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EXPECTED ECONOMIC IMPACTS OF THE EMERGING BIOTECHNOLOGIES ON U.S. AGRICULTURE

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The emerging biotechnologies will eventually have major economic impacts on the agricultural input industry, on farm production, an on food manufacturing and processing. Yet most of the early impacts will be selective so that in the aggregate, they will be of an evolutionary rather than a revolutionary nature for the U.S. farm production sector. There is no feasible quantitative model for accurately projecting future economic impacts. But one can, I believe, provide some general perspective on the likely magnitude of future effects.

For purposes of this discussion, my informal approach to evaluating future economic impacts of the emerging biotechnologies on agriculture is a three-stage procedure. First, I identify some of the key factors expected to affect the rate and magnitude of economic impact. Second, I briefly discuss some selected examples of biotechnology applications in the crop, livestock products and food processing areas. Third, I use the above two perspectives to make some judgements about the future.

Factors Affecting Economic Impacts

Several factors will have important influences on the future rate and magnitude of biotechnology applications in agriculture. Although the following list is not complete, it probably includes most of the major factors.

First, although animal growth hormones are somewhat of an exception, most near term applications in farm production will not result in major increases in product yields. Rather, they will impact mainly by reducing or eliminating adverse effects resulting from environmental stress factors on the crop and animal organisms involved. Increased resistance of economic plants to herbicide induced stress and new vaccines which modestly reduce animal disease losses are good examples.

Second, applications will vary greatly as to their costs and the technical sophistication required for their application and management. This will be reflected in their adoption rates by users. For example, applications which are embodied in hybrid corn germ plasm will likely be of modest cost to farmers and will be quickly and easily adopted merely by switching to a new seed variety. Other applications, particularly some in the animal area, will require major, and in some cases costly, modifications in on-farm production systems, including controlled environments and/or sophisticated management procedures.

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Third, and closely related to item two, is the profitability of adopting the new technology. Some new biotechnologies such as bovine somatotropin appear to have the potential for generating a large revenue-above-cost differential for early adopters. Other applications, such as some animal health products, will probably be only marginally superior, profit-wise, compared to existing technologies. And as for earlier agriculture technologies, successful adoption will require profit potential for the users, at least for the early innovators.

Fourth, the farm input industry will give highest near term priority to developing technologies with large-volume potential. Thus corn with an 80 million acre per year volume potential will receive much more attention than a minor economic crop such as buckwheat. And, dairy and swine applications will proceed more rapidly than for minor livestock subsectors. There are exceptions to this "large volume" rule which I will refer to briefly later.

Fifth, and importantly, is the rate at which new biotechnology products and processes are approved for commercial use by the regulatory agencies involved. In addition to time requirements, the dollar cost of moving new biotechnology products and processes through the regulatory approval process is a factor of significant importance. Although mainly beyond the scope of this paper, the regulatory process will be affected by a variety of economic, ethical, health, environmental and bureaucratic considerations. And, compared to earlier agricultural technologies which needed only to pass the test of profitability-in-use, the emerging biotechnologies will be subjected to intensive scrutiny and regulation.

Sixth, and finally in this short list of key factors affecting the rate of economic impacts, is the macro economic environment vis-a-vis the aggregate demand and general price levels for major farm commodities. Although profitability of adoption and size of the market were mentioned in factors 3 and 4, the rate of R&D investment in new technologies, particularly in the private sector, is also a function of general price and profit levels in the technology adopting sector(s). For example, there is no question but what a $4.00 per bushel price for corn will induce a higher rate of investment in R&D for new corn technology development, ceteris paribus, than will a $1.00 per bushel price. And the higher the rate of R&D investment, the greater the rate of expected technology achievement.

In general and largely as a result of the state of current application achievements, near term applications (those occurring within 5 to 10 years) will vary greatly between major categories of agricultural enterprises. Thus, while milk production will probably be affected in a major way through the adoption of the dairy growth hormone, bovine somatotropin, any impacts of wheat production will probably be minimal.

Selected Areas of Application

For several reasons, including differences in the current state-of-the-art in biotechnology applications, I have chosen to divide biotechnology applications into those for field crops, those for livestock products and those for food processing.

A. Field Crops

In the field crops sector, plant tissue culture and related biotechnologies are already in wide spread use and have enhanced the germ plasm selection process by increasing the size of the plant population from which selection can occur as well as reducing the time cycle for producing new generations of plant material. This gain in diagnostic and selection capability occurs even when genetic engineering processes are not involved. The major expected effects of these "diagnostic and R&D process" related applications are mainly those of (1) sustaining and, in some cases, accelerating the rate of genetic gain in germ plasm, (2) consolidating the private sector agricultural germ plasm industry into a sector with fewer, larger and more capital intensive firms, and (3) generating incentives for the integration of seed and chemical firms via both contracting and mergers. For example, both chemical firms and seed companies have mutual interests in the development of herbicide resistant crop varieties. Moreover, because of the increased sophistication and higher cost structure for R&D, recent indications are that only a very small number of very large chemical firms such as Du Pont and American Cyanamid, will compete in the future market for plant growth regulators. This leaves open the questions of how, and under what transfer policies and costs, some new technologies will be made available to crop producers. One major conclusion is, I believe, that partly as a consequence of the expected future importance of the emerging biotechnologies and other R&D developments, we are seeing and will continue to see a major restructuring in the manufacturing and distribution sectors for farm chemicals and germ plasm for field crops.

The farm production sector for field crops, however, is another story. My personal inclination is to agree in large part with the recent OTA projections for annual yield gains for major field crops which are summarized in Table 1. These numbers suggest that, except for cotton, new technologies will not accelerate the annual rate of yield gain to the year 2000 compared to that for the historical period 1960-82. Moreover, yield gains expected for cotton between now and the year 2000 are only in modest part a product of the emerging biotechnologies. And to fully understand the slow rate of <u>average</u> yield gains for cotton since 1960, it is necessary to break out the acreages and yields for that crop by major production regions and to evaluate the differential rate of yield gains between regions. One rather pervasive conclusion from these yield projections is that, barring a major unexpected surge in real grain prices, it will be after the year 2000 before the emerging biotechnologies have major yield impacts on the large acreage field crops. To the extent which biotechnology induced yield gains do occur in the near term, they will mainly serve only to offset expected declines in

the rate of yield gains attributable to chemical and mechanical technologies, particularly fertilizer. The results are expected to be quite different for many smaller acreage specialty crops, particularly those such as tomatoes where the fruit composition can be modified in a major way through application of biotechnology. In the latter case, the prospects are strong for increased integration between the firms developing and supplying improved germ plasm and the commercial producers of these specialty crops.

Table 1. Historical (1960-82) and Projected (1982-2000) Rates of Annual Growth in Crop Yields

	Actual 1960-1982	Projected 1982-2000
Corn	2.6%	1.2
Cotton	0.1	0.7
Rice	1.2	0.9
Soybean	1.2	1.2
Wheat	1.6	1.2

SOURCE: OTA, March, 1986.

B. Animal Products

In the animal products sector, a broad range of applications of the emerging biotechnologies are underway. These include those in animal genetic engineering, animal reproduction, regulation of growth and development, nutrition, disease and pest control and others. Some of these applications have been abetted by being extensions of R&D initiated in the fields of human health and nutrition. As in the case of plants, many of the initial animal applications are for diagnostic purposes although applications in reproduction and in monoclonal disease vaccines have also been significant. Moreover, barring regulatory and/or policy constraints, animal growth hormones will have significant economic impacts within the next two to five years. In order to assess the likely impact of these new technologies on the animal products sector, it may be useful to first look briefly at the current economic status of that sector.

The animal products sector has been impacted in a major way in recent years by a decline in per capita consumer demand for red meat, eggs and animal fats. At the same time per capita consumption of poultry meats has increased sharply. While per capita demand for animal products in the aggregate has declined, the poultry, swine and cattle feeding

components of the sector have all seen substantial structural changes into larger, more labor efficient and more capital intensive production units. And, many smaller, less efficient production units have gone out of existence. Thus it is mainly in the beef cow-calf sector that numerous smaller, more labor intensive production firms remain, many in conjunction with part-time farming.

As a result of declining per capita demand, the red meat subsector has experienced substantial excess capacity since the size of the national beef cow herd peaked at more than 45 million head in 1975. And, any major future increases in aggregate demand for livestock products from current levels probably must come from a successful penetration of the export market by one or more of the major livestock product components. Although this does not appear to be a likely near term development, significant product changes via the emerging biotechnologies could change this picture.

Despite the above described fairly stagnant future demand scenario and, probably at best, constant future real prices for animal products, there is a prospect for important applications and major near term productivity gains from the emerging biotechnologies. Increased rates of genetic gain are already available via embryo transfer and related reproduction technologies. Bovine growth hormone is already a technical accomplishment and other animal growth hormones are in experimental stages. Thus, in the absence of regulatory constraints, both meat and milk production are probably on the verge of rather significant increases in rate of gain both per animal and per unit of feed. How well one projects the future economic impacts of these new technologies relates closely to how well one projects the incidence of regulatory constraints on the adoption of these technologies. My inclination is to think it will be difficult to impose constraints on technology use for economic policy reasons only. But policy induced constraints on the use of bovine growth hormone will likely receive intensive discussion in the near future. In the absence of regulatory or policy constraints, I am inclined to project a rather major impact deriving from the use of animal growth hormone inputs. The result will probably be a modest decline in feed inputs and a larger decline in animal numbers, particularly dairy cows. Table 2 shows the actual 1982 and OTA estimated year 2000 production efficiencies for selected animal product groups. My inclination is to believe that the projected gains in feed/meat conversion factors for beef and swine in Table 2 may be on the low side and the milk production per cow on the high side. None-the-less, all indications are that in the absence of major gains in export markets, both animal and livestock producer numbers will decline significantly by the year 2000 from their current levels. Moreover, production management requirements will be increased due to increased sophistication of technology including biotechnology applications, increased environmental controls and computerized decision making.

Table 2. Estimates of Animal Production Efficiency

	Actual 1982	Projected 2000
Beef:		
lbs meat/lb feed	.07	.072
calves/cow	.88	1.0
Dairy:		
lbs milk/lb feed	.99	1.03
milk/cow (1000 lbs)	12.3	24.7
Poultry:		
lbs meat/lb feed	.40	.57
eggs/layer/year	243	275
Swine:		
lbs meat/lb feed	.157	.176
pigs/sow/year	14.4	17.4

SOURCE: OTA, March, 1986.

At the same time that some important biotechnology applications are imminent in the domestic livestock products sector, some other applications which have received a good deal of publicity, such as a new foot-and-mouth disease vaccine, will probably have relatively negligible economic impact over the near term pending resolution both of remaining technical problems and of implementation strategy issues.

C. Food Processing

On a simple numerical count basis, current and potential applications of the emerging biotechnologies in food processing probably exceed all others in the agricultural and food industry. These applications include those for both traditional food processing and for new product development and differentiation.

Among the biotechnology products for the food industry are those of: amino acids; vitamins; enzymes; improved organisms (yeast and bacteria); low calorie products; microbial polysaccarides; flavors, fragrances and colorants; single cell protein and food testing kits (Newell and Gordon in Biotechnology in Food Processing edited by Harlander and Labuza, 1986). It is already clear that in order to compete in today's food products market, all major food processing firms must have state-of-the-art biotechnology capabilities.

But, although these biotechnology applications portend dramatic future changes for the food processing industry, they probably will not affect the agricultural input and production sectors in a major way in the near term. Over the longer term new food products could, of course, have major effects on the effective demand for farm produced agricultural products. And, not all of these changes can be expected to be favorable to the existing farm production sector.

Summary of Future Economic Impacts

Given the broad diversity of expected applications of the emerging biotechnologies to the agricultural and food industry and the uncertainties surrounding the regulatory environment for both new biotechnology processes and products, any projection of economic impacts is at best highly speculative as is the projection of the timing incidence of these impacts. However, once successful applications of the emerging biotechnologies are made they will be quickly transferred not only throughout the U.S. but throughout a sophisticated international market system as well. Numerous projections have been made of the worldwide market for biotechnology via agriculture and food processing products. Some of these projections are shown in Table 3.

Table 3. Forecasts on Size of Worldwide Market for Biotechnology - Agriculture and Food Processing Products

Source	Year	$ (in millions)
Arthur D. Little	1990	2,000-4,000
Business Communications Co.	1990	430
Policy Research Corp.	2000	50,000-100,000
Predicasts, Inc.	1985	6,200
	1995	101,000
Strategic, Inc.	1990	4,500
	2000	9,500
T.A. Sheets & Company	2000	21,300

SOURCE: Newell and Gordon in Biotechnology in Food Processing edited by Harlander and Labuza, 1986.

Some of these projections are very large numbers and they have a large coefficient of variation associated with them. Moreover, many of the products involved will be only modest modifications of existing products. Thus, my inclination is to avoid playing the numbers game. Rather, I will limit my summary of economic impacts to the following modest generalizations.

Selected components of the farm supply and food processing industries are already being impacted in a major way by the emerging biotechnologies. But, with the exceptions of growth hormone applications for dairy and meat animal production, and herbicide resistance for some crops, economic impacts on most agricultural producers are likely to be rather minimal and evolutionary for several years. Even these evolutionary changes in the technical complexity of agricultural production systems, however, will result in even further increases in the size and degree of specialization in farm enterprises. In short, farming will become even more high tech than it now is and successful managers will need to adjust accordingly. Producers of some specialty crops will likely face increased product specifications as a result of biotechnology applications. And, over the longer term, quality tolerances for meat producers will likely tighten as well. But the latter product constraints do not appear imminent.

In the farm supply industry, not all participants will need to add biotechnology capability within their own firm. But, many will need to develop effective organizational or contractual relationships with firms that do. This is particularly true for the farm chemical and seed subsectors.

Finally the current surplus supply-low price economic environment for farm commodities has slowed the rate of investment in agricultural R&D, including that for biotechnologies, from what it would have been with a continuation of the high price-rapid demand expansion scenario of the 1970's. But over the longer term, the technical barriers are being removed for a broad range of new biotechnology applications which will have major economic impacts on agricultural production systems no later than early in the next century.

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