Chapter 1

# Summary

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# Summary

The dairy industry will lead U.S. agriculture into the biotechnology era of the 1990s, and also will feel the first profound impacts of emerging technologies. Recombinant DNA techniques, cell culture and antibody methods are but a few of the new biotechnology techniques that will produce technologies that will sustain or accelerate the historical 2-percent annual increase in milk output per cow.

Whereas farmers once had no choice but to pasture bulls with cows and let nature run its course, artificial insemination has provided a means of controlled breeding since about 1950. In the near future, farmers will potentially exercise even more control over herd reproduction and genetics and over the health and milk-producing potential of their animals, For example, embryos produced by in vitro fertilization (of ova from selected females with sexed sperm) and placed at predetermined times into the uteri of estrous-cycled animals can result in higher conception rates than are now obtained by artificial insemination. This will accelerate genetic gains. Monoclinal antibodies used as diagnostic agents will greatly reduce the cost, time, and labor required to maintain animal health. Bovine somatotropin produced with recombinant DNA technologies has the potential to greatly enhance milk production per cow.

The emerging biotechnologies will require considerable management expertise on the part of farmers. Information technologies will be powerful aids to farm operators. Expert systems, for example, make onfarm consulting accessible via a microcomputer and can aid farmers with decisions regarding management and new technology adoption.

Many biotechnologies will be controversial, most notably bovine somatotropin (bST). Although bST can boost milk yield per cow significantly---doing in 1 year what it would take 10 to 20 years to achieve with current reproductive technologies, concerns have been raised about its safety for humans and animals and about the economic consequences of its use for the industry. In response to these concerns, two States placed a moratorium on the use of bST if approved by the Food and Drug Administration (FDA); up to four States are seriously considering laws that would require milk and dairy products produced from bST-supplemented cows to be so labeled. Major retail food chains have curtailed sales of milk and dairy products from bST test herds even though FDA has approved their sale.

In addition, issues concerning science policy have been raised in conjunction with biotechnology—including bST. These issues include the social needs being met by these *new* technologies, the appropriateness of public sector investment in their development, and lack of information about benefits and risks of a new technology prior to commercialization. This report analyzes the major questions concerning the use and safety of bST, examines other technologies that will affect the dairy industry in this decade, and evaluates the economic and policy implications of these issues.

## AN EMERGING TECHNOLOGY: BOVINE SOMATOTROPIN (bST)

Some *50 years* ago, research showed increased growth rates in rats injected with a crude pituitary extract. Later it was discovered that the extract, which contains a protein hormone called somatotropin, also affects lactation, and research with lactating cows ensued. Prior to the 1980s, progress was slow in bST research because: 1) the availability of bST was restricted to that which could be extracted from pituitary glands of slaughtered animals, limiting studies to a few cows and short timeframes; and 2) the mechanism of action for bST was thought to be acutely stimulated use of body fat reserves: scientists believed it would only work in fat cows with a low milk yield. No studies used high milk-producing cows because it was assumed that acute mobilization of body fat reserves would cause ketosis[1] and other adverse health effects.

In the late 1970s, new research showed that the physiological basis for more efficient milk production in genetically superior cows was better use of absorbed nutrients. Scientists recognized the need for new concepts regarding nutrient regulation in

[1] A metabolic disorder which occurs when production of ketones exceeds the ability of the body to use them. Occurs in dairy cows when the need for glucose exceeds the production of glucose.

animals. Recent work has demonstrated that somatotropin exerts key control over nutrient use. When administered exogenously, bST markedly improves productive efficiency in lactating cows. In the last decade, as the important role of somatotropin has been established, bST produced by recombinant DNA technology has replaced pituitary-derived bST in research with cows. Since that time, the quantity and scope of the research with bST has increased exponentially.

### *Production Response*

The impact of bST on milk production will vary according to quality of management on individual farms, but a reasonable expectation is that successful adopters would experience, on average, a 12-percent boost in production. However, the increase in output per cow tends to be absolute (in number of pounds) rather than proportional to normal production. Thus, approximately the same increase in pounds of milk produced might be expected (in comparably managed herds) from all cows producing 12,000 to 20,000 pounds of milk per year. Supplementation with bST not only results in an immediate increase in milk yield, it also reduces the normal decline in milk yield during the lactation period.

Because bST is rapidly cleared from the bloodstream and is not stored in the body, exogenous bST is needed every day to sustain the increase in milk yield. This requires daily injections or use of a prolonged release formulation of bST. Several prolonged release formulations have been developed and are administered by subcutaneous injection at intervals ranging from 2 or 4 weeks.

Obtaining a milk response to bST does not require special diets or unusual feed ingredients. Substantial milk responses have been observed on diets ranging from pasture to the more typical forage/concentrate diets used in the United States. However, voluntary intake of feed increases in bST-supplemented dairy cows. This increase in voluntary intake occurs after a few weeks of bST supplementation and persists throughout the interval of bST use. It has been consistently observed across a wide range of diets.

Poor management results in a near zero response from bST supplement. Facets that contribute to the quality of management (and milk response to bST) include the herd health program, milking practices, nutrition program, and environmental conditions.

### *Food Safety Considerations*

Somatotropin is produced by the anterior pituitary gland and is transported by the blood to various body organs where it has certain biological effects. If somatotropin is given orally it is broken down to its constituent amino acids in the digestive process just like any other dietary protein. Thus, somatotropin must be injected to be biologically active.

Somatotropin is species-limited, and the biological effects of somatotropin from one species on others varies. In order to have any biological effect, a protein hormone first must bind to a specific cell-surface receptor. Studies have shown conclusively that due to its unique three-dimensional shape, bST does not elicit any of its normal biological actions in humans even if injected.

Recombinantly derived bST products may differ slightly from the bST produced by the pituitary gland because in the manufacturing process a few extra amino acids can become attached at the end of the bST molecule. The number of extra amino acids varies from one to eight depending on the particular manufacturing process. Some manufacturing processes produce no additional amino acids. The additional amino acids that may be produced do not change the three-dimensional shape of the active part of the molecule and, hence, do not alter the biological activity of bST in dairy cows or the lack of activity of bST in humans.

Some biological actions of somatotropin in cows may be mediated by insulin-like growth factor 1 (IGF-1). This protein hormone, a member of the somatomedian family, normally occurs in trace levels in milk and also in human saliva. Administration of bST to dairy cows augments IGF-1 in milk, but the levels are still within the range typically observed in early lactation of untreated cows. Similar to results with bST, studies with laboratory animal models have demonstrated that IGF-1 has no biological activity if administered orally. The importance of increased amounts of IGF-I in milk from bST-treated animals is uncertain. However, the amount of IGF-I ingested in 1 liter of milk approximates the amount of IGF-I in saliva swallowed daily by adults.

### Effect on Milk and Meat Composition

***The*** overall composition of milk (fat, protein, and lactose content) and meat is not substantially altered by bST supplementation. There can be minor changes, primarily in fat content of milk during the first few weeks of bST supplementation as the cow's metabolism and voluntary feed intake adjust. However, these changes are temporary and within the standard variation that occurs naturally during a lactation cycle. The meat derived from treated cows has a lower fat content but is otherwise identical.

In manufacturing characteristics, milk from bST-supplemented cows does not differ from the milk of untreated cows. Characteristics that have been evaluated include freezing point, pH, alcohol stability, thermal properties, susceptibility to oxidation, and sensory characteristics, including flavor. Similarly, no differences were observed in cheesemaking properties, including starter culture growth, coagulation, and acidification or in the yield, composition, or sensory properties of various cheeses.

### Effects on Bovine Reproductive Performance

Of special interest are bST effects on reproductive variables such as conception rate (services per conception), pregnancy rate (proportion of cows becoming pregnant), and days open (days from parturition to conception). As expected, cows administered bST show decreased pregnancy rates and increased days open; these changes are associated with increases in milk yield and occur regardless of whether or not the high milk yields are achieved using bST. The management of the reproduction cycle may need to be adjusted to account for these physiological changes. Conception rate is unchanged by bST supplementation.

### Effect on Bovine Health and Stress

Catastrophic effects such as the incidence of ketosis (underproduction of glucose), fatty liver, crippling lameness, milk fever (feverish disorder following parturition), mastitis (inflammation of the udder), sickness, suffering, and death have been postulated to occur with bST. However, no such effects have been observed with bST-supplementation of dairy cows in any scientifically valid published studies, nor have subtler health effects been in evidence. From the hundreds of investigations with bST, no study reported the lower milk yield and decreased productive efficiency likely to be associated with increased sickness and suffering. Relevant studies include short- and long-term research and both chronic and acute toxicity studies. In acute toxicity studies, dairy cows were given 30,000 mg of bST over a 2-week period, an amount of bST approximately equaling what would be administered in four lactation cycles.

Reduced resistance to infections has not been found to occur in bST supplemented dairy cows although such an effect has also been postulated. Indeed, basic biological studies have demonstrated that rather than reducing resistance to infection, somatotropin plays a key role in several aspects of maintaining immune competence.

Animal stress is more difficult to evaluate than disease, but several indices exist that demonstrate no stress effects due to bST supplementation. Dairy cows would be expected to produce less milk and to be less efficient if they are stressed. Several hundred studies utilizing bST demonstrate increased milk yield and productive efficiency. Studies have also clearly demonstrated that bST has no effect on the energy expended (as heat) for maintenance or for efficiency of milk synthesis.

### Commercial Introduction

***The*** FDA must approve bST before it can be sold legally in the United States. Each company seeking FDA approval to market bST must demonstrate that its product is effective (does what the company claims) and safe. The safety evaluation involves three areas:

1. safety of the animal-food products for humans,
2. safety of the bST-supplement to the target animals, and
3. safety of using bST in the environment.

In addition, FDA requires that each company prove that its manufacturing process can produce bST to consistent and acceptable quality standards.

FDA has determined that sufficient scientific information exists to indicate that the milk and meat from bST-supplemented cows is safe for human consumption, and has allowed for these animal products to be marketed from the test herds during the remainder of the investigational period.

In addition to the United States, many countries are reviewing bST for commercial use. In all countries where bST studies are being conducted, the appropriate regulatory agencies have completed the human safety evaluations and without exception, have found it safe for human consumption.

### *Product Labeling*

Some States are considering requiring all food products derived from the milk of bST-supplemented cows to be labeled as such in the marketplace. The basis for labeling seems to relate to a concern about the safety of the products for human consumption. At least two considerations need to be addressed.

First, is the scientific merit or basis for labeling. If there is a valid safety concern, then the food should *not* be marketed for human consumption. Labeling is not the appropriate method for handling a food safety concern. If the regulatory system to evaluate food safety is inadequate, then the system should be changed. Labeling does not excuse the inadequacy.

The second consideration is verification. An effective labeling program requires development and adoption of appropriate regulations and the establishment and funding of a system for implementation and verification. In the case of bST, no known test or technology exist that could be used to distinguish milk from bST-supplemented cows from milk from non-treated cows. Indeed, no change in milk composition as a result of bST supplementation was found in FDA human safety evaluations.

## OTHER EMERGING TECHNOLOGIES

There are a number of emerging technologies that will have a significant influence on the dairy industry in the 1990s in addition to bST. Advances in animal reproduction, animal health, and food processing are occurring, and many of the new technologies being developed use highly sophisticated and complex biotechnology methods. By comparison, the biotechnology methods used to produce bST are rather rudimentary; potentially some of these new technologies could make bST obsolete.

Animal reproduction technologies are advancing rapidly. Researchers have significantly improved their understanding of egg development in the ovary, how to stimulate the release of numerous eggs at once, and how to enhance the development and fertilization of eggs outside of the cow. Embryos can be frozen for later use. Both embryos and sperm can be sexed. It is possible to create multiple copies of an embryo, each of which can be transplanted into a cow whose reproductive cycle has been adjusted to be able to accept the embryo and carry it to term. These new technologies make it possible to improve herd quality more rapidly than can be achieved using traditional breeding methods.

It is possible to create transgenic cattle,[2] however, the techniques currently used are inefficient and require the use of thousands of eggs to produce one transgenic animal. These inefficiencies make it too expensive to produce and market transgenic livestock commercially. However, scientific breakthroughs are leading to the development of technologies that will improve the efficiency of transgenic animal production and substantially lower the cost of doing so. Transgenic livestock may become commercially available in small numbers by the end of the decade.

BST potentially could be supplanted by the development of transgenic cattle. Dairy cows can be developed to produce higher levels of bST so that daily injections or timed release formulations are no longer needed. Alternatively, genes that code for chemicals that suppress bST production can be altered in the cow such that a cow's normal bST production will increase.

New biotechnology products are also being developed to improve animal health. Products include new vaccines and diagnostic kits, as well as compounds that enhance an animal's ability to fight disease.

Not only are new biotechnology products being developed for use in livestock production, but they are also being developed for use in food processing. New products will improve the production of milk products such as cheese and yogurt. They can also be used to detect milk contaminants.

Effective use of these new technologies will place a premium on management skills. New information technologies are being developed to aid farm management. These new technologies can incorporate

[2] Animals whose hereditary DNA has been augmented by the addition of DNA from a source other than parental germplasm using recombinant DNA techniques.

individual farm data, with pertinent information from national databases, into computer programs that will aid farmers in the decisionmaking process.

These new technologies are in various stages of development. Some, such as embryo transfer, recombinant DNA vaccines, and information technologies are already available commercially or will be soon. Other technologies, such as transgenic cattle and advanced reproductive technologies, will not be available until the end of the decade. The collective effect these emerging technologies, including bST, will have on the economic and policy environment of the 1990s is examined next.

## ECONOMIC AND POLICY IMPACTS

### *Dairy Industry Trends*

Before discussing the economic and policy impacts that emerging technologies discussed above have on the dairy industry, it is important to consider the major economic trends already at work within the industry. Milk output per cow has been increasing at a very steady rate for many years. Output per cow has grown more rapidly than milk consumption per capita, resulting in a gradual trend toward reduced cow numbers.

Changes in output per cow vary regionally. The Pacific region's output per cow has been about 30 percent higher than the national average and 50 percent higher than that of the lowest producing region. Climatic conditions contribute to some of these differences, but the main factors seem to be related to progressiveness, philosophy, and quality of management demonstrated by different dairy farmers. These factors directly impact technology adoption and the size of dairy farms. Generally, larger dairy farms experience lower production costs. The Pacific Coast and Florida lead the Nation with herd sizes in the 500- to 1,500-cow range. The traditional milk producing regions of the Upper Midwest and Northeast are typically in the 50- to 150-cow range.

There is a corresponding variation in regional profits. The Pacific and Southeast regions realized favorable returns in 1988 ($1.05 per cwt and $1.94 per cwt. respectively) whereas the Upper Midwest and Corn Belt regions had negative returns (–$0.62 per cwt and –$0. 18 per cwt, respectively). Returns in the early months of 1991, however, are less favorable in all regions. Farm milk prices have declined significantly from January through March and are expected to fall by 15 to 20 percent for the year compared to 1990. Dairy farms in the traditional milk producing regions are expected to lose considerable equity under these conditions. Pacific and Southeast farms, although still profitable, are expected to operate much closer to their respective break-even points.

These differences have led to shifts in production patterns. The largest increases in milk production have been in the Pacific region where marketing have risen by nearly 40 percent. The traditional Upper Midwest and Northeast regions have each increased milk production about 5 percent. These traditional regions produce about half of the Nation's milk supply and will continue to be a major force in the dairy industry. But if the Upper Midwest and Northeast regions are to maintain their roles as the "dairy States," major changes in scale of operation, progressiveness in technology adoption, philosophy, and quality of management and perhaps dairy policy may be required.

### *Technology Adoption*

When emerging technologies, such as bST, become available commercially it is not known with any degree of certainty how many dairy farmers will use them or when. Farmers have been surveyed to project expected adoption levels once bST becomes available. Results indicate relatively rapid adoption—50-percent adoption within the frost year and at least 80-percent within 3 years.

However, these surveys may not be accurate indicators of prospective adoption. Many of the bST surveys were conducted prior to the availability of widespread information on bST. Most other dairy technologies, moreover, have not been adopted rapidly. Artificial insemination technology is used only by 70 percent of dairy farms despite being available for some 40 years. Dairy Herd Improvement technology, available for 50 years, is used by only 45 percent of farmers.

OTA's statistical analysis of historical rates of technology adoption by dairy farmers provides another basis for predicting bST adoption. The analysis found:

- A slower rate of adoption than suggested by producer surveys of farmers on probable bST use (17 percent or less the first year).
- Regional variations in rates of technology adoption in the dairy industry. Based on this, bST adoption after 5 years is forecast to be 40 percent in the Pacific region, where technology adoption is most rapid, and 25 percent in the Corn Belt. This and other traditional milk production regions tend to be slower to adopt new technologies.

## *National Impacts*

The interactions of technology adoption, dairy policy, and consumer reaction and their effects on future milk supply prices and returns to dairy farmers were captured using LIVESIM, a regional and national computer simulation model.[3] The policy options analyzed included a fixed price support, a price-support trigger, and a quota program. In all policy scenarios, the government purchases at least 3 billion pounds of milk annually to satisfy food-program needs (i.e.. school lunch programs).

### Fixed Price Support

**This** scenario frees price at the 1989 level of $10.6O per cwt. This serves as a useful bench mark for comparing other policy options. In this case, the government purchases excess milk, at the support price, in order to clear the market. Without bST, milk production would increase from the present level of 144 billion pounds to 152 billion in 1995. With bST, production would increase an additional 4 to 5 billion pounds over the period (see table l-l); government purchases would rise as high as 7 and 9 billion pounds in any one year, and overall would increase by 3 to 6 billion pounds over the minimum purchases of 3 billion pounds for food programs (see table 1-2).

### Trigger Price Policy

This option triggers a price-support reduction each time the level of government purchases rises above 5 billion pounds annually. This scenario is similar to the producer-assessment option in the 1990 farm bill because the assessment will effectively trigger reductions in producer returns through milk price declines. Without bST, a single price-support reduction is triggered to a level of $10.10 per cwt in 1991. With bST, two price-support reductions are triggered in 1991 and another in 1993 to a level of $9.60 per cwt. These price reductions moderate production increases to keep government purchases near the 3-billion-pound minimum.

### Quota Policy

A quota policy is another method to manage excess production. It establishes a level of milk production for each farm and provides effective disincentives to the farmer if production exceeds the quota. This might be accomplished by a two-tiered pricing system or some other mechanism that provides disincentives for producing over quota levels.

In the analysis, the quota policy was designed to maintain government purchases at or near the minimum government use target of 3 billion pounds. The quota was adjusted downward any year government expenditures exceeded 3 billion pounds. The results show that the quota avoids the high level of government purchases that result under the fixed price-support scenario (see table 1-2).

### Demand Reduction

While claims that consuming milk and milk products from cows supplemented with bST or other new technologies could adversely affect human health have not been substantiated, a range of food safety and other considerations will affect consumer purchases. Policy needs to be designed considering the full range of potential consumer response; accordingly two scenarios of reduced milk consumption were analyzed.

*Small Demand Reduction-In* this scenario, per-capita demand decreases by 10 percent in 1991, 5 percent in 1992 (i.e., demand increases from 1991 to 1992), and 2.5 percent annually thereafter. Government purchases total 21.2 billion pounds in the first year (1991), 9.7 billion in 1992, and 8.4 billion in 1993. The support trigger decreases the price-support level to 9.10 per cwt in 1994. Even though government purchases are high for 3 years, the trigger mechanism seems to accommodate a temporary demand reduction.

***Large Demand Reduction-The*** second demand scenario assumes a permanent 1 O-percent annual

[3] A major focus of the analysis is on the use of bST because of its effect on productivity and commercial availability in the early 1990s.

**Table l-l—Level of Milk Production, With and Without bST, Under Alternative Policy Scenarios, 1990-98 (billions of pounds)**

| | Fixed support | | Trigger | | Quota | |
|---|---|---|---|---|---|---|
| Year | With bST[a] | Without bST | With bST[a] | Without bST | With bST[a] | Without bST |
| 1990 | 144 | 144 | 144 | 144 | 144 | 144 |
| 1991 | 146 | 144 | 146 | 144 | 146 | 144 |
| 1992 | 146 | 143 | 146 | 143 | 145 | 144 |
| 1993 | 153 | 150 | 153 | 150 | 148 | 146 |
| 1994 | 153 | 149 | 152 | 148 | 150 | 148 |
| 1995 | 156 | 152 | 156 | 152 | 152 | 150 |
| 1996 | 157 | 153 | 155 | 153 | 155 | 153 |
| 1997 | 160 | 155 | 159 | 155 | 157 | 155 |
| 1998 | 161 | 157 | 159 | 157 | 160 | 157 |

[a]bST is assumed to be commercially available in 1991.

SOURCE: Office of Technology Assessment, 1991.

**Table 1-2—Level of Government Purchases, With and Without bST, Under Alternative Policy Scenarios, 1990-98, Milk Equivalent (billions of pounds)**

| | Fixed support | | Trigger | | Quota | |
|---|---|---|---|---|---|---|
| | With bST[a] | Without bST | With bST[a] | Without bST | With bST[a] | Without bST |
| 1990 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 1991 | 7.3 | 5.3 | 7.3 | 5.3 | 7.3 | 5.3 |
| 1992 | 4.3 | 3.0 | 3.0 | 3.0 | 3.5 | 3.0 |
| 1993 | 9.0 | 5.7 | 6.8 | 3.8 | 3.4 | 3.0 |
| 1994 | 6.0 | 3.0 | 3.0 | 3.0 | 3.1 | 3.0 |
| 1995 | 7.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 1996 | 4.8 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 1997 | 5.3 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 1998 | 3.6 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |

[a]bST is assumed to be commercially available in 1991.

SOURCE: Office of Technology Assessment, 1991.

reduction in per-capita consumption. The trigger mechanism does not easily adjust the industry under this scenario. The support price must be lowered to $7.60 in 1997 to bring government purchases below 4 billion pounds (see figure l-l). Such a low support price would make it difficult (impossible) for even the best managed dairy farms to avoid economic losses. A quota program or termination program (a one-time government buy-out of dairy herds) would be needed to bring government purchases back to the 3-billion-pound minimum. However, as this study shows, termination programs do not result in permanent reductions in supply. Quota programs can effectively reduce supply over a period of time. But with either program, approximately 1 million cows would need to be slaughtered causing beef prices to decline by 4 to 6 percent.

### Conclusions

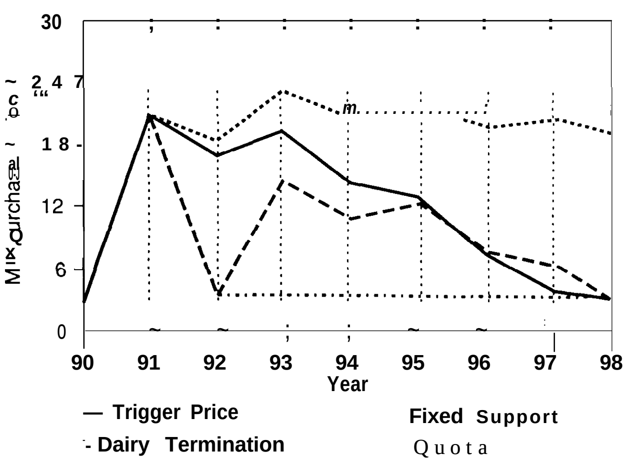
A mechanism such as the trigger price policy or producer assessments, which allow producer returns to decline as government purchases increase, could effectively adjust supply without excessively large inventory accumulations. However, if sharp reductions in demand accompany the introduction of bST, production quotas may be required. A quota policy, however, has some potentially harmful effects, including:

- higher production costs,
- elimination of dynamic adjustment within the industry,
- negative impact on beef cattle prices,
- difficulty of discontinuing, once initiated, and
- the capitalization of benefits into the quota.

### *Farm Level Impacts*

The effects of emerging technology, dairy policies, and consumer demand can be more easily visualized by analyzing the impacts on representative dairy farms. The farm-level impacts of the three policy scenarios-fixed price support, trigger, and quota---over a 10-year period were analyzed using FLIPSIM, a farm level simulation model.

**Figure I-l—Projected Impact of a 10-Percent Permanent Demand Reduction on U.S. Government Milk Purchases Under Alternative Dairy Policies, 1990-98**




SOURCE: Office of Technology Assessment, 1991.

## Adoption Incentives

Once bST becomes available, strong incentives will exist to adopt the technology. Payoffs from bST adoption are substantial, regardless of region (see table 1-3). Nonadopters of bST will have more problems surviving and will be more likely to exit the industry. Likewise, dairy farmers located in States that have a moratorium on adoption will be placed at a substantial disadvantage relative to those in States where a moratorium does not exist.

### Regional Competitiveness

Several reasons for regional shifts in milk production patterns can be seen in tables 1-3 and 1-4. Upper Midwest farms have problems realizing sufficient earnings to achieve a reasonable return on equity, compete, and survive. While Northeast farms perform 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.

## Policy Impacts

**The** fixed price-support policy, with its higher earnings, increases the probability of farm survival and the chances of earning a 5-percent return on initial equity (see table 1-5). While Upper Midwest dairies are able to maintain cash flow, net worth continues to erode on the 125-cow Upper Midwest dairy due to the relatively high investments in fixed assets (buildings, equipment, etc.).

From the producer standpoint, the quota program does not perform as well as the trigger price or freed price-support programs. This is because the quota price objective is the same as the fixed price support ($10.60) and because restrictions on output curb expansion and raise production costs. To maintain dairy farm income under a quota system, the price objective must be sufficiently high to offset the effects of lower production—and this will result in higher prices to consumers.

The economic payoff from bST adoption is about the same for a trigger price policy and a freed price-support policy. However, all the representative farms experienced at least a 20- to 40-percent decrease in economic payoff under a quota compared to the trigger price policy. Adoption of bST would be slowed by imposing a quota as opposed to the trigger price policy.

Even with reduced demand, strong incentives would exist f-or all farms in all regions to adopt bST. With the continuation of the current trigger policy, a 52-cow Upper Midwest dairy's probability of survival declines under a small decrease in demand, but is relatively enhanced by adopting bST (see table 1-6). The same is true for the larger dairies. If a major decrease in demand occurs, small and large dairy farms in the Upper Midwest will be most vulnerable.

### Increased Pressure on Traditional **Farms**

A major controversy concerning bST is that it will force many dairy farms out of the industry, especially in traditional milk-producing regions. BST alone, however, will not force these traditional farms out of existence. As discussed earlier, the trend toward fewer total cows and larger farms has been underway for many decades. This trend is a result of the combination of emerging technology, industry economics, and policy. The trend will no doubt accelerate in the 1990s as the result of the combination of bST and other cost-reducing technologies and a more market-oriented dairy policy. As has been the case for years, such changes inherently puts increased pressure on traditional dairy farms. These pressures are not new, although they are accentuated by technological change.

If policymakers decide to change or at least slow this trend toward fewer but larger farms, changes in policy will be needed. First, to reduce the magnitude

## Table l-3—impacts of bST Adoption on the Economic Viability of Moderate-Size Representative Farms, Assuming No Change in Demand for Milk Due to bST, Trigger Price Policy, by Region, 1989-98 (in percent)

| | 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[a] | 58% | 74% | 10070 | 100% | 950/0 | 97% | 100% | 100% |
| Probability of earning 5-percent return on equity | 58 | 74 | 100 | 100 | 95 | 97 | 100 | 100 |
| Probability of increasing equity[b] | 0 | 0 | 3 | 3 | 60 | 79 | 13 | 24 |
| Present value of ending net worth as percent of beginning net worth[c] | 16 | 29 | 72 | 77 | 109 | 128 | 76 | 89 |

[a]Chance that the individual farm will remain solvent through 1998, i.e., maintain more than a 10-percent equity in the farm.
[b]Chance that the individual farm will increase its net worth in real 1989 dollars through 1998.
[c]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, 1991.

## Table l-4—impacts of bST Adoption on the Economic Viability of Large Representative Farms, Assuming No Change in Demand for Milk Due to bST, Trigger Price Policy, by Region, 1989-98 (in percent)

| | 125-cow Upper Midwest | | 200-COW Northeast | | 1 ,500-cow Pacific | | 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[a] | 9570 | 99% | 100% | 100?40 | 10070 | 100?40 | 100% | 1 00% |
| Probability of earning 5-percent return on equity | 90 | 95 | 99 | 100 | 100 | 100 | 100 | 100 |
| Probability of increasing equity[b] | 8 | 12 | 43 | 53 | 100 | 100 | 88 | 99 |
| Present value of ending net worth as percent of beginning net worth[c] | 57 | 69 | 92 | 102 | 195 | 214 | 129 | 147 |

[a]Chance that the individual farm will remain solvent through 1998, i.e., maintain more than a 10-percent equity in the farm.
[b]Chance that the individual farm will increase its net worth in real 1989 dollars through1998.
[c]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. 1991.

**Table I-5—impacts of bST Adoption on the Economic Viability of Representative Large (1 25-cow) Upper Midwest Farms Under Alternative Dairy Policies, Assuming No Change in Demand for Milk, 1989-98 (in percent)**

| | Trigger price | | Fixed price support | | Quota | |
|---|---|---|---|---|---|---|
| Measure of impact | Non-adopter | bST adopter | Non-adopter | bST adopter | Non-adopter | bST adopter |
| Probability of survival[a] | 95% | 99% | 99% | 100% | 85% | 920/. |
| Probability y of earning 5-percent return on equity | 90 | 95 | 95 | 98 | 67 | 78 |
| Probability of increasing equity[b] | 8 | 12 | 11 | 18 | 2 | 3 |
| Present value of ending net worth as percent of beginning net worth[c] | 57 | 69 | 67 | 78 | 37 | 46 |

[a]Chance that the individual farm will remain solvent through 1998, i.e., maintain more than a 10-percent equity in the farm.
[b]Chance that the individual farm will increase its net worth in real 1989 dollars through 1998.
[c]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, 1991.

of adjustment the rate of technology adoption by traditional farms would need to be increased. This would require additional expenditures on public research and extension with the specific goal of enhancing the survivability of these farms. During times of rapid technological change, research and technology adoption strategies for traditional farms need to be developed and implemented by USDA, land-grant universities, and dairy cooperatives if these farms are to survive.

Second, dairy policy may need to change back to a fixed price-support policy. As seen in the previous analysis, a fixed support policy enhances the traditional farm's probability of survival compared to other policies. It is, however, significantly more costly to the government than current policy.

It is possible to at least slow the trend toward fewer total cows and larger dairy farms. However, such change may be costly. As noted, to keep less progressive traditional farms in the industry will require increased expenditures for research and extension to improve technology adoption and increased funds to support the price of milk at a level that will allow these farms to compete. Policymakers will need to weigh the benefits of traditional farms with these costs in determining the policy path to follow in the 1990s. This is particularly the case for dairy farms outside the areas with a comparative advantage in dairying where a large share of feed supplies are purchased.

### *Science Policy and Emerging Technology*

***The*** controversy surrounding biotechnology—including bST—raises questions concerning what social needs are being met by these technologies and the appropriateness of public sector investment in their development. The questions raised point to the need for broadbased, ex ante information concerning new technologies. Presently, little information about new technologies is available prior to commercialization. There is no institution within the agricultural science policy community that develops information on the benefits and risks of any technology ex ante. There also is no formal structure that provides input to decisionmakers from all affected parties (farmers, marketers, researchers, consumers, etc.). Thus there is no comprehensive information about the benefits and risks of a new technology prior to commercialization and, therefore, no inclusive criteria to determine how public research resources should be allocated.

The development of an institutional framework to provide and act on such information is needed. Had such an institution been in existence a decade ago, it is possible that the bST controversy could have been avoided or minimized. Consideration of the costs and benefits of new technologies and input from a wider range of clientele could lead decisionmakers to consciously choose a different allocation of public sector research funding than that which occurs in the absence of such information.

Clearly, all benefits and risks of new technology development cannot be determined a priori, and overcentralization of research decisionmaking raises legitimate concerns. Care must be taken in establishing such an institution. However, a broad based discussion of issues involving all relevant users of new technologies can point to potential problems, determin e further research needs, and provide information about the relative social benefits to be gained

Table I-6—impacts of bST Adoption on the Economic Viability of Moderate-Size Representative Farms, Assuming Small Decrease in Demand for Milk Due to bST, Trigger Price Policy, by Region, 1989-98 (in percent)

| | 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[a] | 40% | 480/0 | 1009!0 | 1009!0 | 88% | 94% | 99% | 100% |
| Probability of earning 5-percent return on equity | 40 | 48 | 100 | 99 | 88 | 94 | 89 | 94 |
| Probability of increasing equity[b] | 0 | 0 | 1 | 2 | 35 | 51 | 4 | 9 |
| Present value of ending net worth as percent of beginning net worth[c] | 3 | 10 | 65 | 70 | 79 | 99 | 58 | 71 |

[a]Chance that the individual farm will remain solvent through 1998, i.e., maintain more than a 10-percent equity in the farm.
[b]Chance that the individual farm will increase its net worth in real 1989 dollars through1998.

[c]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, 1991.

by investments in competing technologies. The seeds of such a framework can be found in the first report of this series, *Agricultural Research and Technology Transfer Policies for the 1990s.* Congress has subsequently taken the first step by authorizing an Agricultural Science and Technology Review Board in the 1990 farm bill that will begin to develop ex ante information on selected technologies. It is a beginning, but much more work will be needed in the future.

## CONCLUSIONS

Emerging technologies, such as bST, industry economics, and public policy will play critical roles in shaping the U.S. dairy industry in the decade of the 90s, Advances in health, reproduction, and information technology all will affect the industry. The most dramatic impact will be due to bST. Claims have been made that bST is unsafe in consumer food products, an unsafe technology for cows, and a technology that will economically destroy many traditional farms. This report concludes just the opposite. It is a technology that, based on today's research findings, poses no additional risk to consumers, one that does not produce adverse health effects to cows, and one that alone will not economically disadvantage the traditional farm operator. Emerging technologies (including bST), industry economics, and current dairy policy will merely accelerate an existing trend-the pressure on traditional farms to grow or exit the industry. Changes in: rate of technology adoption, research and extension policy, and perhaps dairy policy may be required to reverse this trend.

A national dairy policy that provides a mechanism for allowing producer returns to decline as government purchases increase, such as the trigger price-support policy or producer assessments as provided for in the 1990 farm bill, could effectively adjust supply without excessively large inventory accumulations. However, if demand for dairy products declines sharply with the introduction of bST, supply-management programs such as production quotas or termination programs may be required, Termination programs are costly and do not effectively reduce supply over a period of time. Production quotas can effectively control supply. However, they also freeze regional production shifts and (because the quota has an economic value) make it more costly for new entrants into the industry. Because of costs and rigidities associated with quota programs, consideration might be given to observing government purchases over a 2-year, as opposed to a l-year, period before implementing such a program. This would permit a more accurate assessment of whether the demand reduction is temporary or permanent.

The introduction of bST has caused considerable controversy. Little, if any, information was available early in its development to foresee the biological, economic, social, and political impacts of its potential adoption. Lack of such information establishes a clear need to consider the benefits and risks of new technology more seriously and to use that information in allocation of public sector research funds. An institutional framework needs to be developed to provide this information and involve all the relevant users of new technology.