt recommended practices. Farmers having more schooling (and more land) were more likely to learn from other farmers and to test and adopt new technologies.

In Kenya, the findings were less clear-cut. However, T&V extension had a positive effect on the probability of adoption of all recommended practices and a statistically significant effect on most. Higher schooling levels of farmers led to more and earlier awareness and adoption of recommended practices.

Antle and Pingali (1994) considered an interesting pesticide choice and production problem where farmers' education might be expected to matter for acquisition of information and choice of technology. They integrated farm-level survey data with health data collected from the same population of Philippine farmers to measure the impacts of pesticide use on farmers' health and the impact of farmers' health on rice production. They, however, indicate that their sample contained too little variation in farmers' education to find a significant effect on either pesticide use or production. However, an alternative interpretation of their results is that they included "choice variables" as regressors in these equations, e.g., the pesticide use equation contains as regressors the number of pesticide applications and dummy variables for farmers' smoking and drinking, which themselves seem likely to be (partially) determined by farmers' schooling. Welch (1970) and others (see later section) have shown that when the effects of education are channeled through farmers' choices, one cannot expect to hold the "choices" constant in a regression sense and also find a significant effect of education.

Overall, the review of the literature has shown 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. Furthermore, care must be taken in empirical modeling so the models are built on a solid choice-based foundation and permit schooling to affect outcomes.

2.3. Agricultural production

Education of farm labor has the potential for enhancing agricultural production as reflected in gross output/transformation functions (see Equations (3) and (18)) 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 that farmers' education may have on production through affecting choices or allocative efficiency – the adoption of new inputs in a profitable manner, the efficient allocation of land (and other quasi-fixed inputs) among alternative uses, the efficient allocation of variable inputs, and the efficient choice of an output mix. The hypothesis is and the empirical evidence has shown that the productivity of farmers' education is enhanced by a wider range of choices. Welch (1970) is generally given credit for delineating these substantive differences.

Some evidence and findings are presented first for developed countries, and second for developing countries. U.S. studies of agricultural production before the 1960s did not focus on farmers' schooling being a potentially important contributor to production, e.g., see Heady and Dillion (1961). Griliches (1963a) presented one of the first studies of the contribution of education to agricultural production. He included an index of the education of farm labor as an input in an aggregate Cobb–Douglas-type production function. The production function was fitted to data for 1949 on aggregate output and inputs for 68 U.S. agricultural regions. Six inputs, including a man-days measure of farm (hired and unpaid family) labor, were included in addition to education. Education per worker was derived from the educational distribution of the rural population and income weighted. Griliches (1963a) found that schooling of farm labor had a positive and statistically significant effect on production and that the coefficient of education was similar in size to the coefficient of farm labor. Griliches (1964) also applied a similar methodology to U.S. state aggregate per farm data for 1949, 1954, and 1959, and obtained similar results for the contribution of education of farm labor to production. His interest in education of workers in agriculture arose primarily from a concern about labor quality and a hypothesis that labor quality was an important input for explaining output.

Huffman (1977, 1981) applied a production function approach to assessing the effects of labor quality in U.S. agriculture, using county data. Huffman (1976a, 1976b) focused on the quantity and quality of farm husband and wife labor allocated to own-farm work. A Cobb–Douglas type production function was fitted to 1964 county data for Iowa, North Carolina, and Oklahoma, where effective labor input was measured as days of work multiplied by a schooling index. The value of the marginal product of husband and wife labor was shown to be larger than the average wage received for off-farm work by farm husbands and wives in these states. However, the implied marginal return in agricultural production to husband's and wife's schooling was generally lower than the average off-farm return to schooling.

Huffman (1981) presented estimates of productivity differences on black- and white-operated farms in the U.S. South (North and South Carolina, Mississippi, and Alabama). Results from fitting a modified Cobb–Douglas production function to 1964 county data showed that the quantity and quality of farmers' education and extension were the primary sources of productivity differences on black- and white-operated farms. The *quantity* differences in schooling and extension on black- and white-operated farms were shown to be *more important* than *quality* difference for explaining black-white farm productivity differences.

Welch (1970) laid the conceptual foundation for broadening the examination of education's contribution to agricultural production, especially allocative effects of farmers' education, but his empirical evidence addressed the issue only indirectly. His model, however, stimulated considerable new research on the topic. Khaldi (1975) and Fane (1975) focused on identifying the contribution of farmers' schooling to allocative efficiency by comparing hypothetical minimum cost of producing realized output to actual cost. For both, hypothetical minimum cost was inferred from an estimated aggregate production function. Khaldi's observations were state average per farm values for all U.S. states for 1964, and Fane used county averages for four Midwestern states for 1959 and 1964. Both studies found that the proportional difference between *actual* cost and *hypothetical* cost declined significantly as the average schooling level of farmers increased (for preferred specifications).

Huffman (1974, 1977) pursued a different route for testing for allocative efficiency effects. He focused on Corn Belt farmers' production of corn and nitrogen fertilizer use in county aggregate average data for 1959 and 1964. This was a period when the price of nitrogen fertilizer fell significantly relative to the price of corn (22–25 percent), and new hybrid seed corn varieties, which could respond well to higher nitrogen fertilizer use, were being developed and marketed by commercial seed corn companies. He found mixed results for the contribution of farmers' schooling to output per acre or technical efficiency. The production function for corn in 1959 and 1964 was shown to be different due to technical change, and schooling's effect was positive and significantly different from zero in Huffman (1974) but not significantly different from zero in Huffman (1977), which used a different set of counties. The next step was to examine changes in nitrogen fertilizer usage. He computed a partial adjustment coefficient showing the actual change in nitrogen fertilizer use as a fraction of the change necessary to reach a hypothetical optimum rate of use, and then related the speed of adjustment to farmers' schooling, extension input, and size. He found a positive and statistically significant relationship between the average education of farmers and the speed of adjustment. Extension and size (of the corn production enterprise) were shown also to be positively related to the speed of adjustment. Hence, both studies found that farmers' schooling increases allocative efficiency.

Huffman and Evenson (1989) examined the effects of farmers' education and other variables on optimal mix of outputs and inputs for multi-output multi-input U.S. cash grain farms. They fitted a system of output supply and input demand equations derived from a profit function to state aggregate per farm data for 42 U.S. states pooled over census years 1949–74. They found that an increase in farmers' schooling biased production decisions on cash grain farms away from fertilizer, labor, and fuel input use, and toward machinery input use; and, with respect to output, toward wheat output and away from soybean and feed grain outputs. Moreover, the relative bias-effects caused by farmers' schooling have been larger among outputs than inputs. They also found that additional agricultural extension biased production decisions in the same direction as farmers' schooling for fertilizer, fuel, and machinery inputs. However, the effects of extension on the other four choices were in the opposite direction from those caused by farmers' schooling.

Some recent agricultural profit function studies, however, have ignored the effects of farmers' education. Weaver (1983) and Shumway (1983) also fitted a system of output supply and input demand functions derived from a profit function to aggregate per farm data for North and South Dakota, 1950–70, and Texas, 1957–79, and omitted education (and extension) from their models. This omission could cause the estimated coefficients of other included variables to be biased and to miss some important effects of education on agriculture. At least the potential effects of farmers' schooling should be carefully examined before deciding that they are insignificant.

Turning to some developing country evidences, Hayami and Ruttan (1985) and Jamison and Lau (1982) summarize much of the early evidence. Few early studies found a positive and statistically significant effect of farmers' schooling on farm output. This seems to have several sources. First, researchers were exploring technical efficiency but not allocative efficiency effects. Second, schooling levels may have been too low to be productive. Third, variance in schooling levels may have been too small. Later studies have had more success.

Pudasaini (1983) chose to examine the effects of education in two regions of Nepal, one undergoing modernization and the other traditional due to its hill country isolation. The average level of schooling was 5 years in the modernizing region and 4.2 years in the traditional region. He fitted yield response, gross sales, and value-added production functions to farm-level data. He found that farmers' schooling had a positive but insignificant effect on crop yields in both regions, but farmers' schooling had a positive and statistically significant effect on the gross sales and value-added for both regions. In the modernizing region, the estimated coefficient of education was 66 percent larger for the value added than the gross sales equation, but in the traditional region, the coefficient of education was only 10 percent larger. The marginal contribution of farmers' schooling to value-added output was about two times larger in the modernizing than in the traditional region. In contrast, he did not find any significant effects of agricultural extension. Hence, this study showed that allocative effects of farmers' education were more important than worker effects, and that allocative effects were quite large in the modernizing region.

Foster and Rosenzweig (1996) used longitudinal Indian rural household data and area- specific information on crop yields and schools to test whether Green Revolution technical change increased the returns to farmers' schooling and whether schooling investments responded to changes in the return to schooling. They argued that the Green Revolution technologies were developed outside of India and imported so the availability of the technologies can be treated as exogenous to rural Indian economic conditions. However, the ability of different regions and households to exploit the new technologies was argued to differ because soils and climates differed regionally and farmers' schooling differed.

Foster and Rosenzweig (1996) used a large sample of households to explain change in farm-level profit, 1969–1970 to 1970–1971. With fixed-effects instrumental-variable estimates, they showed that the profitability of HYV acreage was significantly increased by a farm household member having completed primary schooling (relative to less than primary schooling). The profitability of HYV acreage was also increased significantly by the share of HYV land irrigated. For primary-schooled farm households having 100 percent irrigated HYV acreage, they concluded that farm profit was 39 percent higher (compared to having less than primary schooling and no irrigation). Their results confirmed positive allocative effects of schooling in Indian farming.

Foster and Rosenzweig (1996) then explained the 1971–82 change in household-specific school enrollment rates for children aged 5–14 using a subset of their sample of rural households. They found that primary school enrollment rates were positive and significantly related to the growth of crop yields in the area, but yield growth had a significantly smaller impact on school enrollment for children in nonfarm than farm households. The results suggested that the expected return to primary schooling in India was higher for farm than nonfarm households, and that the difference was associated with the steady change of technologies associated with the Green Revolution.

Subsistence peasant households in the Peruvian Sierra provided Jacoby (1993) with evidence for the contribution of schooling to agriculture for poor Latin American farm households. The sample was from a sizeable survey conducted in 1985-86 from households that reported harvesting some crops and with at least one adult male and female who worked on the family farm during the survey year. The mean schooling of male heads in these households was only 2.9 years. Farm output was defined as the value of crop and livestock production. Jacoby fitted Cobb–Douglas and translog specifications of a farm production function. He found that the head's schooling increased farm output. However, the head's age (as a proxy for experience) did not statistically affect farm output. In these households, work effort (hours of farm work) among adult males and females seemed to respond positively to their productivity, which suggested the opportunity cost of not working was higher for more educated individuals.[6]

Evenson and Mwabu (1997) examined the impact of agricultural extension and farmers' schooling on crop yields of poor African farmers. They pooled 1981–82 and 1990 samples of Kenya farm households. The average level of schooling of these farmers was very low: 47 percent had less than 2.5 years of schooling (only one was a high school graduate). They applied a quantile-regression technique for investigating productivity effects of schooling over the conditional distribution of crop yields. Farmers' schooling (measured qualitatively as greater than or less than 2.5 years) had a positive and significant impact on yields only at the bottom of the yield distribution. Agricultural extension (number of field extension workers per farm) had a generally positive impact on crop yields, but in contrast to schooling, the marginal product was largest at the top end of the yield distribution.

[6] Benjamin (1992) presents a rigorous modeling and econometric analysis of Java farm household labor use due to household composition and presence or absence of labor markets.

A few studies have also examined the effect of schooling in non-democratic and emerging market economies, especially for China. The opportunities for schooling to contribute to farm production in China were very limited under the collective farming system but seem to have increased after 1984 with the change to household-responsibility system and opening input markets. Fleisher and Liu (1992) used a large 1987–88 survey of Chinese farm households located in six different geographical regions to test for diseconomies associated with small-scale and multiple plots and effects of schooling and experience of household heads on productivity. Farm output was defined as weighted "rice-equivalence" of "field crops" produced (which excluded largely vegetables and fruits). They fitted a Cobb–Douglas type production function and found positive, but not significantly different from zero effects of schooling and experience of the household head on farm production.

In another study, Yang (1997b) examined effects on production of alternative measures of education in an attempt to strengthen the connections between education and agriculture on small Chinese farms. He chose a value-added measure of farm output so as to capture allocative effects. Although farmers' choices may still be somewhat restricted in China, he hypothesized that the allocative effects would be larger than the worker effects. He considered alternative measures of education that might be expected to affect farm production, including years of schooling of the household head, highest year of schooling completed by any household member, and average schooling of all farm labor. The sample mean values of these variables were 5.6, 7.3, and 6.0 years, respectively. He fitted several different specifications of a Cobb–Douglas type production function. The head's education had a positive but insignificant effect on farm production. Farm workers' education had a positive and significant effect on farm production, but education measured as the highest level completed by *any* farm household member performs *best*. In addition, Yang found that farm workers' experience (post-schooling experience weighted by farm work participation) also had a positive and significant effect on value added. He concluded that the schooling evidence from his sample of small Chinese farms showed allocative effects of education to be more important than worker effects. Furthermore, on these farms, the beneficial effects of schooling were obtained from an individual who frequently did not report any farm work. This seems possible only when farms are small and allocative decisions are relatively simple. The allocative benefits for these small farms were attainable with one well-schooled person per household.

The frontier production and profit function literature also provides evidence of the contribution of farmers' education to increased efficiency. Abdulai and Huffman (1999) showed that schooling of Ghana rice farmers reduces significantly profit inefficiency, which implies enhanced technical and allocation or economic efficiency. The empirical evidence for farmers' education reducing production or technical inefficiency is mixed, e.g., Belbase and Grabowski (1985) and Flinn and Ali (1986) found significant schooling effects but some other studies have found insignificant effects [see Bravo-Ureta and Pinherio (1993)].

Overall, in developing, transition, and developed countries, the review of the literature 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. Farmers' schooling has also been shown to change the optimal mix or composition of farm inputs and outputs where production is multi-input and multi-output.

2.4. *Total factor productivity decomposition*

Productivity statistics, measuring output per unit of input, started in the 1950s showing seemingly costless increases in output. Schultz (1953), Kendrick (1961), and Denison (1962) started to search for underlying sources of productivity for these increases. Their work focused on the general economy and on agriculture where the data were better. 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, this volume). 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.

The best-known early studies of sources of total factor productivity (TFP) change in U.S. agriculture are by Griliches (1963a, 1963b, 1964). In Griliches (1964), an index of education of farm labor was found to have a coefficient in an aggregate production function fitted to state average per farm data for 1949, 1954, and 1959 that was positive and not significantly different from the coefficient for farm labor (person days). This result has frequently been used by other researchers as a justification for constructed quality-adjusted farm labor input measures for TFP measures [e.g., see Ball (1985), Jorgenson and Gollop (1992), Ball et al. (1997)]. When Griliches (1964) then conducted an analysis of differences between unadjusted and adjusted residual agricultural output growth, 1949–59, education of farm labor accounted for about 14 percent of the explained difference.

Huffman and Evenson (1993) assessed research and education's contribution to TFP through statistical decomposition of state agricultural TFP levels. In their TFP measure, farm labor was measured as person-hours of unpaid farm family and hired labor, but no adjustment of education (or experience) was made. They derived TFP measures by state, 1950–82, for a crop sector, livestock sector, and aggregate farm sector. They then used public and private research, farmers' schooling, extension, and government commodity program variables to econometrically explain TFP in an analysis of 42 pooled states, 1950–82. To attain consistency of interpretation they impose some coefficient restrictions across the three productivity equations. They however found that farmers' schooling made a positive and statistically significant contribution to state TFP levels. Their results implied a positive marginal product of farmers' schooling and a relatively large social rate of return (19–40 percent). They concluded that farmers who have more schooling have an advantage in being able to understand scientific advances in the public and private sector, to draw inferences from results and make successful adaptation to their own particular farming operation, and to quickly adapt superior technologies, economic organizations, and management practices.

Huffman and Evenson (1993) also found that farmers' schooling and agricultural extension interact negatively in explaining TFP levels. The marginal product of aggregate crop and livestock extension is positive, and the marginal product is larger in the crop than in the livestock sector. For the livestock sector, the marginal product of extension was negative or zero. The authors, however, obtained evidence that farmers' schooling and extension were substitutes. Over the study period, the average level of farmers' schooling increased by about 4 years, which greatly reduced the marginal product of extension by the end of the period.

In some North American studies of agricultural TFP, authors surprisingly have chosen to ignore the effects of education [see Capalbo and Denny (1986), Antle and Capalbo (1988), and Chavas and Cox (1992)]. It is more common to ignore labor quality adjustments in TFP analyses for developing countries where schooling completion levels are low and data are poor.

Rosegrant and Evenson (1993) are an exception in their TFP research for India and Pakistan. They constructed TFP indexes for the crop sectors for 271 districts in 13 states of India (1956–87) and for 35 districts in 3 states of Pakistan (1955–85) and then conducted a statistical decomposition analysis. The empirical models were similar for the two countries. Average schooling completion levels for farmers in these districts of India and Pakistan were low, perhaps averaging 2 years. They chose to measure farmers' education as the literacy rate. They found that the literacy rate made a positive and statistically significant contribution to crop sector TFP in both countries. In India, agricultural extension (expenditures per farm) also made a positive and significant contribution to TFP.

A few studies have examined the effects of education on agricultural productivity across many countries. Hayami and Ruttan (1970) examined agricultural labor productivity, rather than TFP, differences for 38 developed and developing countries. [See Hayami (1960) for presentation of preliminary results for the same countries.] They assumed that a meta-production function (the envelope of all known and potentially discoverable production activities) exists across countries at a given point in time and over time in a given country. They fitted a Cobb–Douglas type production function to average per farm data. Output was measured as gross (net of feed and seed), and the labor input was measured as the *number* of male workers active in agriculture. In the 1960 data (which seems to be better than for 1955 or 1965), they found a positive and statistically significant effect of the rural literacy rate and of agricultural technical education (graduates from agricultural education facilities at above the secondary level per farm worker) on farm output per worker. They concluded that about one-third of the difference in agricultural labor productivity across the 38 countries was due to differences in human capital (education).

In a related study, Kawagoe, Hayami and Ruttan (1985) expanded the set of countries to 43 (22 less developed) and focused on data for the years 1960, 1970, and 1980. They used the same methodology as Hayami and Ruttan (1970), but the education variables did not perform as well. Positive and significant effects of the literacy rate and agricultural technical education on farm output per worker were obtained from the data pooled across the three years for the less developed countries. For the developed countries, the two education variables did not perform well. This may be due to literacy rates having little variation across developing countries, and to agricultural college graduates frequently taking nonfarm employment rather than working on farms.

Craig et al. (1997) have attempted to push the labor productivity analysis further by expanding the number of countries to 98, making crude adjustments for input quality, and including proxies for rural infrastructure and agricultural research. Conventional agricultural labor is measured as the number of workers, i.e., the economically active agricultural population. No measure of work intensity, i.e., annual hours of work per worker, is included, but they included two labor quality measures, the literacy rate for the population over 15 years of age and life expectancy of the overall population at birth. They fitted a meta-Cobb–Douglas labor productivity equation, including the above adjustments, to the observations on 98 countries pooled over six observations per country (obtained by creating five-year averages from thirty years of annual data). Surprisingly, the coefficient of adult literacy is negative, and sometimes significant, in all reported regression equations. In contrast, the coefficient of life expectancy is positive and significant. The poor performance of literacy seems likely to be due to its very crude measure of schooling, perhaps failing to capture dimensions of schooling that affect production, and no adjustment for intensity of work.

The authors can be criticized for trying to stretch their inferences by including the USSR, Central European countries, and China. From both an economic and econometric perspective this seems highly questionable. First, over the study period, the choice of where and when to work, the range of choices available to farm managers or farmers, the availability of variable inputs, and the incentives to perform were very different in these centrally planned non-market economies than in the market-oriented largely free countries. Little evidence exists that centrally planned economies produced agricultural output at anything like cost-minimizing input combinations. Hence, the methodology applied by Craig et al. (1997) made an unnecessarily heterogeneous sample.

Overall, it seems that some dimension of schooling contributes to TFP or labor productivity, but the current evidence is mixed. In U.S. 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 at USDA, emphasizes effective units of labor, which is the product of agricultural labor quantity (days or hours) and an index of labor quality. 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 TFP 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 most likely to be due to data problems rather than to absence of real effects. Although the progress may be slow, this is an area where progress can be made.

2.5. *Household income*

In the first section, the three-period model has household utility derived from leisure and purchased consumption goods. In that model, household (net) cash income is spent on purchased consumption goods and on purchased inputs for human capital production. Within this model, the optimal life-cycle path of purchased consumption goods will be less concave than net cash income because of the incentive to invest early in human capital and to reduce consumption early and to raise it later in life [Ghez and Becker (1975)]. Furthermore, in both the three-period and single-period models of agricultural household resource allocation, cash income in each period is determined by the household's initial human capital endowment, past net investments in human capital, and current allocation decision for human capital services between leisure and work, farm production decisions, and wage rates and prices. Hence, these models imply that household cash income is *not* an *exogenous variable*, but rather a variable that is the result of current and past decisions of the household, given market wage rates and prices. Hence, household income should not be treated as an exogenous variable in econometric studies of consumption, labor supply, and welfare analyses.

This subsection will focus on the narrower issue of the impacts of education on incomes of agricultural workers and farm households. The impact of schooling on incomes of hired agricultural labor seems to be small in developed countries and insignificant in other countries. Emerson (1989) examined the earnings structure for migratory and nonmigratory work of 559 domestic males in a 1970 survey of Florida farm workers. In fitted annual earnings equations (adjusted for selection), he found a very small positive and significant effect of workers' schooling on earnings (1.4 percent per year for migrants and 1.6 percent per year for nonmigrants, holding weeks worked per year constant). He also found a quadratic effect of workers' experience on earnings. The coefficients for experience were about 50 percent larger for migrants than for nonmigrants. Furthermore, he found that these 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.

Ise and Perloff (1995) employed a hedonic wage equation and static labor supply model to examine the effects of an agricultural worker's legal status on wage earned and hours of work or labor supply. Legal status of a worker was hypothesized to be determined by an individual's demographic attributes. The model was fitted to a random sample of seasonal agricultural service workers from the National Agricultural Workers' Survey. They found that an individual being an English speaker and having more schooling increased the odds of having a preferred legal status. For seasonal agricultural service workers, work experience had a positive and significant effect on the hourly wage in all equations, except for workers having unauthorized status. However, a worker's education did not have a significant effect on the wage. In the labor supply equation for workers having Amnesty or Green Card status, additional schooling reduced significantly weekly hours of work. The authors concluded, not too surprisingly, that agricultural workers who work in the U.S. legally earned substantially more per hour and per week than those having unauthorized status. Thus, investing in obtaining a preferred legal status becomes another form of human capital with highly relevant cost-benefit calculations for potential immigrants and significant effects on workers' incomes.

The attributes of farm work, of farm workers, and employers affect the type of pay system used, e.g., time or piece rate. A piece-rate system is not workable in many circumstances, e.g., due to quality control or no easily defined output, but it is frequently the pay system for harvest labor. A piece-rate system is incentive pay for speedy work, a skill that seems likely to be unrelated to schooling. Rubin and Perloff (1993) examined workers' choice of pay system and hedonic wage equations for both pay systems in a small 1981 sample of harvest workers (in Tulare County, California).[7] The average schooling level for time-pay workers was 4.9 years, and for piece-rate pay workers, 4.1 years. They found that the probability of using/choosing the piece-rate system was strongly related to the age of the workers, where young and older workers who have unproven skills are more likely to choose the piece-rate pay system than are prime age workers, holding the expected pay differential constant. The lowest probability of piece-rate pay occurred for a 34-year old worker. In the hedonic wage equations, adjusted for sample selection, Rubin and Perloff (1993) found that *workers' schooling had a small positive* and statistically significant effect on the *time-rate of pay wage but not on the piece-rate wage*. Experience, proxied by age and age-squared, had a statistically significant effect on the wage rate in both pay systems, and the age at which the peak occurred was about 39 years. The coefficients were, however, larger by a factor of two for the piece-rate than for the time-rate system, suggesting more exaggerated effects of experience for the piece-rate than for the time-rate pay system. Hence, these results suggest that a worker's pay is not related to his or her schooling when the work is piece-rate, but the return is small when it is time-rate of pay.

In a developing country, transportation and communication are relatively expensive, schooling is minimal, and housing in a new location may be difficult to find. Hence,

[7] The authors, however, ignored the possibility that employers of agricultural workers are also making a decision about which pay system to offer. This could affect the results [Gibbons (1998)].

workers tend to be less geographically mobile than in the United States, and rural labor markets less integrated. Rosenzweig (1980) used data from a 1970–71 national sample of rural households in India to examine several labor issues, including hedonic wage equations for casual workers employed on a monthly or daily basis. In his sample, mean schooling of male and female landless workers was 1 year and 0.5 year, respectively. The wage equation (adjusted for selection) included individual and local village attributes, and separate equations were fitted for men and women. He found that schooling of males had a small positive (3.9 percent) and statistically significant effect on their wage, but schooling had no significant effect on the female wage. Also, potential experience (as represented by age, and age-squared) had no significant effect on male or female wage rates. Rosenzweig, however, concluded that human capital variables *were not significant predictors of the wage rate for casual labor* in India, and village attributes that affect local labor demand and supply were relatively important.

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.[8] In the third subsection, evidence was summarized showing that farmers' schooling increased farm profit in an environment where technology and relative prices are changing. 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 (1991b) provides an extensive survey and critique of agricultural household models that have proved useful for examining off-farm labor supply. In U.S. studies of off-farm work, a male farm operator's schooling increases his off-farm wage by 4 to 13 percent [see Sumner (1982), Jensen and Salant (1985), Gould and Saupe (1989), and Huffman and Lange (1989)]. The direct effect of a male operator's education on his off-farm hours, holding his wage constant, has sometimes been significant and positive [e.g., Huffman (1980), Lass and Gempesaw (1992)], and, when only the operator works off-farm, significant and negative [e.g., Jensen and Salant (1985)], and sometimes insignificant [e.g., Sumner (1982), Huffman and Lange (1989)]. Given that the wage elasticity of off-farm hours has been positive [an exception is Lass and Gempesaw (1992)], schooling of farm operators who work off-farm makes a positive contribution to household income in the United States.

The effects of schooling on off-farm income of farm households in developing countries may be different from those in the United States. In a 1970–1971 national sample

[8] The seemingly perverse effect of farmers' schooling on cost of milk production from the U.S. Department of Agriculture 1993 Farm Costs and Return Survey (see Short and McBride, 1996) seems most likely due to the way schooling is defined (as dichotomous rather than continuous variable) and the fact that ability or age of farmers is not controlled for. Before 1940, ability and schooling completion among rural youth were not positively correlated. With some selection on who chooses to operate a dairy enterprise, a seemingly positive relationship between schooling and cost should not be taken as evidence that schooling of dairy farmers is unproductive. A negative schooling effect on the cost of milk production does not show up in a study using later data (see El-Osta and Johnson 1998).

of rural households in India, Rosenzweig (1980) found that an individual's schooling and experience were relatively unimportant for explaining wage rates for *casual* labor. In his results for landholding households, schooling had a negative and generally significant effect on off-farm work days of both males and females. The implication was that farm households can better employ members with schooling on the farm than in the casual labor market. In the Philippines, Evenson (1978) found a positive and significant effect of a farm husband's market wage on his hours of wage work and implicitly on household income. For a 1990 sample of Chinese farm households, Yang (1997a) found that an individual's schooling and potential labor market experience have a positive and significant effect on the off-farm wage. He also found that the person in these households who had completed the most schooling was the off-farm work participant. In another study, Yang (1997b) showed that the person having the most schooling in these households also made the allocative decisions on the farm. Hence, schooling for one person in the Chinese farm households has positive effects on household incomes that come from farm and nonfarm effects.

Given that there are several channels through which education can affect farm household income, Huffman (1996a) fitted a reduced-farm household income equation to data for U.S. Current Population Survey married couple farm households, 1978–1982. He used as explanatory variables the following: husband's and wife's education, husband's age and race, family size, local labor market conditions, cost of living and locational amenity variables, and agricultural input and output prices and climate. He found that a husband's and wife's schooling had a significantly positive effect on farm household income. An added year of schooling for husbands increased household income by 1.3 percent, and for wives by about 1 percent.[9]

Overall, the review of the literature has shown 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 Indian 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 focused infrequently on the effects of education on household or family income.

[9] However, a similar model fitted to data for nonmetropolitan nonfarm household income gave estimated coefficients for husbands' and wives' schooling that were about 60 percent larger than for farm households. This model excluded agricultural prices and climate.

3. Summary and research gaps

Economists continue to search for a better understanding of the sources and causes of economic growth and development of regions and nations. Schultz (1988) concluded that a significant set of studies show strong empirical regularities between the educational attainment of a population and their productivity and performance in both market and nonmarket production activities. Furthermore, this chapter has shown that a now sizeable body of empirical evidence on the effects of education in agriculture has accumulated. In particular, the returns to education of farmers increases substantially as a country goes from traditional agriculture to modernizing, which itself becomes a continuing process. First, with modernizing, new technologies are becoming available and the economic environment is changing so that enhanced decision-making skills of farmers (and possibly other family members) are more productive. Second, when the productivity of agriculture increases, the aggregate demand for agricultural labor is reduced and the share of the labor force employed in agriculture declines and in other sectors increases. All currently developed countries have progressed from ones where a very large share of the labor force (over 75 percent) was employed in agriculture [Johnson (1997)], but with modernization of agriculture and economic development the share of the labor force in agriculture is less than 20 percent (and for the United States only 3 percent). There is accumulated empirical evidence that individuals' schooling plays a very important role in occupational choice (increasing the probability in developed countries of working outside of agriculture), migration (more educated individuals have greater geographic mobility out of rural areas), and part-time farming (the probability of off-farm work by those who remain in farming increases), which are all important in reallocating human resources among sectors in a growing and developing country, but could contribute to the remaining rural population having little education.

There is also accumulated evidence that education seems to be a poor private investment. First, in casual rural labor markets of low income countries, schooling (and experience) does not seem to affect wage rates. In urban labor markets of these countries, the returns to education are better. Second, in high income countries, schooling of field workers in fresh fruit and vegetable production has a very low return. Some fresh fruits and vegetables have large income elasticities of demand, and high quality fresh produce is possible only with hand harvesting. Thus, in the United States and some other developed countries, there is growth in the demand for relatively unschooled migratory farm labor to work on a piece-rate pay system. For the United States, this labor is supplied largely by legal and illegal immigrants from Mexico and Central America. Interestingly, the accumulated evidence shows that ethnic migration networks or social capital have been an effective substitute for migrants' own schooling in being successful in the U.S. low-skilled migratory labor market. Furthermore, an assumption that hired farm labor and farm operator (and family) labor are homogeneous in agricultural household models should be carefully scrutinized. In modernizing agriculture, the assumption is almost certainly dubious.

It is useful to think critically about the empirical evidence. Schultz (1988) emphasized that outcomes on educational attainment, occupation, location, labor force participation, and social-economic program participation are never random. This opens the door to nonrandom selection of comparison groups and potential sample-selection bias in parameter estimates of econometric models. Techniques have been developed for trying to offset sample selection bias, and they have been applied in many of the studies reviewed. These techniques are, however, imperfect, and researchers have discovered that identification problems sometimes arise in implementing selection correction procedures [see Nawata and Nagase (1996) and Heckman (1997)]. The identification problem creates another set of serious parameter biases. Researchers must continue to raise data quality issues, promote and pursue good experimental designs for new data sets, and pursue careful analysis where selectivity is likely to be serious.

In our empirical research, we use an individual's years of schooling as proxy for his or her education, but in the U.S. and in many other countries, the quality of this proxy has not been constant over time. Education is really general intellectual achievement (GIA), including developed abilities, e.g., reading, writing, doing mathematics, reasoning, and knowing important facts and principles of science, history, and art [Bishop (1989)]. These are skills essential for performing many job tasks, the tools for learning new tasks, and the foundations upon which much job-specific knowledge is built. The production of GIA is multi-factor: school attendance (years completed), quality of schooling, quantity and quality of out-of-school learning, the general socio-intellectual environment, innate ability, and other things.

Bishop (1989) summarizes how general intellectual achievement in the U.S. rose steadily from 1915 to about 1967. For twelfth (and eighth) graders, GIA went into a decline over 1967–1980, equaling 1.25 grade equivalents and a 2 grade equivalent deviation from trend. Since 1980, GIA of twelfth graders has been increasing again. Thus, what a year of schooling completed measures has not been constant over time nor does it have a linear trend. Hence, when individuals included in a survey have graduated from high school at different times, complex schooling vintage effects may exist, which complicate using years of schooling completed as a proxy for education in cross-sectional and panel studies, and in interpreting the impact of schooling on social-economic outcomes.

This information does suggest that a better estimate of the impact or return of a year of schooling can be obtained from U.S. micro-data by including as variables in a regression equation with an individual's years of schooling his or her year of graduation from high school (or grade school, if he or she is not a high school graduate) and a dichotomous variable for graduation after 1967. Given the incentive for individuals to obtain schooling at a young age and to graduate at approximately the same age, at least in developed countries, and that most surveys do not ask about year of high school (or elementary school) graduation, we can obtain almost the same information from an individual's age. Including as regressors an individual's age rather than date of graduation and a dichotomous variable for birth after 1950 contains approximately the same information as the two variables constructed from year of graduation. From the review in earlier sections, recall that human capital wage, labor supply, and adoption equations generally include an individual's age (and age squared) as regressors to take account of finite life or on-the-job training effects, but production, profit, and cost functions generally do not. Hence, estimates of impacts of schooling from the latter group might be suspect.[10]

The potential for endogenous or stochastic regressor bias in human capital research area is especially high. For example, in some of the off-farm participation and labor supply studies, farm characteristics like size (acres operated) and presence of a dairy enterprise are used as regressors. Our economic models of farm household decision making (for developed countries), however, imply that acres operated, presence of a dairy enterprise, and off-farm work participation are farmers' choices (and not exogenous or randomly assigned). Jointly determined variables are not legitimate regressors, even though they seem to have large explanatory power. Similar types of issues also arise with farmers' information acquisition and technology adoption and with variables to explain migration. The solution seems to be careful economic and econometric modeling of behavior and outcomes and using instrumental variables for regressors that may be stochastic because of endogeneity or serious measurement errors [Green (1997, pp. 435–443)].

Some research gaps or potentially fruitful research directions exist. First, skilled labor and (technologically enhanced) capital services seem to be complements in manufacturing. Agriculture in developed countries is relatively capital-intensive too, but except for farm operators' education, no good evidence exists on whether skilled labor and capital services are substitutes or complements. Also, empirical evidence is missing on the extent to which workers in agriculture are at a disadvantage (or advantage) compared to workers in other sectors for obtaining productivity gains from greater worker specialization, or whether potential productivity gains from specialization differ across crop and livestock enterprises. Some large-scale broiler, swine, cattle feed lot, and dairy operations seem to have production attributes much like manufacturing plants. A key difference between agriculture and other sectors might be differences in opportunities to increase labor productivity through larger investments in skill and specialization of workers. A closely related issue is how new biotechnology and information systems affect the demand for skilled labor in agriculture.

Second, although farmers' schooling and frequently extension have been shown to enhance successful adoption of new technologies in agriculture where heterogeneity of land and climate are important factors, a set of related management decisions has been largely ignored. They are the joint decisions on technology, information acquisition, and risk-bearing methods, and how farmers' schooling affects these choices. In most agricultural societies, a wide range of options exist for technologies, information, and risk-bearing, but models and empirical analyses have generally focused on only one of these outcomes. This limits our ability to learn about successful management strategies

[10] See Bishop (1989) for a methodology for constructing vintage of schooling effects in aggregate data.

that farmers use internationally as the technical and institutional environments change. It also limits our ability to learn about potentially important public-private substitution possibilities in providing information and risk-bearing instruments for farmers.

Third, general intellectual achievement of elementary and secondary school students is produced both through schooling and out-of-school activities, so the total decline over 1967 to 1980 in GIA cannot be attributed to a decline in the quality of schooling. Huffman (1998), however, summarizes some of the changes in the organization of U.S. schooling starting in the late 1960s that undoubtedly contributed significantly to the decline in general intellectual achievement of students. He and others have concluded that the last 50 years of schooling research provides a weak knowledge base for guiding schools and school administrators. Too little is known about the successful organization of schooling for efficient production of general intellectual achievement, and new rigorous research is needed.

Fourth, although it is widely accepted that schooling creates new skills that increase workers' productivity in market and nonmarket activities, relatively little empirical research has attempted to identify the effects of adults' schooling on total farm family income net of farm expenses. Farm families in most countries have significant nonfarm income, and cash income is used to purchase consumption goods/inputs, schooling, and health care. Empirical studies have largely focused on individual pieces of a much larger story, e.g., effects on farm gross output, farm profit (value added), off-farm wage rates, or off-farm work hours, but this misses some of the important trade-offs that exist. Although farm income is notorious for large measurement errors and although farm expenses in developed countries generally receive favorable tax treatment, these do not seem serious enough to prevent useful research. Given that governments generally invest in schooling, research, extension, commodity, and credit programs with some intention of increasing farm families' income, it is interesting to ask which of them have been successful. Although Gardner (1992) concluded that there is no empirical evidence in the literature that U.S. government farm program payments have increased net farm income, it is important for future research to estimate and compare the impacts of these government policies on farm family income.

Overall, this chapter has summarized the impacts of education in agriculture for several different environments – e.g., developing country, transition economy, developed country, technically dynamic, and technically static – and concluded that the impacts are positive in some but not all environments. It remains somewhat of a puzzle, however, why schooling in developed countries does not have broader direct impacts in agriculture. One hypothesis is that the dominance of agriculture by biological production processes which are controlled largely by climate and are land surface-area intensive, at least for crop production, greatly limits the potential for raising labor productivity through skill acquisition and specialization of labor that is possible in the non-farm sector. After reviewing the extensive literature cited in this chapter, one should not miss the fact that the dominant effect of education in agriculture of developed countries is to aid and assist farm people with education make the transition to nonfarm work and ultimately to full-time nonfarm occupations. This process has important implications for the composition of the population left behind in agriculture and on the optimal financing of schooling in rural areas.

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References

Abdulai, A., and C.L. Delgado (1999), "Determinants of nonfarm earnings of farm-based husbands and wives in Northern Ghana", American Journal of Agricultural Economics 81(February):117–130.

Abdulai, A., and W.E. Huffman (1999), "Structural adjustment and economic efficiency of rice farmers in Northern Ghana", Economic Development and Cultural Change (forthcoming).

Antle, J.M., and S.M. Capalbo (1988), "An introduction to recent developments in productivity theory and productivity measurement", in: S.M. Capalbo and J.M. Antle, eds., Agricultural Productivity: Measurement and Explanation (Resources for the Future, Washington, DC) 17–95.

Antle, J.M., and P.L. Pingali (1994), "Pesticides, productivity, and farmer health: A Philippine case study", American Journal of Agricultural Economics 76:418–430.

Ball, V.E. (1985), "Output, input, and productivity measurement in U.S. agriculture, 1948–1979", American Journal of Agricultural Economics 67:475–486.

Ball, V.E., J.-C. Bureau, R. Nehring and A. Somwaru (1997), "Agricultural productivity revisited", American Journal of Agricultural Economics 79:1045–1063.

Barkley, A.P. (1990), "The determinants of the migration of labor out of agriculture in the United States, 1940–85", American Journal of Agricultural Economics 72:567–573.

Barro, R., and J.-W. Lee (1993), "International comparisons of educational attainment", Journal of Monetary Economics 32:363–394.

Becker, G.S. (1993), Human Capital, 3rd edn. (The University of Chicago Press, Chicago, IL).

Becker, G.S., and K.M. Murphy (1993), "The division of labor, coordination costs, and knowledge" in: G.S. Becker, Human Capital, 3rd edn (The University of Chicago Press, Chicago, IL) 299–322.

Belbase, K., and R. Grabowski (1985), "Technical efficiency in Nepalese agriculture", Journal of Development Areas 19:515–526.

Benjamin, D. (1992), "Household composition, labor markets, and labor demand: Testing for separation in agricultural household models", Econometrica 60:287–322.

Ben-Porath, Y. (1967), "The production of human capital and the life cycle of earnings", Journal of Political Economy 75:352–365.

Besley, T., and A. Case (1993), "Modeling technology adoption in developing countries", American Economic Review 83:396–402.

Bindlish, V., and R.E. Evenson (1997), "The impact of T&V extension in Africa: The experience on Kenya and Burkina Faso", The World Bank Observer 12:183–201.

Birkhaeuser, D., R.E. Evenson and G. Feder (1991), "The economic impact of agricultural extension: A review", Economic Development and Cultural Change 39:607–650.

Bishop, J. (1989), "Is the test score decline responsible for the productivity growth decline?", American Economic Review 79(February):178–197.

Bollman, R.D. (1979), Off-Farm Work by Farmers, Catalogue No. 99-756 (Statistics Canada, Ottawa, Canada).

Bravo-Ureta, B.E., and R.E. Evenson (1994), "Efficiency in agricultural production: The case of peasant farmers in Eastern Paraguay", Agricultural Economics 10:27–37.

Bravo-Ureta, B.E., and A.E. Pinherio (1993), "Efficiency analysis of developing country agriculture: A review of the frontier function literature", Agricultural and Resource Economics Review 22:88–101.

Bryant, W.K. (1986), "Technical change and the family: An initial foray", in: R. Deacon and W.E. Huffman, eds., Human Resources Research, 1887–1987 (College of Home Economics, Iowa State University) 117–126.

Capalbo, S.M., and M.G.S. Denny (1986), "Testing long-run productivity models for the Canadian and U.S. agricultural sectors", American Journal of Agricultural Economics 68:615–625.

Chavas, J.-P., and T.L. Cox (1992), "A nonparametric analysis of the influence of research on agricultural productivity", American Journal of Agricultural Economics 74:583–591.

Craig, B.J., P.G. Pardey and J. Roseboom (1997), "International productivity patterns: Accounting for input quality, infrastructure, and research", American Journal of Agricultural Economics 79:1064–1076.

Denison, E.F. (1962), The Sources of Economic Growth in the United States and the Alternatives Before Us (Committee for Economic Development, New York, NY).

Dhakal, D., R. Grabowski and K. Belbase (1987), "The effect of education in Nepal's traditional agriculture", Economics of Education Review 6:27–34.

Easter, K.W., M.E. Abel and G. Norton (1977), "Regional differences in agricultural productivity in selected areas of India", American Journai of Agricultural Economics 59:257–265.

El-Osta, H., and J.D. Johnson (1998), "Determinants of financiai performance of commercial dairy farms", Technical Bulletin No. 1859, July, USDA, ERS.

Emerson, R.D., ed. (1984), Seasonal Agricultural Labor Markets in the United States (Iowa State University Press, Ames, IA).

Emerson, R.D. (1989), "Migratory labor and agriculture", American Journal of Agricultural Economics 71:617–629.

Evenson, R.E. (1978), "Time allocation in rural Philippine households", American Journal of Agricultural Economics 60:322–330.

Evenson, R.E., and G. Mwabu (1997), "The effects of agricultural extension on farm yields in Kenya" (Economic Growth Center, Yale University).

Fane, G. (1975), "Education and the managerial efficiency of farmers", Review of Economics and Statistics 57:452–461.

Feder, G., R.E. Just and D. Zilberman (1985), "Adoption of agricultural innovations in developing countries: A survey", Economic Development and Cultural Change 33:255–298.

Fleisher, B.M., and Y. Liu (1992), "Economies of scale, plot size, human capital, and productivity in Chinese agriculture", Quarterly Review of Economics and Finance 32:112–123.

Flinn, J.C., and M. Ali (1986), "Technical efficiency in Basmati rice production", Pakistan Journal of Applied Economics 5:63–79.

Foster, A.D., and M.R. Rosenzweig (1995), "Learning by doing and learning from others: Human capital and technical change in agriculture", Journal of Political Economy 103:1176–1209.

Foster, A.D., and M.R. Rosenzweig (1996), "Technical change and human-capital returns and investments: Evidence from the Green Revolution", The American Economic Review 86:931–953.

Gabbard, S.M., and R. Mines (1995), "Farm worker demographics: Pre-IRCA and post-IRCA field workers", in: P.L. Martin et al., eds., Immigration Reform and U.S. Agriculture, Publ. 3358 (University of California, Division of Agriculture and Natural Resources, Oakland, CA) 63–72.

Gardner, B.L. (1992), "Changing economic perspective on the farm problem", Journal of Economic Literature 30:62–101.

Ghez, G.R., and G.S. Becker (1975), The Allocation of Time and Goods over the Life Cycle (Columbia University Press for the National Bureau of Economic Research, New York).

Gibbons, R. (1998), "Incentives in organizations", Journal of Economic Perspective, 12(Fall):115–132.

Goetz, S.J., and D.L. Debertin (1996), "Rural population decline in the 1980s: Impacts of farm structure and federal farm programs", American Journal of Agricultural Economics 78:517–529.

Goldin, C. (1998), "America's graduation from high school: The evolution and spread of secondary schooling in the twentieth century", Journal of Economic History 58(June):345–373.
Goldin, C., and L.F. Katz (1999a), "Education and income in the early 20th century: Evidence from the Prairies, 1915 to 1950" (Harvard University).
Goldin, C., and L.F. Katz (1999b), "Human capital and social capital: The rise of secondary schooling in America, 1910–1940", Journal of Interdisciplinary History 29(Winter):683–723.
Gould, B.W., and W.E. Saupe (1989), "Off-farm labor market entry and exit", American Journal of Agricultural Economics 71:960–969.
Green, W.H. (1997), Econometric Analysis, 3rd edn. (Prentice-Hall, Upper Saddle River, NJ).
Griliches, Z. (1963a), "Estimates of the aggregate agricultural production function from cross sectional data", Journal of Farm Economics 45:419–428.
Griliches, Z. (1963b), "The source of measured productivity growth: United States agriculture, 1940–1960", Journal of Political Economy 71:331–346.
Griliches, Z. (1964), "Research expenditures, education, and the aggregate agricultural production function", American Economic Review 54:961–974.
Griliches, Z. (1969), "Capital-skill complementarity", The Review of Economics and Statistics 51:465–468.
Griliches, Z. (1970), "Notes on the role of education in production functions and growth accounting", in: W.L. Hansen, ed., Education, Income and Human Capital. Studies in Income and Wealth, NBER, Vol. 35 (Columbia University Press, New York, NY).
Hallberg, M.C., J.L. Findeis and D.A. Lass (1991), Multiple Job-Holding Among Farm Families (Iowa State University Press, Ames, IA).
Hayami, Y. (1960), "Sources of agricultural productivity gap among selected countries", American Journal of Agricultural Economics 51:564–575.
Hayami, Y., and V.W. Ruttan (1970), "Agricultural productivity differences among countries", The American Economic Review 60:895–911.
Hayami, Y., and V.W. Ruttan (1985), Agricultural Development: An International Perspective (The Johns Hopkins University Press, Baltimore, MD).
Heady, E.O., and J.L. Dillon (1961), Agricultural Production Functions (Iowa State University Press, Ames, IA).
Heckman, J. (1997), "Instrumental variables: A study of implicit behavioral assumptions used in making program evaluations", Journal of Human Resources 32:441–462.
Huang, T.-L., P.F. Orazem and D. Wohlgemuth (2001), "Rural population growth, 1950–1990: The roles of human capital, industry structure and government policy", American Journal of Agricultural Economics, forthcoming.
Huffman, W.E. (1974), "Decision making: The role of education", American Journal of Agricultural Economics 56:85–97.
Huffman, W.E. (1976a), "Productive value of human time in U.S. agriculture", American Journal of Agricultural Economics 58:672–683.
Huffman, W.E. (1976b), "The value of the productive time of farm wives: Iowa, North Carolina and Oklahoma", American Journal of Agricultural Economics 58:836–841.
Huffman, W.E. (1977), "Allocative efficiency: The role of human capital", Quarterly Journal of Economics 91:59–80.
Huffman, W.E. (1980), "Farm and off-farm work decisions: The role of human capital", Review of Economics and Statistics 62:14–23.
Huffman, W.E. (1981), "Black-white human capital differences: Impact on agricultural productivity in the U.S. south", American Economic Review 71:94–107.
Huffman, W.E. (1985), "Human capital, adaptive ability, and the distributional implications of agricultural policy", American Journal of Agricultural Economics 67:429–434.
Huffman, W.E. (1991a), "Human capital for future economic growth", in: G.L. Johnson and J.T. Bonnen, eds., Social Science Agricultural Agendas and Strategies. Part III (Michigan State University Press, East Lansing, MI) 61–67.

Huffman, W.E. (1991b), "Agricultural household models: Survey and critique", in: M.C. Hallberg, J.L. Findeis and D.L. Lass, eds., Multiple Job-Holding Among Farm Families (Iowa State University Press, Ames, IA) 79–111.

Huffman, W.E. (1996a), "Labor markets, human capital, and the human agent's share of production", in: J.M. Antle and D.A. Sumner, eds., The Economics of Agriculture, Vol. 2, Papers in Honor of D. Gale Johnson (The University of Chicago Press, Chicago, IL) 55–79.

Huffman, W.E. (1996b), "Farm labor: Key conceptual and measurement issues on the route to better farm cost and return estimates", Staff Paper No. 280 (Department of Economics, Iowa State University).

Huffman, W.E. (1998),"Modernizing agriculture: A continuing process", Daedalus 127(Fall):159–186.

Huffman, W.E., and R. Evenson (1989), "Supply and demand functions for multiproduct U.S. cash grain farms: Biases caused by research and other policies", American Journal of Agricultural Economics 71:761–773.

Huffman, W.E., and R. Evenson (1993), Science for Agriculture (Iowa State Press, Ames, IA).

Huffman, W.E., and T. Feridhanusetyawan (2001), "Migration, fixed costs, and location-specific amenities: A hazard rate analysis" (Department of Economics, lowa State University, Staff Paper No. 340).

Huffman, W.E., and M.D. Lange (1989), "Off-farm work decisions of husbands and wives: Joint decision making", Review of Economic and Statistics 71:471–480.

Huffman, W.E., and S. Mercier (1991), "Joint adoption of micro computer technologies: An analysis of farmers' decision", Review of Economics and Statistics 73:541–546.

Ise, S., and J.M. Perloff (1995), "Legal status and earnings of agricultural workers", American Journal of Agricultural Economics 77:375–386.

Jacoby, H. (1993), "Shadow wages and peasant family labor supply: An econometric application to the Peruvian sierra", Review of Economic Studies 60:903–921.

Jamison, D.T., and L.I. Lau (1982), Farmer Education and Farm Efficiency (Johns Hopkins University Press, Baltimore, MD).

Jensen, H.H., and P. Salant (1985), "The role of fringe benefits in operator off-farm labor supply", American Journal of Agricultural Economics 67:1095–1099.

Johnson, D.G. (1997), "Agriculture and the wealth of nations", Richard T. Ely lecture, American Economic Review 87:1–12.

Jones, C.I. (1998), Introduction to Economic Growth (Norton, New York, NY).

Jorgenson, D.W., and F.M. Gollop (1992), "Productivity growth in U.S. agriculture: A postwar perspective", American Journal of Agricultural Economics 74:745–750.

Kawagoe, T., Y. Hayami and V.W. Ruttan (1985), "The intercountry agricultural production function and productivity differences among countries", Journal of Development Economics 19:113–132.

Kendrick, J.W. (1961), Productivity Trends in the United States (Princeton University Press, Princeton, NJ).

Khaldi, N. (1975), "Education and allocative efficiency in U.S. agriculture", American Journal of Agricultural Economics 57:650–657.

Kimhi, A. (1994), "Quasi maximum likelihood estimation of multivariate probit models: Farm couples' labor participation", American Journal of Agricultural Economics 76:828–835.

Kimhi, A., and M.-J. Lee (1996), "Off farm and work decisions of farm couples: Estimating structural simultaneous equations with ordered categorical dependent variables", American Journal of Agricultural Economics 78:687–698.

Klotz, C., A. Saha and L.J. Butler (1995), "The role of information in technology adoption: The case of rbST in the California Dairy industry", Review of Agricultural Economics 176(Fall/Winter):287–298.

Lass, D.A., J.L. Findeis and M.C. Hallberg (1989), "Off-farm employment decision by Massachusetts farm households", Northeastern Journal of Agricultural and Resource Economics 18:149–159.

Lass, D.A., and C.M. Gempesaw II (1992), "The supply of off-farm labor: A random coefficients approach", American Journal of Agricultural Economics 74:400–411.

Lin, J.Y. (1991), "Education and innovation adoption in agriculture: Evidence from hybrid rice in China", American Journal of Agricultural Economics 73:713–723.

Lin, J.Y. (1995), "Endowments, technology, and factor markets: A natural experiment of induced institutional innovation from China's rural reform", American Journal of Agricultural Economics 77:231–242.

Martin, P.L., W.E. Huffman, R.D. Emerson, J.E. Taylor and R. Rockin, eds. (1995), Immigration Reform and U.S. Agriculture, Publ. 3358 (Division of Agriculture and Natural Resources, University of California, Oakland, CA).

Mincer, J. (1974), Schooling, Experience, and Earnings (Columbia University Press for the National Bureau of Economic Research, New York, NY).

Nawata, K., and N. Nagase (1996), "Estimation of sample selection bias models", Econometric Review 15:387–400.

Newey, W.K., J.L. Powell and J.R. Walker (1990), "Semiparameter estimation of selection models: Some empirical results", American Economic Review 80:324–328.

OECD (1995), Technological Change and Structural Change in OECD Agriculture (OECD, Paris).

Olson, M. (1969), "The principle of fiscal equivalence: The division of responsibilities among different levels of government", American Economic Review 59(May):479–487.

Olson, M. (1986), "Toward a more general theory of government structure", American Economic Review 76(May):120–125.

Orazem, P.F., A. Hallam and E.M. Paterno (1997), "Capital deepening, biased technical change and earnings inequality: A re-examination of the Griliches hypothesis", paper (Department of Economics, Iowa State University).

Orazem, P.F., and J.P. Mattila (1991), "Human capital, uncertain wage distribution, and occupational and educational choice", International Economic Review 32:103–122.

Perloff, J. (1991), "The impact of wage differentials on choosing to work in agriculture", American Journal of Agricultural Economics 73:671–680.

Perloff, J.M., L. Lynch and S. Gabbard (1998), "Migration of seasonal agricultural workers", American Journal of Agricultural Economics 80:154–164.

Pitt, M.M., and G. Sumodiningrat (1991), "Risk, schooling and the choice of seed technology in developing countries: A meta-profit function approach", International Economic Review 32:457–473.

Pudasaini, S.P. (1983), "The effects of education in agriculture: Evidence from Nepal", American Journal of Agricultural Economics 65:509–515.

Putler, D.S., and D. Zilberman (1988), "Computer use in agriculture: Evidence from Tulare County, California", American Journal of Agricultural Economics 70:790–802.

Rahm, M.R., and W.E. Huffman (1984), "The adoption of reduced tillage: The role of human capital and other variables", American Journal of Agricultural Economics 66:405–413.

Romer, P. (1990), "Endogenous technological change", Journal of Political Economics 98:S71–S102.

Rosegrant, M.W., and R.E. Evenson (1993), "Agricultural productivity growth in Pakistan and India: A comparative analysis", The Pakistan Development Review 32:433–451.

Rosenzweig, M. (1980), "Neoclassical theory and the optimizing peasant: An econometric analysis of market family labor in a developing economy", Quarterly Journal of Economics 94(February):31–56.

Rubin, D.K., and J.M. Perloff (1993), "Who works for piece rate and why", American Journal of Agricultural Economics 75:1036–1043.

Schultz, T.P. (1988), "Education investments and returns", in: H. Chenery and T.N. Srinivasau, eds., Handbook of Development Economics, Vol. 1 (North-Holland, Amsterdam, Netherlands) 543–630.

Schultz, T.W. (1953), The Economic Organization of Agriculture (McGraw-Hill, New York, NY).

Schultz, T.W. (1963), The Economic Value of Education (Columbia University Press, New York, NY).

Schultz, T.W. (1964), Transforming Traditional Agriculture (Yale University Press, New Haven, CT). Reprint edition (Arno Press, New York, 1976).

Schultz, T.W. (1975), "The value of the ability to deal with disequilibria", Journal of Economic Literature 13:827–846.

Schultz, T.W. (1978), "On economics and politics of agriculture", in: T.W. Schultz, ed., Distortions of Agricultural Incentives (Indiana University Press, Bloomington, IN).

Short, S.O., and W.D. McBride (1996), "U.S. milk production costs and returns, 1993", Agricultural Information Report No. 732, May, USDA, ERS.
Shumway, C.R. (1983), "Supply, demand, and technology in a multiproduct industry: Texas field crops", American Journal of Agricultural Economics 65:748–760.
Singh, I., L. Squire and J. Strauss (1986), Agricultural Household Models: Extensions, Applications and Policy (Johns Hopkins Press, Baltimore, MD).
Soule, M.J., A. Tegene and K.D. Wiebe (1999), "Land tenure and the adoption of conservation practices", Resource Economics Division, March, USDA, ERS.
Strauss, J., M. Barbosa, S. Teixeira, D. Thomas and R.G. Junior (1991), "Role of education and extension in the adoption of technology: A study of upland rice and soybean farmers in Central-West Brazil", Agricultural Economics 5:341–359.
Sumner, D.A. (1982), "The off-farm labor supply of farmers", American Journal of Agricultural Economics 64:499–509.
Taylor, J.E. (1986), "Differential migration networks, information and risk", in: O. Stark, ed., Migration, Human Capital and Development (JAI Press, Greenwich, CT).
Taylor, J.E. (1987), "Undocumented Mexico–U.S. migration and the returns to households in rural Mexico", American Journal of Agricultural Economics 69:626–638.
Tokle, J.G., and W.E. Huffman (1991), "Local economic conditions and wage labor decisions of farm and rural nonfarm couples", American Journal of Agricultural Economics 73:652–670.
Weaver, R.D. (1983), "Multiple input, multiple output production choices and technology in the U.S. wheat region", American Journal of Agricultural Economics 65:45–46.
Welch, F. (1970), "Education in production", Journal of Political Economy 78:35–59.
Williamson, O. (1985), The Economic Institution of Capitalism (The Free Press, New York, NY).
Willis, R. (1986), "Wage determination: A survey and reinterpretation of human capital earnings functions", in: O. Ashenfelter and R. Layard, eds., Handbook of Labor Economics, Vol. I (North Holland, New York, NY) 525–602.
World Bank (1997), World Development Report, 1997 (Oxford University Press, New York, NY).
World Resources Institute (1992), World Resources, 1992–93 (Oxford University Press, New York, NY).
Wozniak, G.D. (1984), "The adoption of interrelated innovations: A human capital approach", The Review of Economics and Statistics 66:70–79.
Wozniak, G. (1993), "Joint information acquisition and new technology adoption: Later versus early adoption", Review of Economics and Statistics 75:438–445.
Yang, D.T. (1997a), "Education and off-farm work", Economic Development and Cultural Change 45:613–632.
Yang, D.T. (1997b), "Education in production: Measuring labor quality and management", American Journal of Agricultural Economics 79(August):764–772.

Chapter 8

WOMEN'S ROLES IN THE AGRICULTURAL HOUSEHOLD: BARGAINING AND HUMAN CAPITAL INVESTMENTS

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Contents

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Abstract

Three themes are related to women's economic roles in the agricultural household. First the unified family as coordinator of production and consumption over a life cycle. Second the role of separability of production and consumption decisions in the agricultural household that depends on the equivalence of hired and of family labor. Third Nash-bargaining or Pareto efficient collective coordination in the family. Increases in women's human capital affects gender bargaining and is closely related to declines in child mortality, fertility, and population growth, and increases in child "quality" as proxied by child schooling and health status.

JEL classification: Q12

1. Introdnction

This chapter takes stock of the methods and empirical findings from economic analyses of women's contribution to social welfare and the determinants of their well-being. To account for women's roles in the agricultural household, economic research has been greatly affected by three steps in the general analysis of the family in the last thirty years. First is the conceptualization of the unified family as a coordinator of the production and consumption of a group of persons over an extended period of the life cycle, with the household production of consumption commodities for family use constrained by the pool of household endowments including time, market prices, and knowledge of home production possibilities [Becker (1965, 1981)]. Second is the role of separability of production and consumption decisions in the agricultural household, which depends on the perfect substitutability of hired and family labor and the adequacy of factor markets [Barnum and Squire (1979); Singh et al. (1986)]. Third is the introduction of individualistic bargaining or collective coordination of the family that preserves the distinct endowments of the individual and the expression of possible differences in personal preferences [McElroy and Horney (1981); Chiappori (1988); Lundberg and Pollak (1993)]. This third innovation has relaxed the unified family model in different ways, and is still being extended and adapted to new problems or forms of game theory and econometrics. It has already been used to guide penetrating empirical studies of the intrahousehold allocation of resources, and much further work is currently underway.

The chapter also explores how gender differentials in various forms of human capital arise, are sustained, and affect social welfare in different cultural regions of the world. Although much of this literature has focused on agricultural households in low income countries, many features of the field are not unique to agriculture, though occasionally issues emerge that are based in the agricultural sciences: effects of crop mix and management for the derived demand for male or female labor, the adoption of new technologies in agriculture, the degradation of the environment due to overused common resources, seasonality, weather as an observable source of risk, etc. One problem area in interpreting existing evidence in this field is the variation in the composition of families, by which I mean both fertility and the extension of nuclear families to absorb other generations and relatives. The consumption, savings, and poverty literatures often mechanically normalize away the variation in household composition, or condition on this composition as though it were an exogenous constraint, when it is widely believed that marriage, fertility, and family extension are choices that respond to the conventional economic variables of prices, sources of income, and personal endowments. The growing numerical importance of female-headed households in many parts of the world, and even the differential survival of existing members of the household, are shown to be responsive to the relative costs and benefits of different family arrangements and compositions.

Changes in women's earning power compared to men's and children's affect what the family specializes in and what other institutions in society, such as firms and government, do. Functions where the family retains a comparative advantage may also be performed with a changing mix of labor and capital in response to the evolution of the wage structure. The secular convergence in productive capacity of men and women is a notable development of this century. This narrowing of the gender gap in labor productivity is closely associated with the narrowing of the difference between male and female adult schooling, and is modified by the improved health and longevity of females compared to males [Schultz (1995a)]. Fertility, mortality, and rural-urban migration determine population growth in the agricultural and nonagricultural sectors, and all of these demographic processes have been shown to respond to the economic productivity of adult males and females, at the household and aggregate levels. Thus, the evolving gender differences in human capital provide the best available explanation for world patterns of demographic transition, interregional migration, and changes in women's participation in the labor force outside of the family [Schultz (1981)]. Yet we have only a poor understanding of what has propelled the advance of women's human capital in different settings throughout the world. Why have women been left at a substantial disadvantage to their male folk in broad parts of South and West Asia and sub-Saharan Africa, and what will be the economic consequences on women's roles, population growth, and economic development?

This chapter is structured as follows. Sections 2 reviews the alternative theoretical approaches to modeling the determinants of individual and family resource allocations and their relevance to the welfare and productivity of women. Section 3 summarizes the empirical evidence on how family allocations respond to changes in the endowments of husband and wife and other features of the family environment. Section 4 examines two attributes of family composition that have received considerable attention: the increased frequency of female-headed households and the gender differentials in child survival that may be related to women's productive roles in society. Section 5 examines the problems of estimating the productivity of women compared with men using either wage functions or production functions, and the general policy implications of the social externalities associated with increasing the schooling of females. Section 6 concludes by reviewing progress made and the challenges that lie ahead in this field.

2. Models of individual and family economic behavior

2.1. Individual consumer demands or expenditure systems

Simple models of consumer demand in a single period generally assume that the consumer receives (exogenously) a disposable income (I) for a reference period such as a year, knows the prices of market goods (P_1, P_2), and then selects a combination of goods (X_1, X_2) to maximize individual utility:

$$U = U(X_1, X_2), \tag{1}$$

subject to the income constraint:

$$I = P_1X_1 + P_2X_2. \tag{2}$$

The decision of how much time to work at a market-determined wage (w) is then incorporated into the consumer's optimization problem by adding leisure (L) to the individual's utility function:

$$U = U(X_1, X_2, L), \tag{3}$$

and a single-period time constraint:

$$T = L + H,$$

where T is assumed to be the total time available for all persons in the reference period and H is the hours worked in the wage market. Market income then becomes the sum of (exogenous) nonearned income (V) and market wage income where the wage is assumed independent of hours worked:

$$I = V + Hw = P_1X_1 + P_2X_2. \tag{4}$$

The concept of full income (F) introduced by Becker (1965) is the potential income the individual could obtain by allocating all of his or her time to wage work:

$$F = V + Tw = P_1X_1 + P_2X_2 + Lw. \tag{5}$$

The equilibrium conditions from maximizing the utility function (3) with respect to the full income constraint (5) include:

$$MU_L/MU_{X_i} = w/P_i, \quad i = 1, 2. \tag{6}$$

The ratio of the marginal utility of time as leisure to the marginal utility of either good is equal to the ratio of the market wage to the good's price. If, however, the individual spends all of her time in nonmarket activities, called here simply leisure, then the shadow price of leisure (MU_L) presumably exceeds the market wage offer.

If the commodity or service that enters the utility function of the individual is purchased in the market in the form in which it is consumed, such as bread, the above model may be satisfactory. But if, alternatively, the commodity or service providing the welfare to the individual is produced in the home with market inputs (i_h) and own time (t_h), such as might be expected with health, human capital, or children, home production functions (H) might be assumed to describe these technological and biological possibilities:

$$H = H(i_h, t_h, e), \tag{7}$$

where e is an individual-specific endowment that increases the home output but is not controlled by the individual, and this form of heterogeneity is generally unobserved by the researcher and may affect the productivity of the other inputs and time used in this and other home production processes.

This intermediate layer of home production functions, introduced between market goods and the commodities from which utility is derived, allows the economist to consider substitution possibilities that the home producer may consider in optimizing home production [Becker (1965, 1981)]. The individual or family can now adjust consumer/producer behavior to exogenous changes in market prices, wages, and nonearned income along two dimensions: they can adjust the composition of what they ultimately consume, including leisure, and they can also modify how these home-produced commodities are produced at least cost, through changes in their input factor proportions, as would a market-oriented firm.

Home production functions are more difficult to estimate than production functions that describe technical relationships determining how goods are produced for exchange in the market. This is partly because the output of home production is generally not sold or quantified, and thus the shadow value of such a nontraded commodity may differ across households. For example, the shadow value of a child to one mother may not be the same as to another, because there is no relevant market, and individual preferences (and fecundity) will vary.

In many types of home production, such as the formation of human capital in children, productive endowments of the individual influence input productivity and therefore possibly influence parent allocation of inputs across family members. If these innate endowments are not observed by the researcher, as denoted by e in (7), direct estimation of the marginal productivity of home inputs by regressing H on I and t are likely to yield biased indications of their technological contribution or productivity because the input e is omitted from the estimated home production function. For example, Becker hypothesizes that "ability" of a child increases the private rate of return to schooling a child [Becker (1967, 1981); Becker and Tomes (1979)]. If parents then allocate more schooling to their more able children, the direct association between schooling and productivity of the children would overstate the returns to schooling, other things being equal [Griliches (1977)]. In attempting to estimate the home production function (7), the relationship among observable inputs and outputs will tend to be biased by any correlation between the individual endowment and the observed market and time inputs, which violates the standard estimation assumption that the inputs are independent of the disturbance in the output equation. In household production of children and health human capital, variation in the biological endowments of the couple and children can be of substantial importance. The technical marginal product of inputs can then be seriously misunderstood [Rosenzweig and Schultz (1983); Schultz (1984)]. A parallel problem arises in attempting to estimate the effectiveness of contraception on controlling fertility, when the choice of birth control is informed by the couple's partial knowledge of their fecundity or likelihood of conception given their observed input behavior [Rosenzweig and Schultz (1985, 1989)].

2.2. *Multiperson agricultural family and household demands*

Issues of allocation and decision-making become more complicated when more than one individual is involved. In reality individuals will differ in their preferences for goods and services and what they can contribute to the welfare of the group. Most of the research on households and the family has been based on the convenient working assumption that families or coresidential groups have identical preferences or one individual dominates the allocation process and consults his, or her, preferences in determining an optimal solution. As a consequence, a stable scheme for the ordering of alternatives is arrived at for the group. In other words, the group is treated as if it were an individual. Because the members of families and households tend to differ in their productive capacities and personalities, as they do in sex and age, households are not likely to be made up of identical individuals. That leaves us with the "dominant dictator" model as the remaining, least implausible, conceptual foundation for the unified family/household decision-making unit. In the next two sections of this paper some alternative approaches for treating the conflicting interests of family members are reviewed and their distinct and testable empirical predictions explored.

These non-unified approaches to household decision-making build on an explicit or implicit bargaining process taking place within the family; they assume either that information is shared symmetrically between cooperative individuals, which then tends to lead to allocations which are Pareto efficient, or that private information is not shared and is hence asymmetrical, with this failure of coordination leading to inefficient allocations across the household members. This is an area of recent methodological progress and an active focus for the new empirical research on family behavior [e.g., Haddad et al. (1997)]. It is accordingly emphasized in this chapter, but two things should be recalled. First the unified household model of Becker (1965, 1981) provided a fruitful general framework to guide research on the division of labor within the family, and the main conclusions drawn in that literature have not yet been called into question by the newer alternative approaches for interpreting family behavior. The exception may prove to be West Africa, where individuals privately manage their own agricultural plots with limited coordination or pooling of resources at the household or family levels [Jones (1983, 1986); Udry (1996)]. Even in this instance, subsequent samples from neighboring regions do not confirm that Burkina families fail the test of Pareto efficiency in their allocation of labor by plot [Akresh (1999)]. Second, documented differences in consumption among persons in the household or family can be interpreted as suboptimal only after researchers specify criteria for optimality [Haddad and Kanbur (1990)], such as calorie distribution between persons within the household. But in this case of calories, for example, the "needs" of individuals may actually be endogenous, to the extent that they vary by the choice of type and amount of work engaged in by individual family members [e.g., Pitt et al. (1990); Higgin and Alderman (1997)] or due to sources of unobserved heterogeneity, such as morbidity and weight. Evidence is only beginning to amass that the error introduced by neglecting intra-household bargaining changes important policy conclusions or alters preferred agricultural development strategies, although the reach of these new approaches to family decision-making is only beginning to be explored [Strauss and Beegle (1996)].

A second significant feature of the agricultural family is the combined functions it performs of producing agricultural output and coordinating consumption and labor supply of its members [Barnum and Squire (1979); Singh et al. (1986)]. It is commonly assumed in such an agricultural model of the family that hired and family labor are identical in production, and that the labor market is perfect in providing the family with both a source of jobs for any excess supply of family workers it may have beyond the profit-maximizing labor demand on its own farm, and a source of hired labor for any shortage of family labor to meet its farm's production requirements. This assumption of separability allows the optimization problem facing the agricultural family to be solved in a two-step process. First, farm outputs and inputs are determined to maximize farm profit. Second, the family maximizes its unified utility to determine how much family labor supply is allocated to farm and off-farm activities, and how much labor is residually hired to satisfy farm labor input requirements [Barnum and Squire (1979); Singh et al. (1986); Pitt and Rosenzweig (1986); Benjamin (1992); Maluccio (1997); DeSilva (1997)]. Without this form of complete and competitive factor market for family and hired labor, the production and consumption decisions would have to be made jointly and they could yield different results from those arrived at by the simpler two-step process. Testing explicitly for this form of separability has not yet produced strong empirical evidence rejecting the simplifying restriction. Risk and uncertainty as well as dynamics in the sequencing of labor and other inputs can complicate separability greatly [Roe and Graham-Tomasi (1986); Skoufias (1993a, 1993b, 1996)], as can other interlinked factor markets, such as those for credit. Specific parameterizations for the profit and family utility functions can be postulated and simulated to trace out the consequences of market failures [de Janvry et al. (1991)]. But these are not, in my view, empirical tests of separability.

Yet it seems likely that there are activities where hired and family labor are not good substitutes, perhaps because of differences in relevant skills and farm-specific management experience, or because incentive and monitoring costs differ in these tasks for family and hired labor. For some special tasks hired labor can be paid according piece rates, as may occur in the case of harvesting, to reduce the cost of monitoring labor. In performing other tasks, family altruism and sharing in final output might provide family labor with better work incentives than can be readily offered hired labor, and then in these tasks family labor would have an efficiency advantage. Even when disaggregated tasks are studied separately by calendar period of the crop cycle, Maluccio finds only a few instances in the Bicol Province of the Philippines where separability is rejected. Pitt and Rosenzweig (1986) and Benjamin (1992) also cannot reject separability among the Indonesian rural families they analyze. One could imagine that in societies in South Asia where it is less common (or socially acceptable) for adult women to work outside of their own family farm, separation would not hold. But in rural India in 1969–1971, families that were relatively short of land and well endowed with female labor did not appear to employ more than the profit-maximizing level of female labor on their own farm. In other words, when both the land and labor markets were modeled jointly, family farms appear to be efficiently allocating their own and hired labor (and land) in a manner that could not be statistically shown to be inefficient due to labor market or family imperfections [Seavy (1987)]. Agricultural production functions estimated at the district level for India suggest that family and hired labor may exhibit different productivity and may deserve to be treated as separate inputs, although this has proven difficult given the extent of gender segregation of agricultural tasks [Deolalikar and Vijverberg (1983); Laufer (1985)]. Where factor markets appear to be least well developed, as in sub-Saharan Africa or parts of South and West Asia, nonseparability in hired-family labor markets is still anticipated by some development economists and these problems are probably more severe for female labor than for male [de Janvry et al. (1991)].

2.3. *Intra household allocations and bargaining*

The unitary model of household resource allocation is based on the maximization of a single household welfare function subject to a time and resource budget constraint and home production technology, taking as given market prices and wage opportunities. Samuelson (1947, 1956) elaborated on the implausible assumptions required for aggregation of individual preferences to deal with family or household choice in a form that would satisfy the axioms of individual consumer choice. Arrow (1951) went so far to as prove the impossibility of consistently aggregating the preferences of agents for the purposes of systematizing choices made by social units such as the family. Nonetheless, with the palpable importance of the family in coordinating consumption and labor supply behavior, the unitary model of the family [Becker (1965)] has been often used to combine in a single model the process determining household consumer demands and labor supply, allowing for cross effects of the shadow wage rates of all family members to affect all of their labor supply choices [Mincer (1963); Kosters (1966); Heckman (1971); Ashenfelter and Heckman (1974)].

Because the unified model of family behavior does not explicitly deal conceptually with how families aggregate the welfare of individual members to guide its decision-making and to determine the distribution of consumption and welfare among members within the family, the unified model of the family has not shed much light on how individual and family resources affect the welfare of persons *within* the family. This failure to study the intrafamily distribution of welfare cannot be entirely attributed to the lack of a theoretical framework, for reduced-form models can be readily estimated for this purpose. Although it is easy to conceive of "private consumption goods" in the family, it is more difficult to measure empirically forms of "assignable consumption", such that one person's consumption of a good can be readily monitored and would not raise (or lower) the utility of other family members. Human capital, assuming it can be valued and quantified, may be such a private or assignable good, if it has no externalities beyond the economic agent in whom it is invested. With the family ascribed a central role in financing (savings and transfers between possibly altruistic generations) and coordinating human capital investments in children, the allocation of human capital