Potential Economic Impacts of Agricultural Biotechnology

An integral part of modern society is the socio-economic change associated with scientific advance. Biotechnology promises potentially significant changes in agricultural production and food processing. Emerging applications of biotechnology to crop and livestock production are capturing the attention of researchers, the business community, farmers, policy-makers, and various special interest groups. Yet, surveys indicate that many people are unaware of agricultural biotechnology, while others are concerned about its potential negative impacts on food safety, small farmers, and rural communities (Office of Technology Assessment, 1985, and Hassebrook and Hegyes, 1989).

Four fundamental questions appear to surround the agricultural biotechnology debate: Is it safe? Is it ethical? Who wins? Who loses? This paper focuses on the latter two questions: Who wins? Who loses? More specifically, some of the potential socio-economic impacts of agricultural biotechnology on farmers and consumers are addressed.

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The paper is divided into three parts. First, a few crop, livestock, and food processing examples of biotechnology applications are very briefly reviewed to place in context the subsequent discussion of the socio-economic issues. Next, some of the socioeconomic implications for farmers and consumers are addressed. Then, a few of the technology assessment research and extension issues are outlined. The paper closes with a few concluding comments.

Some Examples of Biotechnology Applications

Our discussion of the potential economic implications of agricultural biotechnology must be cast in the context of an often emotionally and politically charged and technically and economically difficult paradox: too much food for a few in the developed countries and too little food for many in the developing countries where 85 percent of the world's population lives. Feeding a growing world population has been a concern of agriculturalists and others for centuries. During the past several decades, scientists, farmers, the agribusiness sector, and government agencies have worked together to achieve enormous agricultural productivity increases, especially in the more developed economies. Often this has resulted in surpluses and extensive and often costly, government efforts to restrict production and support farm prices and income. Yet, the world population has passed the 5 billion mark and is expected to double by the mid-21st century. The challenge before us is to increase agricultural production to meet the growing world-wide demand for food without harming the environment and without exhausting nonrenewable resources. Furthermore, this must be accomplished in a world where countless agricultural and trade policy distortions exist. These are currently under discussion in the General Agreement on Tariffs and Trade (GATT) negotiations in Geneva, Switzerland.

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Biotechnology holds promise for contributing to additional agricultural productivity increases. But it is important to remember that biotechnology tools complement and extend, rather than replace, traditional methods used to enhance agricultural productivity and to develop new production systems. While some see biotechnology as a revolutionary development, others, including myself, see the development and application of biotechnology tools as an evolutionary process in a stream of agricultural technology developments that began with the mechanical inventions of McCormick and Deere and the genetic discoveries of Mendel. But, of course, modern agricultural production and food processing systems have their earliest roots in humankind's domestication and genetic selection of plants and animals and food fermentation processes that span many centuries.

In plants, genetic engineering can be used to enhance classical breeding. Engineering plant resistance to herbicides, insects, diseases, and environmental stress shows great promise. Excessive or improper herbicide and insecticide use can cause environmental damage. Altering the genetic makeup of plants to render them resistant to insects will lessen the need for chemical insecticides. Except for some concern about possible buildup of insect resistance to genetically-altered plants, there is relatively little controversy about the development of insect-resistant plants and bioinsecticides.

Controversy is growing concerning the development of herbicide-resistant plants, however. The critics suggest that this will result in more herbicide use and more soil and water pollution (Hassebrookand Hegyes, 1989, p 26). They also worry about excessive dependence on monoculture of row crops such as corn or cotton, rather than the use of rotations that include nitrogen-fixing legumes and biological weed and insect control techniques. The critics fear that the development of herbicide-resistant crops will not encourage a more sustainable agricultural system. In contrast, advocates claim that with herbicide-resistant plants, more environmentally benign herbicides can be used. They believe that fewer and less toxic compounds will be applied. Frequently, this debate centers around who will control the technology, i.e., what control the agricultural chemical and seed companies will have (Doyle, 1985).

In animals, biotechnology has already made economically feasible the use of bovine somatotropin (BST) to increase milk production and feed efficiency in dairy cattle. Milk productivity increases in commercial herds of 10 to 15 percent are anticipated with a 5 to 10 percent increase in feed efficiency. Use of porcine somatotropin (PST) and ractopomine, two swine repartitioning agents, can result in leaner pork and more efficient feed conversion. Research trials have reported increases in rate of gain of 10 to 45 percent, feed efficiency increases of 15 to 35 percent, backfat reductions of 15 to 70 percent, and increases in loin-eye of 10 to 50 percent. Other promising applications of biotechnology to animal agriculture include disease diagnostic probes, embryo transfer, and genetically-engineered vaccines (Riepe and Martin, 1989).

Thus tar, there seems to be less controversy surrounding the applications of biotechnology to food processing. This is somewhat surprising given the growing national interest in nutritious diets and food safety.

Some believe that biotechnology will have its greatest impact on increasing food processing efficiency. There are several ways this could be achieved: altering raw materials, such as the water content of tomatoes;

altering enzymes and microorganisms used in bioprocessing, such as chymosin for cheese production; or discovering new uses for food processing wastes, such as whey from cheese production. Thus far, there seems to be less controversy surrounding the applications of biotechnology to food processing. This is somewhat surprising given the growing national interest in nutritious diets and food safety. Yet, much of the diet debate has been on cholesterol and red meat consumption, fiber intake and oat bran consumption, weight control and exercise programs, and fat and calorie intake. Much of the food safety debate has been on pesticide residues. This may change, however, as biotechnology is increasingly used to alter the ingredients in processed foods and food processing techniques. A current example of this are the concerns raised by some about the safety of milk from BST-treated cows.

Producers and Consumers

Many biotechnology innovations will be cost-reducing which will benefit farmers and food processors initially. However, consumers can ultimately benefit through lower prices and improved food quality and variety. This has been the pattern of most agricultural technology adoption over the past one-half century or more (Cochrane, 1979). However, the magnitude and distribution of these potential cost-saving benefits to producers and consumers will depend on the nature of the technology, its review and approval by government regulatory agencies, its acceptance by producers and consumers, the market structure for the commodity or food, and regulations in the food industry. Consumers will benefit more in relatively competitive markets with price inelastic demand functions.

Much of the concern over agricultural biotechnology is directed towards its potential to accelerate the long time trend towards fewer and larger production units (Office of Technology Assessment, 1985). This trend may increase the influence of large corporations on the decision-making and fate of farmers and residents of rural communities. Technology-driven changes in farm structure are not new. Over the past 3 decades the number of farms in the United States has fallen by 45 percent from 4 million in 1960 to 2.2 million in 1990, while average farm size has increased by over 50 percent. Concurrently, the farm population declined from 19 million to 5 million, i.e., from about 9 percent to 2 percent of the United States population. Also, farm employment declined from 7 million to 2.8 million people (Council of Economic Advisers, 1990 and United States Department of Agriculture, 1974 and 1989). The controversy surrounding BST in the dairy sector offers an object lesson in the biotechnology and structural change debate (Sun, 1989). Mechanical milking machines, artificial insemination, nutrition research, and other innovations have pushed average milk production per cow from 5,842 pounds in 1955 to 14,244 pounds in 1989, about a 2.5 percent annual increase. Since cow numbers fell by about one-half from 21 million to 10.3 million during this period, the total milk supply increased only about 0.5 percent annually. However, during the most recent 15-year period increases in milk production per cow and total milk supplies both have grown about 2 percent annually. A recent United States Department of Agriculture (USDA) study estimates that with a dairy price support of $10.10 per hundred weight (cwt) and the introduction of BST, the annual increase in milk productivity per cow would be about 3 percent and the annual increase in the total milk supply would be about 1.5 percent (Fallert *et al.*, 1984). These anticipated increases in milk production and productivity due to BST are not significantly different from the impacts of past dairy technologies. The interpretation of the above data for the dairy sector depends, in part, on one's policy goals and value system. The critics of the introduction of BST emphasize that, in most years, milk has been in surplus, and that in the early-1980s the federal government spent about $ 2 billion annually to support the price of milk through Commodity Credit Corporation removals of cheese, butter, and nonfat dried milk (United States Department of Agriculture, 1990). Despite these government programs with relatively high milk price supports, the number of farms with milk cows has declined from 1.8 million in 1959 to 202,068 in 1987 (United States Department of Commerce, Bureau of the Census). Those who have left the dairy industry generally have been the smaller, less efficient producers, poorer managers, those with less access to capital, or those less able to make technological adjustments. A coalition of consumers, save the family farm advocates, and critics of biotechnology have successfully influenced legislation in Wisconsin and Minnesota that placed a temporary moratorium on the use of BST

On the other hand, advocates of BST emphasize that most technological advance begins with early adopters who benefit from the new technology by increasing production efficiency, reducing per unit production costs, and increasing per unit profits. Eventually, competitive pressures encourage a wider adoption of the new technology and the efficiency and cost-saving attributes of the technology are passed on to food processors and consumers in the form of lower prices and more abundant supplies.

The advocates of BST claim that this technology is just the latest in a long stream of new technologies in the dairy sector that has influenced the structure of the dairy industry and resulted in a more efficient, competitive dairy sector, with most of the economic benefits eventually being passed on to consumers. Advocates of BST also note that it is not a capital-intensive technology such as the installation of milking facilities, but a relatively inexpensive variable cost of production. However, BST use will require excellent production, record keeping, and financial management skills.

Both critics and advocates of BST recognize the influence that government dairy price support policy has had on the rate of structural change in the dairy sector and on taxpayer costs. Where they disagree is on the desirability of further structural change in the dairy industry and on whether consumers will actually realize any benefits from the technology. Food and environmental safety and government program costs also are sometimes mentioned.

There are some interesting similarities and differences between the public debates over biotechnology products in the swine and dairy sectors. Although PST and ractopomine also are awaiting Food and Drug Administration (FDA) approval in the near future, there has not been the public outcry as in the case of BST. This may be because of less media attention, because pork is not associated with mothers and babies as is milk, or because consumers want leaner pork with less fat. The application of these new technologies in the swine sector will offer larger supplies of cheaper, leaner pork and make pork more competitive with beef and chicken at the retail-level.

The swine industry in the United States has experienced considerable structural change as evidenced by a 50 percent reduction in the number of hog producers over the last 10 years. Potential structural changes in the hog sector due to biotechnology parallel those of the dairy sector, i.e., early versus late adopters, additional management requirements, and increased competitive pressures (Riepe and Martin, 1989). It is also important to examine the effects of a new technology on the input markets such as the demand for various feeds when BST is introduced into the dairy sector or PST and ractopomine into the swine sector (Kuchler and McCelland, 1989).

There has been less assessment of the economic implications of the application of biotechnology to crop production and food processing. In many cases the farmer, and consumer, will not even be aware that a biotechnology tool has been used. An example might be restriction fragment length polymorphism (RFLP) techniques to assist conventional plant breeding programs in improving the disease resistance of a plant. These efforts to rapidly screen genetic material should reduce the research and development costs and time required to produce new varieties, and in this turn should help reduce seed costs to farmers. In other cases, such as insect- and herbicide-resistant plants, the agricultural chemical and seed companies will promote the sale of these genetically-engineered varieties as substitutes for current seed varieties and chemical pesticides.

The Research and Extension Agenda

Until very recently most technology assessment research by agricultural economists and rural sociologists was ex post analysis. Such studies examined observed adoption rates, surveyed farmers about their production practices and financial conditions, or calculated the benefits and costs associated with a technology that farmers had already adopted. (For more detail on technology assessment see Martin, 1990).

The challenge before us as a research community is to conduct ex ante research. Policy-makers and various public interest groups want to know more about a new technology before it is approved by a government agency. Information on efficacy, proper scientific testing protocols, and possible environmental impacts will continue to be an important part of the FDA or the Environmental Protection Agency (EPA) approval process. Furthermore, socioeconomic information, even though not part of the official scientific approval process, will be demanded by legislative and public interest groups.

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Such socioeconomic assessment requires much closer interdisciplinary cooperation among social scientists and biotechnology researchers. We must learn to speak each others' language, to write joint research proposals, and to publish in appropriate cross-disciplinary research journals and extension outlets.

Extension specialists must learn to treat biotechnology as a public policy issue much like we have treated agricultural policy. In the past, extension agents basically helped farmers adopt a new technology without much public discussion of its broader social and economic impacts. Today a much broader clientele wants to influence the development and adoption of agricultural biotechnology. There clearly are issues and choices that society must make through both the input and product markets as well as through the "political" markets.

A public policy extension approach that has been successfully used in many states involves public meetings where extension specialists help define the problem and explain policy choices. Furthermore, policy specialists provide objective technical and economic information on the implications of each of the potential policy choices. The goal of these public policy meetings is not to tell people what technology is best for them but to help them make more informed judgments as producers, consumers, and "voters" at the ballot box or through the lobbying process.

As scientists, we sometimes forget that few in society have the training or time to understand emerging scientific developments. Yet the public is a "consumer" of our "product". Ultimately, it is the public that adopts or rejects the products generated through our research. Moreover, their understanding and approval of what we do influences the allocation of tax dollars to support our research activities.

In a democratic society such as ours, we have an obligation to inform and involve the public in the process of scientific development and technology transfer. The public is no longer willing to accept self-regulation by scientists. But if we can provide objective, understandable information on the potential technical and socio-economic consequences of emerging agricultural biotechnologies, most people will be able to make rational, informed decisions.

For many of us this is a new role, and one which may take us away from our research laboratories. Yet it is critical, if the benefits of biotechnology are going to be enjoyed and the economic, social, environmental, and political costs minimized.

Concluding Comments

It is vital that the public becomes aware of and knowledgeable about the scientific advances of our day and the implications and issues surrounding these innovations. Biotechnology offers great potential to increase farm production and food processing efficiency, lower food costs, enhance food quality and safety, and increase international competitiveness. There are, however, potential environmental risks and adjustment costs that must be assessed.Careful evaluation of the likely benefits and costs of biotechnology can ensure the timely and reasonable application of these emerging technology developments in our society. This will require increased research cooperation among bench and social scientists from a wide range of disciplines. Moreover, we in the Land-Grant system must design and implement appropriate public policy extension programs to help the public better understand the technical and socio-economic ramifications of alternative choices before us as a society. If we fail in this task, controversy will grow and potential benefits to society will be lost. Yet, it is important to listen and respond objectively to those who are critical of biotechnology. Through this dialog we can perhaps avoid some of the errors or accidents that have occurred with new technologies in the past. Furthermore, by being sensitive to the concerns of those who do not understand or who fear the emerging biotechnologies, we may be able to design appropriate public policies to help people anticipate and adjust to changing market and structural conditions as the new technologies are introduced.

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