Part II

Implications of New Technologies for Agricultural Production

Chapter 5

Productivity Implications of New Technologies

Photo credit: Grant Heilman, Inc.

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Chapter 5
Productivity Implications of New Technologies

Technologies discussed in the preceding chapters have the potential to increase American agricultural productivity, enhance the environment, improve food safety and food quality, and help increase U.S. agricultural competitiveness. Many of these technologies are fast approaching commercialization. Research in crop agriculture has advanced at a much faster pace than anticipated just a few years ago. Much of the research is aimed at improving crop resistance to weeds, insects and diseases: geoclimatic adaptation; and quality characteristics. In animal agriculture, new vaccines and diagnostics are on the market or soon will be. Growth promotants are going through the regulatory process. Reproduction technologies are advancing at a rapid pace and cloned embryos are currently being marketed. Transgenics are still in the future, but considerable strides are being made in the use of livestock to produce high-value pharmaceuticals.

The advance of agricultural biotechnology and computer technologies will play an important role in increasing agricultural productivity and accelerating structural change in agriculture. These technologies, however, are not magic—a high degree of management skill will be needed to capitalize fully on their potential benefits. It will be important to develop management systems that make the most effective use of these technologies. This chapter and chapter 6 address these issues. In this chapter the technologies' impacts on productivity are analyzed and implications for the agricultural industry are discussed. In the next chapter management issues will be examined.

TECHNOLOGY ADOPTION AND PRODUCTIVITY IMPACTS: NEW PROJECTIONS

OTA conducted two workshops—one for animal agriculture and the other for crop agriculture—in part to assess the impacts of these emerging technologies on agricultural productivity. Workshop participants, carefully selected to include those with expertise in different stages of technological innovation, included physical and biological scientists. engineers, economists, extension specialists, commodity specialists. representatives from agribusiness and public interest groups, and experienced farmers.

The workshop participants were provided state-of-the-art papers on each technology prepared by leading scientists in the respective areas. These papers provided data on: 1) timing of commercial introduction for each technology area; 2) net yield increases (by commodity), expected from the technologies; and 3) number of years needed to reach various adoption rates (by commodity). The Delphi technique[1] was used to obtain collective judgments from each workshop participant on the development and adoption of the technologies.

Timing of Commercial Introduction

Workshop participants were asked to estimate the probable year of commercial introduction of each technology under three alternative scenarios/environments assumed to extend to the year 2000:

1. Most likely scenario—a) a real rate of growth in research and extension expenditures of 2 percent per year, and b) continuation of all other forces that have shaped past adoption of new technology.
2. More new technology scenario (relative to the most likely scenario)—a) a real rate of growth in research and extension expenditures of 4 percent annually, and b) all other factors more favorable to new technology adoption than those of the most likely scenario.
3. Less new technology scenario (relative to the most likely scenario) -a) no real rate of growth in research and extension expenditures, and b) all other factors less favorable to new technology adoption than those of the most likely scenario.

Table 5-l shows in more detail the sets of assumptions made under the alternative scenarios. Table 5-2 shows workshop participants' estimates of the probable years of commercial introduction of animal technologies, and table 5-3 shows the same for crop technologies under the three alternative scenarios.

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[1] The Delphi technique is a systematic procedure for eliciting and collating informed judgments from a panel of experts. It has distinctive feedback characteristics. During the Delphi process, responses are collated and made available to the experts for review. Each expert reevaluates his or her original answer after examining the group's response. The iterative process of evaluation, feedback, and reevaluation continues until a consensus is reached. Since this is not a random sampling, the results obtained through the Delphi process depend heavily on the experts selected.

Table 5-1—Alternative Technology Scenarios

Factors	More new technology	Most likely technology	Less new technology
Population growth rate			
U.S	1.0%	0.7%	0.5%
World	1.8%	1.6%	1.3%
GNP growth rate			
U.S	4%	3.4%	3.0%
World	5%	3.5%	2.0%
Trade policy	Less protectionist, more favorable terms of trade	Continuation of present policy	More protectionist, less favorable terms of trade
Tax policy	More favorable toward technology development	Continuation of present policy	Less favorable toward technology development
Rate of growth of export demand			
Grain	1.8%	1.4%	.8%
Oilseeds	2.3%	1.8%	1.2%
Red meat	2.0%	1.0%	0.0%
Energy price growth rate (constant dollars)	5%	3%	1%
Growth rate of research and extension expenditures (constant dollars)	4%	2%	0%
Inflation rate	8%	5%	3%
Regulatory environment	Less regulation, more favorable climate for technology development	Continuation of present policy	More regulation, less favorable climate for technology development
Consumer acceptance of new technology	High	Moderate	Low

SOURCE: Office of Technology Assessment 1992

These estimates range from the very near term for genetically engineered growth promotants and animal health technologies to 2000 and beyond for transgenic animals and certain crops. Participants thought that many of the advancing technologies may be available by the mid- 1990s. Of the 41 potentially available animal technologies, 21 were estimated to be available by 1995 under the most likely scenario. In crop agriculture, 19 of the 30 technologies examined were projected to be available for commercial introduction by 1995.

Primary Impacts

When technologies are adopted on farm their immediate technical impact on crop agriculture is usually increased yields, a changed product characteristic, and/or increased percentage of planted acreage harvested. For animal agriculture the impact is on feed efficiency for all animals, reproductive efficiency for beef cattle and swine, milk production for dairy cows, and the number of eggs per layer (producing hen) for poultry.

To estimate the net impact of emerging technologies on agricultural production, workshop participants, using information provided about the new technologies at the meeting, projected net increases in crop yields, animal feed efficiencies, and other performance measures that could be expected if the technologies were commercially available and fully adopted by farmers (i.e.. adopted by all farmers). Since in practice most technologies would be used in combination with other technologies (including existing technologies), the individual technologies were grouped by the workshop participants according to their probable impacts on particular commodities under different scenarios. The commodities included corn. cotton, soybeans, wheat, beef cattle, dairy cattle, poultry, and swine. Through a Delphi process. OTA obtained estimates for each package of technologies on each of the commodities under the three alternative scenarios.

Adoption Profiles

When a new technology is introduced into the marketplace, only a small number of farms, mostly the large and innovative ones, will adopt the technology initially. This is because the possible payoff of the new technology is uncertain and because potential adopters need time to learn how to use the new technology and evaluate its worth. As early adopters benefit from using a new technology. more and more farmers are attracted to it, increasing the speed of adoption exponentially. Eventually. as most farmers who will adopt a new technology do so, the adoption rate will level off. Thus, the adoption profile follows an S-shaped curve (2).

Table 5-2—Timing of Commercial Introduction of Advancing Animal Technologies

Technology	Technology scenarios: More new technology	Most likely technology	Less new technology
Somatotropins			
Bovine:			
Dairy	1991	1991	1991
Beef	1995	1997	2000
Pork:			
pas t	1991	1992	1995
GRF	1994	1995	1998
Poultry:			
Broilers	1998	2000	>2000
Turkeys	1998	2000	>2000
Beta-agonists	1991	1992	1995
Reproduction and embryo transfer			
Control of ovarian functions	1993	1995	1995
Separation of X&Y bearing sperm	1992	1995	1995
In vitro fertilization	1990	1990	1990
Embryo sexing	1998	2000	>2000
Cloning and nuclear transfer	1993	1995	1995
Gene transfer	2000	>2000	>2000
Animal health			
rDNA technology	1991	1993	1995
Gene deletion	1991	1995	1995
Monoclinal antibodies	1991	1995	1995
Peptides	1994	1996	>2000
Immunomodulators	1994	1996	>2000
Antibiotic growth promotants	1990	1990	1990
Steroid-like growth promotants			
Estrogen/androgen combinations	1990	1990	1990
Controlled/sustained release	1990	1990	1990
Transgenic			
Ruminants:			
Hormonally enhanced growth	2000	>2000	>2000
Pharmaceutical production	2000	>2000	>2000
Enhanced disease resistance	2000	2000	>2000
Poultry	'>2000	>2000	>2000
Swine:			
Improved productivity	2000	>2000	>2000
Disease resistance	2000	>2000	>2000
Disease immunity	2000	>2000	>2000
Fish:			
Rapid growth...	1995	2000	>2000
Disease resistant	1995	>2000	>2000
Expert systems	1992	1995	2000
Human-computer interactions			
Add-on systems	1992	1995	2000
Integrated systems	1995	2000	>2000
Sensor technology/robotics			
Reproduction	1992	1995	1998
Health,	1995	2000	>2000
Stress	1998	>2000	>2000
Carcass evaluation	1992	1995	1998
Milking system	1994	1995	1998
Environment and animal behavior			
Optimizing environmental stimuli	1992	1995	>2000
Stress and immunity	1993	1995	2000
Cognitive processes	1995	2000	>2000
Facilities and equipment	1992	1994	1996

SOURCE Office of Technology Assessment 1992

Table 5-3-Timing of Commercial Introduction of Advancing Crop Technologies

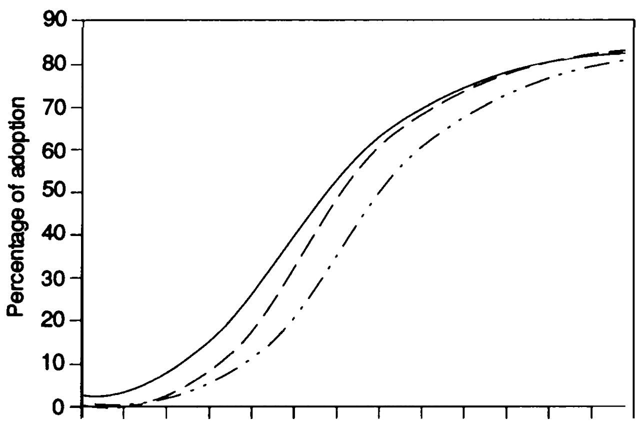
	Technology scenarios		
Technology/problem area	More new technology	Most likely technology	Less new technology
Pest control			
Pathogens for insect control:			
rDNA - microbial insecticides	1993	1995	>2000
Introduction and colonization/rDNA	1998	>2000	>2000
Use of parasites/predators	1998	>2000	>2000
Genetic modification for resistance to insects:			
Bacteria	1992	1995	>2000
Viruses	1993	1995	>2000
Plants	1995	1998	>2000
Insect and mite management	1990	1990	1990
Weed control			
Biocontrol for weeds:			
Host specific pathogens	1995	1998	>2000
Bioherbicides	1991	1995	>2000
Anthropoids	1997	2000	>2000
Genetic modification for weed control			
Herbicide tolerance	1993	1995	2000
Allelopathy	>2000	>2000	>2000
Disease control			
Microbial biocontrol of plant diseases:			
Manipulation of resident microbial communities	1993	1997	>2000
Antagonistic organisms	1993	1997	>2000
Genetic modification for disease resistance	1995	2000	>2000
Disease management:			
Crop loss assessment	1991	1995	2000
Cropping system/agroecosystem interaction	1990	1990	1990
Plant stress			
Temperature and water stress:			
Biochemical/physiological indicators	1995	2000	>2000
Genetic modification	2000	2000	>2000
Root responses to stress	2000	2000	>2000
Detection of stress	1991	1995	2000
Information technology			
Knowledge-based systems for crops:			
Farm-level planning systems	1991	1993	1998
Information networks	1993	1995	2000
Expert systems for business decisionmaking	1990	1990	1990
Networks/telecommunications:			
Commercializing public databases	1992	1995	2000
Private databases	1992	1995	2000
Commercializing public software	1992	1995	2000
Private software	1992	1995	2000
Robotics:			
Plant materials sensing/handling	1993	1995	1998
Machine guidance	1994	1997	>2000

SOURCE: Office of Technology Assessment, 1992.

Many factors go into the decision to adopt a new technology. A factor of growing importance is the ratio of consumer acceptance to rejection of a new technology. For example, it is likely that a portion of the population will prefer to purchase products that have been produced without the use of growth hormones. The size of this market segment is difficult to estimate, but it will probably support some producers who do not adopt hormones.

Other biotechnology products, suchas improved disease vaccines. most likely can be implemented effectively by most producers and will have fewer new

Figure 5-l—Logistic Adoption Curves for Corn, Package A



SOURCE" Off Ice of Technology Assessment

management requirements than recombinant somatotropins. The extent to which such innovations are commercialized and adopted will depend on their profitability and effectiveness compared to that of other available technologies.

To derive an adoption profile for each package of technologies under different scenarios, workshop participants were divided by expertise into commodity groups. There were four groups in the animal technology workshop (beef, dairy, poultry, and swine) and four in the crop technology workshop (corn, cotton, soybeans, and wheat). The participants were then asked the question, ' 'If a specific package of technologies was introduced in the market today, how long would it take for farmers to adopt it'?' Based on their answers, a logistic curve depicting the rate of adoption was fitted for each package of technologies applied to the eight commodities under different scenarios (see example in figure 5-1).

Projection of Animal and Crop Production Efficiencies

Based on information obtained from the workshops on: I) years to commercial introduction, 2) primary impacts by technology package, and 3) adoption profile, OTA computed ''performance measurements" for the eight commodity areas by the year 2000 under alternative scenarios. The results are presented in tables Table 5-4 and 5-5.

Under the most likely scenario, feed efficiency in livestock production will increase at an annual rate of from 0.39 percent for dairy to 1.62 percent for swine. In addition. reproduction efficiency will also increase, at an annual rate ranging from 0.67 percent for beef cattle. to 1.25 percent for swine. Milk production per cow per year will increase at 3.01 percent per year. from 14,200 pounds to 19,200 pounds per cow, in the period 1990–2000.

During the same period, major crop yields are estimated to increase at rates ranging from 0.39 percent per year for soybeans to 2.02 percent for wheat. Wheat yield, for example, is projected to increase from 34.8 bushels per acre to more than 42 bushels per acre in 2000 under the most likely scenario.

How do these rates of increase compare with historical trends and with OTA's last projections (8)? The most dramatic productivity increase is in milk production with a 3-percent annual rate of growth. Since 1960. the annual rate of growth has been about 2.5 percent. However, OTA's 1985 projection (24,200 pounds of milk per cow by 2000) was higher than its current one (19.200 pounds of milk per cow by 2000). A major reason for this discrepancy is the delay in marketing of bovine somatotropin. In 1985 it was predicted to be commercially available in 1987. As of early 1992 it has yet to be approved. In addition, the high milk yields projected in 1985 were revised downward in 1990 as more knowledge about the bST technology became available through additional research.

Further increases in feed efficiency in livestock will lag behind historical trends in some cases and surpass these trends in others. Poultry feed efficiency has been increasing at about 1.2 percent per year for the past decade. This has resulted in making the chicken an extremely efficient converter of feed to meat. Further increases in feed efficiency will be difficult. Feed efficiency will continue to increase at 0.5 percent per year to 2000 under the most likely scenario. Feed efficiencies for beef and swine, on the other hand, have been static for the last decade. New technologies will increase feed efficiencies. Under the most likely scenario. feed efficiency for beef is projected to increase at an annual rate of 0.74 percent, reaching 0.154 pounds of beef per pound of feed in 2000; feed efficiency for swine will increase at the rate of 1.62 percent per year, reaching O. 18 pounds of

Table 5-4—Estimates of Crop Yield and Animal Production Efficiency by 2000

	Actual 1990	Less new technology 2000	Most likely technology 2000	More new technology 2000
Crops				
Corn—bu/acre	116,2	113.8	128.5	141.6
Cotton-lb/acre	600.0	NA	708.0	NA
Soybeans—bu/acre	32.4	32.6	33.7	36.4
Wheat—bu/acre	34.8	37.7	42.6	53.8
Beef				
Lbs meat/lb feed	0.143	0.146	0.154	0.169
Calves/100 cows	90.0	93.750	96.221	102.455
Dairy				
Lbs milk/lb feed	1.010	1.030	1.050	1.057
Lbs.milk/cow/year	14,200.0	17,247.200	19,191.600	20,498.800
Poultry				
Lbs meat/lb feed	0.370	0.373	0.389	0.428
Eggs/layer/year.	250.0	250.500	258.0	273.125
Swine				
Lbs meat/lb feed	0.154	0.174	0.181	0.196
Pigs/sow/year	13.900	14.420	15.750	17.791

NOTE” OTA expresses its appreciation to Yao-chi Lu and Phil Calling, Agriculture Research Service, U.S. Department of Agriculture for their assistance in deriving the estimates for this table.

NA = Not available.

SOURCE: Office of Technology Assessment, 1992.

Table 5-5—Projected Annual Rates of Growth (1990-2000)

	Less new technology	Most likely technology	More new technology
Corn	–0.21%	1.00%	1.97%
Cotton	NA	1,66	NA
Soybeans	0.06	0.39	1,16
Wheat	**0.80**	**2.02**	**4,36**
Beef			
Lbs meat/feed	**0.21**	**0.74**	**1.67**
Calves/cow	**0.41**	**0.67**	**1.30**
Dairy			
Lbs milk/feed	**0.20**	**0.39**	**0.46**
Milk/cow/year	**1.94**	**3.01**	**3.67**
Poultry			
Lbs meat/feed..	**0.08**	**0.51**	**1.46**
Eggs/lay/year	**0.02**	**0.32**	**0.89**
Swine			
Lbs meat/feed..	1.22	1.62	2.41
Pigs/sow/year	0.37	1.25	2.47

NOTE: OTA expresses its appreciation to Yao-chi Lu and Phil Coiling, Agriculture Research Service, U.S. Department of Agriculture, for their assistance in deriving the estimates for twistable.

NA = Not available.

SOURCE: Office of Technology Assessment, 1992.

pork per pound of feed in 2000. OTA made the same projection in 1985.

Efficiencies in crop production will about match historical trends or climb slightly, and for the most part will exceed OTA's 1985 projections. This, in part, reflects the movement of many of the new technologies from the laboratory to the field at a much quicker pace than thought possible in the mid-80s. For example, in 1985 OTA projected wheat yields to increase at an annual rate of 1.2 percent under the most likely scenario. In the early 1990s they are projected to increase at a rate of 2 percent to the year 2000. Cotton was expected to increase at an annual rate of 0.7 percent in the mid-80s, but now is projected to increase at a rate of 1.66 percent to the year 2000. Soybeans are the exception. They were projected to increase at a rate of 1.2 percent in the mid-80s but now are projected to increase at the more modest rate of 0.39 percent, in part because biotechnology products are projected to become available to the soybean industry more slowly than previously thought. Note that corn is expected to decline from actual 1990 yield under the less-new technology scenario. This is due, in part, to the anticipated loss of existing chemical technologies and a very slow rate of new biological technologies to replace them.

Even though annual rates of growth in many agricultural products may accelerate during the 90s. the absolute quantity of yields will, for the most part, be lower than projected in the mid-80s. This is due, in part. to the fact that many of the early biotechnology inputs will be substitutes for chemical inputs and, hence, the absolute gain in productive efficiency will in many cases be negligible. This is expected to improve in the latter part of the decade as more is learncd about the genetic makeup of plants.

IMPACTS OF NEW TECHNOLOGIES ON THE STRUCTURE OF CROP AGRICULTURE

Production agricultural commodities generally fit into two categories: large-acreage volume crops. such as wheat, corn. and soybeans: and less volume small-acreage specialty crops, such as tomatoes, potatoes, and onions. There are several important distinctions between the two categories.

First. there is less verticul integration of input, production, and marketing stages for large-acreage volume crops than for some small-acreage specialty crops. Second. the potential market for new technologies is much greater for large acreage crops than for specialty crops. This is an important driving force in terms of technoigical innovations. Third, biotechnology processes are already available to alter the harvestable component of some specialty crops such as tomatoes. This is due. in large part. to the fact that many specialty crops are easier to manipulate genetically than food and feed grain crops. Such developments are for the most part further away for the major food and feed grain crops (5).

Large-Acreage Volume Crops

As discussed in chapter 2, biotechnology i.implications such as herbicide resistant plants and biopesticides should be available in the near future. Unlike previous mechanical technologies. most biotechnologies will not, in themselves. generate significant economies of size. Also. there appears to be lttlc incentive for firms supplying seed and chemical inputs to expand vertically into crop production. Biotechnololgies that increase yield will have supply-increasing, price-dampening effects. These will adversely affect the survival of high-cost producers. which for the most part are small to moderate-size farm operations.

Small-Acreage Specialty Crops

As indicated in chapter 2, biotechnology already has the capability to modify the harvestable product for some specialty crops. This capability will increase the extent to which processes specify product quality. It will also provide an incentive for vertical coordination between production inputs and the production and processing stages for a number of specialty crops. Thus, even though there are no obvious economies of size to be captured with biotechnology innovations, these innovations will facilitate vertical coordination in some cases. Small producers will be at a competitive disadvantage in specialty crops markets unless they have a particular market niche (5).

For fruits and vegetables, biotechnologies will be important where product quality, shelf life, and taste are important characteristics. Technologies that allow for greater selectivity in specifying performance characteristics of different crop varieties will allow more rapid development of desirable cultivars and much more rapid propagation of plant stocks. Markets for tomatoes, let-

Photo credit' Grant He//man, Inc.

Advancing technologies will have supply-increasing, price-dampening effects on large-acreage volume crops such as wheat. This will adversely affect high-cost farming operations.

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tuce, and carrots are large and relatively focused on a few specific varieties. Improvements in these crops have the potential for rapid and widespread adoption to the benefit of growers, plant stock breeders, and consumers. There will be significant price differentials connected to biotechnology-based improvements and consumers can expect to pay higher prices for products more tailored to specific segments of the market.

New Crops and New Uses of Existing Crops

Biotechnology offers great potential for developing new crops and/or modifying existing crops for food, feed, and industrial uses. Examples include the modification of seed composition of corn and soybeans.

Industrial use of corn for glucose, dextrose, starch, and alcohol has expanded rapidly, and biotechnology offers the capability to modify the protein, starch, and oil content of grain. Currently in the United States, approximately 3 percent of corn acreage is planted to special-use hybrids such as white corn for corn meal and grits, waxy corn for use as thickeners in the food industry, and hard yellow corn for snack chips. The other 97 percent is sold under the broad market classification of No. 2 yellow corn, without measurement of protein, starch, or other quality characteristics (6).

For it to be economically feasible for farmers to grow products such as special-use corn hybrids, they must be able to capture price-premium incentives for these products. The current marketing system cannot easily accommodate new market channels for special varieties. It is expected that direct contracting between processors and growers will play an important role in the market development and growth of special-use products.

The above example for corn hybrids suggests the likely pattern for marketing of other special-use crops. Where specialty market niches are small, incentives for a high degree of vertical integration in production and marketing will be substantial. This will limit the production opportunities for most independent producers (5).

IMPACTS OF NEW TECHNOLOGIES ON THE STRUCTURE OF ANIMAL AGRICULTURE

The U.S. livestock industry is divided into two components. One is increasingly space-concentrated, higher technology, and intensively managed. This component includes specialized cattle feedlots, broiler and swine production under confinement, and some large, highly specialized dry-lot dairy operations. A second component is the range livestock sector, which includes a large number of beef cow-calf operations along with a variety of small, lower technology livestock farms, many of which are operated by part-time farmers.

A number of biotechnology applications is expected to have rather high adoption rates within the higher technology component of the livestock sector, compared to the lower technology, spatially dispersed sector. This is due, in large part, to the fact that increased managerial expertise is needed to use these new technologies effectively; such expertise tends to be associated with confinement systems.

Growth promotants will be the first major biotechnology products to be made available to U.S. agriculture. The dairy and pork sectors will be the first to make use of these technologies.

Case Studies

Dairy Sector

The dairy industry will most likely be the first to adopt technologies from the biotechnology era of the 1990s,

Photo credit: Grant Heilman, Inc.

In the dairy industry the trend toward fewer and larger farms has been on-going for decades. The trend will accelerate as a result of new cost-reducing technologies and a more market-oriented dairy policy.

and also will feel the first profound impacts of the emerging technologies. Biotechnology advances in reproductive technologies. animal health technologies, and growth promotants will make major contributions to the sector. In particular, bovine somatotropin (bST), a growth promotant, will significantly increase milk production. Bovine somatotropin is a naturally occurring hormone that increases milk yield in the dairy cow. Its effect has been known for decades but until it could be produced by rDNA procedures, it was not economically viable. This technology will increase milk yield per cow in 1 year to what it would take 10 to 20 years to achieve with current reproductive technologies (7).

The economic effects of these emerging technologies can be visualized by analyzing the impacts on different sized farms in different regions. Representative farms used in the analysis are briefly described in table 5-6. Once bST becomes available, strong incentives will exist to adopt the technology. Payoffs from bST adoption are substantial, regardless of region (see table 5-7). Nonadopters of bST will have more problems surviving and will be more likely to exit the industry.

Regional shifts in milk production patterns are expected for several reasons (tables 5-8 and 5-9). Upper Midwest farms have problems realizing sufficient earnings to achieve a reasonable return on equity, compete. and survive. While Northeast farms fare better, they too were found to be at a disadvantage relative to Pacific and Southeast farms. In all regions, adoption of bST increases the potential to survive, especially for larger farms.

Concern that bST will force many dairy farms out of the industry, especially in the traditional milk-producing region of the Upper Midwest and Northeast, has helped make this new technology the center of controversy. BST alone, however, will not force these traditional farms out of existence. The trend toward fewer total cows and larger farms has been underway for many decades. This trend is the result of a combination of emerging technology. economies of size, and policy. The trend will no doubt accelerate in the 1990s as the result of a combination of bST and other cost-reducing technologies, and a more market-oriented dairy policy. Such changes inherently put increased pressure on smaller traditional dairy farms. These pressures are accentuated by technological change but they are not new. For a more extensive discussion and analyses of these trends see the OTA report entitled *U.S. Dairy Industry at a Crossroad: Biotechnology and Policy Choices.*

Table 5-6—Summary Characteristics of Representative Moderate-Size and Large Dairy Farms, by Region

Characteristic	Upper Midwest		Northeast		Southwest[a]		Southeast	
	Moderate	Large	Moderate	Large	Moderate	Large	Moderate	Large
Cow numbers	52	125	52	200	350	1,500	200	1,500
Output/cow (pounds)	16,850	16,850	17,940	17,830	18,590	19,690	15,340	15,310
Total asset value ($000)	470	940	608	1,395	1,097	3,858	1,569	7,723
Land value ($000)	133	295	274	640	118	492	813	4,591
Percent of feed raised	63	60	50	46	0	0	25	2

[a]Includes farms from both the Pacific and Mountain USDA production regions

SOURCE: Office of Technology Assessment, 1992.

Table 5-7—Comparison of Average Annual Economic Payoffs From bST Adoption for Eight Representative Dairy Farms Under Three Alternative Dairy Policies, 1989-98[a]
(thousand $)

Region size	Policyscenarios		
	Trigger[b] price	Fixed[c] support	Quota[d]
Lake States:			
Moderate , ...	**3.9**	4.1	2.4
Large	**10.3**	10.9	7.0
Northeast:			
Moderate	3.4	3.6	1.0
Large	15.8	16.6	8.8
Southwest:			
Moderate	26.5	26.6	18.3
Large	90.5	91.7	61.2
Southeast:			
Moderate	21.9	22.8	17.2
Large	166.4	166.3	132.0

[a]**Economlc payoffs from** bST are the average annual change **in net** cash farm income between a nonadopter and a bST adopter over the 1989 to 1998 planning horizon. The payoff is net of the cost of bST, the added transportation costs for milk, and the additional feed.
[b]This option triggers a price support reduction each time the level of government purchases of milk products exceeds 5.0 billion pounds annually.
[c]This option fixes the price support level at $10.60 per cwt. for all years.
‘The quota policy is designed to maintain government purchases at or near a minimum government use target. This is accomplished by reducing the number of cows in a herd through a two-tiered pricing system or some other mechanism that provides disincentives for producing over quota levels.

SOURCE: Office of Technology Assessment, 1992

Swine Sector

As with the dairy industry, the swine sector will benefit from biotechnology improvements in the areas of reproduction, health, and growth promotants. Porcine somatotropin (pST), a growth promotant, will be one of the first technologies from the biotechnology era for the swine industry. Porcine somatotropin is a naturally occurring hormone in swine that accelerates the rate of growth, increases feed efficiency, and produces leaner hogs. Although the effects of pST on feeder hogs has **been known** for many years, it was not used commercially because of lack of availability. The ability to produce recombinant pST has heightened interest in using the product on commercial hog farms. Porcine somatotropin research has shown that it increases feed efficiency by as much as 40 percent, reduces fat by as much as 30 percent, and increases growth rate by as much as 33 percent. (See ch. 3.)

The economic benefits of pST can be discussed by analyzing representative hog producers in the Midwest who adopt pST, and the costs to producers who do not adopt pST. An economic model was used to simulate the economic viability of two Missouri grain-hog farms (75 and 225 sows) and two Indiana grain-hog farms (150 and 600 sows) before and after the introduction of pST. The Missouri and Indiana hog farms represent two different types of Midwest hog farms. The Missouri farms raise fewer pigs per sow, in part. because their operations are not total confinement operations like those representative of Indiana (table 5- 10). All the farms represent high-level management by progressive. full-time farmers intent on producing hogs efficiently with the best resources at their disposal. The farms were assumed to adopt pST on its introduction (1992) or not adopt it over the 6-year planning horizon (3).

Two pST/feed response scenarios were evaluated. The first represented the average gains from pST, i.e., 25.1-percent improvement in feed efficiency and a 12.7-percent increase in average daily gain. The second scenario assumed a more optimistic pST/feed response, a 34.8-percent improvement in feed efficiency and a 33.3 percent increase in average daily gain. In recognition of the reduced fat to lean reported for pST-treated hogs, a 5-percent price premium for market hogs was analyzed. This 5-percent carcass merit premium is within the range suggested in the literature.

Results of the analysis indicate that farms that do not adopt pST will experience lower annual net cash farm

Table 5-8—Impacts of bST Adoption on the Economic Viability of Moderate-Size Representative Farms, by Region, 1989-98 (in percent)[a]

	52-cow Upper Midwest		52-cow Northeast		350-COW Southwest		200-COW Southeast	
Measure of impact	Non-adopter	bST adopter	Non-adopter	bST adopter	Non-adopter	bST adopter	Non-adopter	bST adopter
Probability of survival[b] . . .	580/0	740/o	100"/0	100"/0	95%	97%	100"/0	1 000/0
Probability of earning 5-percent return on equity	58	74	100	100	95	97	100	100
Probability of increasing equity[c]	0	0	3	3	60	79	13	24
Present value of ending net worth as percent of beginning net worth[d] . .	16	29	72	77	109	128	76	89

[a]The analysis used a trigger-price dairy policy.
[b]Chance that the individual farm will remain solvent through 1998, i.e., maintain more than a 10-percent equity in the farm
[c]Chance that the individual farm WiIl increase its net worth m real 1989 dollars through 1998.
‘Present value of ending net worth divided by initial net worth indicates whether the farm increased (decreased) net worth in real dollars

SOURCE: Off Ice of Technology Assessment, 1992.

Table 5-9—impacts of bST Adoption on the Economic Viability of Large Representative Farms, by Region, 1989-98[a] (in percent)

	125-cow Upper Midwest		200-COW Northeast		1 ,500-COW Southwest		1 ,500-COW Southeast	
Measure of impact	Non-adopter	bST adopter	Non-adopter	bST adopter	Non-adopter	bST adopter	Non-adopter	bST adopter
Probability of survival[b] . . .	95°/0	99%	100"/0	100"/0	100"/0	100"/0	100"/0	100"/0
Probability of earning 5-percent return on equity	90	95	99	100	100	100	100	100
Probability of increasing equity[c]	8	12	43	53	100	100	88	99
Present value of ending net worth as percent of beginning net worth[d] .	57	69	92	102	195	214	129	147

[a]The analysis used a trigger-pnce dairy policy
[b]Chance that the individual farm will remain solvent through 1998, ı e , maaintain more than a 10-percent equity in the farm.
[c]Chance that the farm WiIl increase its net worth in real 1989 dollars through 1998.
‘Present value of ending net worth divided by initial net worth indicates whether the farm increased (decreased) net worth in real dollars.

SOURCE: Office of Technology Assessment, 1992

incomes (ranging from $13 to $33 per sow) due to lower hog prices (table 5-1 l). (The lower hog prices are due to the increased supply of meat caused by the availability of pST.) This range of lost income is about the same across the four farms analyzed because it is a direct result of lower hog prices. For pST adopters this loss is more than offset by a 5-percent carcass merit premium for a leaner carcass. Increases range from $110 to $134 per sow (table 5-1 l).

Increasing the feed efficiency and average daily gain from pST to the more optimistic feed response scenario more than doubles the economic payoffs to adoption. Without the carcass merit premium, the economic payoffs for pST average $265 per sow per year, more than double the $100 spent for pST.[2] If the producers can garner a 5-percent carcass merit premium, the per sow returns to pST adoption to a total of about $370 per sow per year.

[2]The pST figure assumes that pST costs $6 per pig and is administered weekly for 6 weeks. The balance of the cost is added labor and feed costs.

Photo credit: Grant Heilman, Inc.

Production of lean meat with porcine somatotropin (pST) will give meat packers a strong incentive to vertically integrate or contract with farmers. Economic pressures will be strong for most swine producers to either adopt pST or to exit the industry.

The economic payoffs of pST adoption are about the same regardless of farm size. For example, the moderate-size Missouri farm's per-sow payoff is within 10 percent of that for the larger Indiana farm. And, the difference in payoffs between the 150-SOW Indiana farm and the 600-sow Indiana farm are within $18 per sow. These results suggest that pST could be scale neutral.

Nevertheless, pST could accelerate the concentration of the U.S. swine industry. PST adoption increases the total income of large-scale farms more than that of smaller scale farms due to the sheer volume of hogs produced on the large farms. For example, pST increases average annual net cash income $232,000 for the large Indiana farm and only $57.000 for the moderate-size Indiana farm. Thus, the large farm gains an internal source of capital for future growth far in excess of what the smaller farm gains. In addition, the smaller farms may experience lower average pST/feed response due to lower management skills while the larger farm experiences a higher than average pST/feed response and a 5-percent carcass merit premium. This results in the moderate farm's average annual returns to pST in the $3,300 to $18,500 per-year range while the large farm receives $232,000 or more per year.

PST may therefore contribute to a significant restructuring of the swine production sector. The production of more lean meat will give meat packers a strong incentive to vertically integrate or contract with producers and possibly pST suppliers. The economic pressures will be strong for most swine producers to either adopt this new technology once it becomes available or to exit the industry.

New Animal Products

Biotechnology methods capable of producing transgenic animals may alter the use of these animals from food to pharmaceuticals. Attempts are "being made to produce rare, medically important proteins in pigs. Production of blood-clotting factors and tissue plasminogen activator (used to dissolve blood clots that cause heart attacks) are being investigated. A private firm has announced that it has successfully produced human hemoglobin in pigs. A blood-clotting agent has been transferred to and expressed in sheep. Transgenic cows producing pharmaceuticals have not yet been reported, but these animals are under development in a number of public and private laboratories. If successful, the production of pharmaceuticals will open new markets for livestock. Incentives will be in place for pharmaceutical companies to vertically integrate or contract with farmers for the production of pharmaceuticals from livestock. Capital costs for breeding stock is most likely to be quite high indicating that successful, large farms are most likely to meet this new market demand.

IMPACT OF NEW TECHNOLOGIES ON AGRIBUSINESS, LABOR, AND RURAL COMMUNITIES

Agribusiness

Advancing products of biotechnology and information technology will have major impacts on agribusiness (input suppliers, processors, wholesalers, etc.). Historically. the commodity-oriented agribusiness sector has been driven by economic forces to produce at maximum efficiency and maintain low costs. This has resulted in a system that is remarkably effective at converting un-

Table 5-10—Characteristics of Representative Moderate and Large Grain-Hog Farms in Missouri and Indiana

	Missouri		Indiana	
	Moderate[a]	Large	Moderate	Large
Hog Enterprise				
Sows	75	225	150	600
Boars	6	10	10	30
Gilts (repl.)	32	100	90	245
Pigs raised/sow/year	15.68	15.68	17.00	18.00
Gilts sold/year	556	,664	1,185	5,155
Borrows sold/year	588	,764	1,275	5,400
Sale weight	240	240	240	250
Lbs. feed/lb. gain	3.875	3.787	3.763	3.299
Assets ($1,000)				
Land	232.0	520.0	630.0	2,475.0
Buildings	70.0	175,0	120.0	500.0
Machinery	86.5	289.1	280.2	834.3
Livestock	34.4	65.7	49.9	158.6
Other Assets	0	0	0	0
Total	422.9	1,049.8	1,080.1	3,967.9
Liabilities ($l,OOO)[b]				
Real estate	30.2	69.5	75.0	297.5
Intermediate Assets	24.2	70.9	66.0	198.6
Other	20.8	54.8	70.6	40.6
Total	75.2	195.2	211.6	536.7
Net Worth ($l,OOO)	347.7	854.3	868.5	3,431.2
Acreage				
Owned	220	520	280	1,125
Leased	110	500	520	1,125
Total	330	1,020	800	2,250
Crops produced (acres)[c]				
Corn	144	300	540	1,800
Soybeans	80	333	175	400
Wheat	76	316	24	50

[a] The moderate size Missouri hog farm also has 25 cows on 100 acres of pasture.
[b] Liabilites are reported assuming the farm has 10-percent debt on real estate assets and 20-percent debt on machinery and livestock.
[c] Acreage of crops represents actual planted acreage in 1990 after accounting for set aside. All farms except the large Indiana farm participated in the farm program

SOURCE: Office of Technology Assessment 1992

differentiated commodities into relatively low cost food. Today this sector is undergoing change inspired in part by the evolution of a more demanding and differentiated food consumer. In response, retailer strategies have emerged which focus on improving service to the end consumer. Information technology has facilitated the shifting of marketing efforts toward the discovery of consumer preferences. Information technology along with legal disclosure requirements have made it easier for the consumer to see a wider range of product attributes. Where buying decisions were once made on such aspects as variety, convenience, price stability, and value, now consumers can also evaluate additional characteristics that were previously experienced only indirectly, such as product quality, nutrition, food safety, and environmental aspects (4).

To respond to a more consumer-oriented environment, input suppliers may need to explore how information technology can facilitate the coordination activities needed to assure particular attributes. In the future information technologies may facilitate new business strategies by providing improved information flows and by facilitating coordination of production and marketing activities. For example, Pioneer's *Better Life Grains* and Frito-Lay's *Frito Corn Chips are* two companies using information technology to assure product quality. Pioneer seeks suppliers who use a specific technology to tailor-make a seed that grows product specific attributes. Producers are required to provide specific production assurances that allow the processor to label the product for a specific set of nutritional attributes. Pioneer stands behind the attributes and accepts the implicit role as the enforcer, and information technology provides the linkages. Likewise, Frito-Lay contracts with producers for specific types of corn. The processed commodity is tracked through the market channel on a bag-by-bag basis to assure product quality (4).

Table 5-n—Average Annual Net Cash Farm Income Due to PST Adoption for Representative Missouri and Indiana Hog Farms Under Alternative PST/Feed Response and Carcass Merit Premium Assumptions

Representative farms	Do not adopt DST	Do adopt average pST/feed response		Do adopt optmistic pST/feed response	
		No CMP[a]	5 percent CMP	No CMP	5 percent CMP
	(thousand $)				
Missouri					
Moderate	56.73	57.70	64.98	75.59	83.19
Large	149.16	153.93	175.66	209.15	231.85
Indiana					
Moderate	214.22	217.53	232.66	255.48	271.70
Large	818.17	838.18	898.78	979.24	1,050.98
	$/sow				
Missouri					
Moderate	756	769	866	1,008	1,109
Large	663	684	781	930	1,030
Indiana					
Moderate	1,428	1,850	1,551	1,703	1,811
Large	1,364	1,397	1,498	1,632	1,752

[a]CMP refers to carcass merit premium.

SOURCE: Office of Technology Assessment, 1992.

Input suppliers have experienced more consequences of the biotechnology era than any other part of the agriculture industry to date. In anticipation of biotechnology-enhanced seed for large-acreage volume crops, seed and chemical input industries already have transformed structurally, just as the hybrid seed-corn industry developed to become a billion-dollar business after hybrid corn became a reality 50 years ago. With the expected future gains from biotechnology, multinational chemical and pharmaceutical companies have acquired almost all of the major seed companies. Only Pioneer Hi-Bred international and DeKalb remain independent firms (6).

Concentration of input industries increases the potential for monopoly power, hence the potential for exploiting farmers in their purchase of improved inputs. Overdependence on a narrow set of genetic material also raises the problem of ecological vulnerability.

Economies of size in process technologies also can foster concentration in the input sector. For example, a 7 million dose-per-day bST plant can supply two-thirds of the Nation's dairy herd. To the extent that efficient biotechnology manufacturing requires large plant sizes, there will be economic pressures to concentrate industry structure to a small number of firms. Moreover, in some cases, there may be incentives for manufacturing firms to integrate the manufacturing and retailing of inputs.

As discussed earlier. the trend toward vertical integration in agriculture and toward proprietary production processes could result in a captive market for some biotechnology products. For example, a genetically engineered seed might be produced by a large, vertically integrated chemical-seed company with specified inputs such as fertilizer, pesticides, and herbicides produced only by that company.

The potential for transgenic farm animals to produce pharmaceuticals will also provide incentives for vertically integrated companies. Firms already involved in pharmaceutical research can easily move into animal agricultural biotechnologies.

The increased importance of proprietary products and processes in the input-supply sector and the increased economic incentives for further industry concentration imply a challenge for small-scale firms. The survival of such firms may depend on public research in technologies that they can effectively use in their production systems; market access to these technologies; and easily acquired information on use and management of available technologies (5).

Farm Labor

As has been true for most past technologies, the emerging biological and information technologies will generally shift labor from farming. At the same time, new employment opportunities will be provided in the agribusiness sector supplying these new technologies. Today

Photo credit: Grant He//man, Inc.

Newly emerging technologies will displace less farm labor than mechinazation, but labor will have to be substantially more skilled than in the past.

only about 2 percent of the U.S. population is living on farms; about 55 percent of nonmetropolitan jobs in the food and fiber system are located off-the-farm in farm input, marketing, and other service sectors.

Newly emerging technologies will displace less farm labor than mechanization, but the farm labor force will have to be substantially more skilled than in the past. This will be particularly true for workers in animal agriculture. Demand for unskilled agricultural workers will fall off. Hired field workers will be limited to specialty crop (mainly fruit and vegetable) farms.

One message seems clear: implementation of the new technologies will require a broad range of specialized Skills. For example, a key requirement of the new information technology will be computer literacy. Enhanced management skills will be needed generally to succeed within a system characterized by increased technical and economic compltexity. Programs to support skill upgrading of the farm labor force will be needed to capture fully the potential benefits of new technologies (see ch. 6 for a more thorough discussion of these requirements.)

Rural Communities

The number of farms and farm population continued to decline in the 1970s and 1980s. The impacts of declining farm numbers are difficult to ascertain. In general, land is bought by other farmers and continues to remain in production so that total agricultural output does not significantly decline. However, declining farm numbers negatively affect rural community employment levels. In farming-dependent communities, for every one farmer that exits the industry, up to one additional job may be lost to the community.

While in most urban areas the 1980s were years of economic recovery and prosperity. this has not been the case for rural areas. The rural economic crisis was due in part to depressed conditions in export-dependent industries such as agriculture. forestry, and mining. However, even when these industries began to recover in the mid- 1980s, the rural-urban gap widened. This was due, in part, to the fact that rural problems run much deeper than those of agriculture alone. extending to inadequate infrastructure, poor schools. lack of access to quality medical services, and lack of leadership to solve problems that exist. While rural communities may have once been dependent on agriculture, only 23 percent of the 3,106 counties in (his country can now be described as agriculture-dependent, nonetheless, more than 75 percent of the Nations counties are nonmetropolitan. Rural communities and agriculture are no longer synonymous (1).

Much of the once agriculturally dependent popultition has moved to larger trade-center communities (many in nonmetropolitan counties), which have therefore grown in population and business volume. Growing communities in rural areas are often preferred locations for consolidated public schools, medical facilities. and other public services. Those communities left behind are suffering the consequences, and some are particularly vulnerable to the structure of agriculture.

The emergence of biotechnology and computer technologies will most likely spur on the decline of many small farms and agriculturally dependent rural communities. And, where product quality is influenced strongly by biotechnologies, such as pST in pork. and where highly specialized new markets are formed, such as pharmaceuticals, increased incentives for production-marketing links via contracting and other forms of vertical integration also can be expected. At the same time, increased demand by many farmers for one-stop shopping centers for farm supplies and technical services— including those involving biotechnologies and computer

Photo credit: Grant Heilman, Inc.

Advancing technologies will most likely spur on the decline of agriculturally dependent rural communities. These business communities will need to substitute additional nonfarm economic activities if they are to remain viable.

technologies—may reduce the viability of business enterprises in smaller rural communities. These business communities will need to substitute additional nonfarm economic activities if they are to remain economically viable (5).

In the near term, biotechnology's effects on rural communities likely will be most significant in regions of concentrated livestock production. The ability of rural communities in these regions to absorb adverse changes in agricultural employment will be closely related to the availability of off-farm employment.

Because rural communities have diversified their economic base and are no longer dependent on agriculture, most rural community residents have little or no personal contact with farming, except as passive observers of environmental changes. The environmental impacts of production practices can, however, become a community issue when such externalities as water quality, chemical residues, worker safety, etc., become sources of concern. Local sensitivities about the implications of novel substances employed in animal and crop production already are significant. Perceptions of risk to health, safety, and/or environmental diversity associated with transgenic organisms may become a further source of community conflict and controversy.

To ameliorate such conflict and controversy, communities should facilitate:

1. open public discussion of biotechnology research priorities;
2. enlightened policies and procedures regarding approval, patenting and regulation of biotechnology innovations; and
3. insistence on high-quality and timely information about biotechnology for public and private decisionmakers.

POLICY ISSUES ‘

A number of policy issues surround the introduction of technological innovations in U.S. agriculture and their impacts on the industry. Many are already on the policy agenda in one form or another. Several are discussed below.

Moratoriums on Agricultural Research or on the Implementation of New Agricultural Technology

Moratoriums have already been placed on the use of bovine somatotropin in Minnesota and Wisconsin. The dairy case study discussed earlier clearly showed that regardless of farm size or region, there will be strong incentives to adopt bST. The farms in Minnesota and Wisconsin, even if they do adopt this new technology, still will have problems realizing sufficient earnings to achieve a reasonable return on equity, compete, and survive. For farms not adopting the new technology the dilemma will be even more severe. The agricultural industry of these States will be at a great disadvantage relative to those States where a moratorium does not exist if bST is approved by FDA for commercial use.

In the process of economic development a maturation process occurs such that fewer human resources are required in primary industries (farming and mining) and proportionately more workers are employed in the knowledge and service industries. American agriculture has achieved its preeminence in the world by substituting knowledge for resources. This knowledge, embodied in more productive biological, chemical, and mechanical technologies and in the managerial skills of farm operators, has given the United States a world-class agricultural industry at a time when many other sectors of our economy are losing their preeminent position. For U.S. agriculture to retain its status it is necessary to enhance public and private-sector capacity for scientific research and technology development. The costs, to consumers and producers, of failure to maintain and enhance our efficiency in production would greatly exceed the adjustment costs resulting from overabundance.

Impacts of Emerging Technologies on Farm Size and Managerial Skill Requirements

The post World War 11 era of farm mechanization made it virtually impossible for small unmechanized production units to compete and survive with farming as the sole source of family income. Some past chemical and biological technologies such as insecticides and hybrid seed, on the other hand, have been rather scale neutral except for price discounts afforded producers who were able to purchase them in large volume. The emerging biotechnology and information industries appear to have the potential for being relatively scale neutral in their application on those *farms already large enough to support mechanization technology.* But two qualifying considerations are important. First, the implementation of these emerging technologies will generally require increased management skills and, for some, computer literacy. Second, at least some of these technologies will be effective and profitable only if they are integrated into rather technically complex production systems at the farm level. Some of these systems in animal agriculture may involve environmentally controlled housing and scientifically based feeding and management procedures. Thus, increased managerial skills, and, in some cases, additional capital in the form of specialized buildings and equipment will be important components of successful farming in the future. This will most likely mean increased concentration of farm production among larger units with more sophisticated technology and management capabilities.

A number of persons who have moved out of farming in the past four decades did have adequate skill levels but had an inadequate resource base of land or operating capital to succeed under a highly mechanical farming regime. Future adjustments in farming will be dictated less by large capital requirements than by the educational and managerial skill requirements for farmers. This is not to suggest that the future capital requirements in farming will not be high. They will. In fact, the capital requirements per worker in farming are very high compared to most other types of employment. But recent major deflation in agricultural capital assets, particularly farm real estate, together with creative procedures by farmers for acquiring access to land and capital resources, may result in educational and managerial skill levels becoming a more limited resource than capital. One clear-cut conclusion emerges. Persons who want to compete successfully in farming will need to upgrade their managerial skills. A critical role for Extension is to develop programs and opportunities for farmers to enhance their management capabilities.

Displaced Farm Operators and Workers

More workers have left farming since 1940 than now remain on U.S. farms. Displacement of farmers and farm workers will continue, though at a slower pace than in the past half century.

Adjustment to alternative employment is most easily accomplished by young people who are just graduating from high schools, vocational schools, and colleges or universities. Thus. strong educational programs and vocational counseling for youth in farming communities are of vital importance. Selected public policies should aim at ensuring the provision of such educational support services. Other displaced farm workers will seek nonfarm employment either with or without retraining for such employment. A number of special training programs are already in place for such individuals. These retraining programs. however, need to be geographically and financially accessible and have appropriate entrance requirements for those displaced from farming. Moreover. they need to target employment training to those skill areas for which jobs are available.

A number of older farm operators and other family members without new training may have to adjust to whatever full- or part-time employment opportunities exist in the local community. The availability of such employment opportunities and the general quality of life in many rural farm-dependent communities will be heavily dependent on the local farm economy. And, in some cases businesses based on newly emerging technologies, particularly those supplying farm inputs, will provide new local employment opportunities.

Adjusting to Change

Policies to help farmers adjust to technological change on the farm or to off-farm employment are lacking. The Food, Agriculture, Conservation, and Trade Act of 1990 and related farm policies are aimed almost exclusively at reducing the use of farm inputs (mainly land) to curtail farm output; providing a price (and income) floor for producers of selected commodities; and enhancing the position of U.S. farm commodities in world trade. A unique exception was the dairy herd buyout program in the late 1980s, which provided some dairy farmers with an opportunity to “cash out” their dairy herds at more attractive prices than those afforded by the free market. New or expanded public policies are needed for upgrading the managerial skill levels of some farmers to cope with technical change and for providing retraining opportunities for others to enable them to exit from farming. Strong educational programs are also needed for all rural young people whether or not they have opportunities in future ‘‘high-tech’ farming. Expanded Federal and State assistance will be required for effective educational programming in those rural areas with an eroding local tax base.

At the institutional level, public institutions need to aim policies and programs at two somewhat different types of participants—those who will adjust by staying in farming, and those who will seek alternative employment. Both groups need to be serviced by effective public technology transfer and training programs and supporting financial services. A reorganized and revitalized public extension service could play a major role in technology transfer while public credit agencies need to focus program delivery on the special needs of the two target groups. At the farmer level, it is crucial that individuals realistically assess their opportunities in and out of agriculture. Most should make deliberate career choices and follow up with the acquisition of the managerial skills to succeed in high-tech farming or the retraining required for employment off-the-farm. Future farm commodity programs are not likely to provide an umbrella of income protection adequate for any but those farm managers who can adjust effectively and quickly to technological change.

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