Chapter 3

Impacts of Emerging Technologies on Agricultural Production

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Introducing to the marketplace the 150 emerging technologies forecasted in this study raises questions about the effects these technologies will have on crop yield, livestock feed efficiency, and future food production. Many people are concerned that the trends of major crop yields are leveling off and that the world may not be able to continue to produce enough food to meet the demands of its growing population. However, OTA's analysis indicates that the United States can continue to meet foreign and domestic demand for agricultural products *if* agricultural research is adequately supported and *if* economic and political environments are favorable. What this conclusion means in practice is the subject of this chapter.

OTA study participants arrived at this conclusion by first projecting where and under what economic and political conditions the various emerging technologies would be adopted and what the primary impacts of those technologies would be on net increases in production. Based on this information OTA projected the impacts of technology adoption on agricultural production on a per-unit basis (e. g., bushels of corn per acre) and then on an aggregate basis (e. g., million bushels of corn produced in the entire country).

TECHNOLOGY ADOPTION AND PRIMARY IMPACTS

OTA commissioned leading scientists, specialists in the 28 technological areas, to prepare state-of-the-art papers. Each paper: 1) defined and delineated the scope of a technology area, 2) identified four or five major lines of research where significant technologies were likely to emerge by 2000, 3) discussed the current state of technology development, 4) identified major breakthroughs in other science and technology areas that would be necessary for successful development of the technology in question, 5) discussed the institutional arrangements necessary for the research of the technology to be conducted or supported, 6) estimated the time in which a particular line of research would likely be completed and the resulting technology introduced commercially, and 7) estimated the potential primary impacts of each technology on crop and livestock production. These papers provided the basis for discussion in two technology workshops conducted by OTA.

The workshops—one for animal technology and the other for plant, soil, and water technology—were conducted to assess the impacts of emerging technologies on agricultural production. Workshop participants, carefully selected to include those with expertise in different stages of technological innovation, comprised physical and biological scientists, engineers, economists, extension specialists, commodity specialists, agribusiness representatives, and experienced farmers.

The participants provided data on: 1) the timing of commercial introduction of each technology area; 2) primary impacts, or net yield increases (by commodity), expected from each package of technologies; and 3) the number of years needed to reach various adoption percentages (by commodity).

The Delphi technique was used to obtain collective judgments from the workshop participants on the development and adoption of the emerging technologies.[1] To facilitate the proc-

[1]The Delphi technique is a systematic procedure for eliciting and collating informed judgments from a panel of experts. It has

ess of obtaining consensus, an electronic Consensor was used to help tabulate the ratings assigned by each expert. A detailed discussion of the methodology and workshop procedures is presented in appendix A.

The Timing of Commercial Introduction

Since the impact of a new technology on agriculture at a given time depends in part on when the technology is available for commercial introduction, workshop participants were asked to estimate the probable year of commercial introduction of each technology under three alternative environments:

1. Most likely environment—assumes to year 2000: a) a real rate of growth in research and extension expenditures of 2 percent per year, and b) the continuation of all other forces that have shaped past development adoption of technology.

2. More-new-technology environment (relative to the most likely environment)—assumes to year 2000: a) a real rate of growth in research and extension expenditures of 4 percent, and b) all other factors more favorable than those of the most likely environment.

3. Less-new-technology environment (relative to the most likely environment)—assumes to year 2000: a) no real rate of growth in research and extension expenditures, and b) all other factors less favorable than those of the most likely environment.

4. No-new-technology environment—assumes to year 2000: a) none of the emerging technologies identified in the study will be available for commercial introduction, andb) all the other factors are the same as those under the less-new-technology environment.

Table A-1 in appendix A shows in more detail the sets of assumptions made under the alternative technology environments.

The year of commercial introduction ranged from now—for genetically engineered pharmaceutical products; control of infectious disease in animals; superovulation, embryo transfer, and embryo manipulation of cows; and controlling plant growth and development—to 2000 and beyond, for genetic engineering techniques for farm animals and cereal crops. Of the 57 potentially available animal technologies, it was estimated that 27 would be available for commercial introduction before 1990, and the other 30 between 1990 and 2000, under the most likely environment. In plant agriculture, 50 out of 90 technologies examined were projected to be available for commercial introduction by 1990, and the other 40 technologies between 1990 and 2000. The major categories of animal and plant technologies are listed in appendix A, tables A-2 and A-3.

Primary Impacts

When a given package of technologies is adopted by a farmer and put into agricultural production, its immediate impact on plant agriculture is increased yields and/or increased percentage of planted acreage harvested.[2] To determine immediate impacts on animal agriculture, OTA considered feed efficiency for all animals and reproductive efficiency for beef cattle and swine, milk production per cow for

two distinct characteristics: feedback and anonymity. During the Delphi process, responses are collated and then referred to the experts for review. Each expert reevaluates his or her original answers after examining the summary of the group's responses. 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.

'It is often stated that U.S. agriculture needs cost-saving technology, not yield-increasing technology. Technologies can be classified into two general types according to their impact: 1) those that reduce the cost of production directly, and 2) those that increase productivity through yield increases, The first type of technology, such as nitrogen fixation and new crop varieties resistant to pest, disease, and environmental stress, saves costs of purchasing agricultural chemicals, at little additional expense. The second type of technology, such as pesticides, herbicides, plant-growth regulators, irrigation, and fertilizer, typically increase yields, but at additional expense. Regardless of the type of technology, all technologies reduce average costs if they are worth adopting. For example, a new variety of corn increases yields from 100 to 140 bushels per acre. Assuming no additional increase in the cost of purchasing the new variety of seeds, the total cost of production using the new variety will be shared by 140 bushels rather than 100 bushels. Thus, the new variety reduces the average cost 29 percent.

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 were first asked to project the performance measures of crop and livestock production, such as crop yields and livestock feed efficiency, to 1990 and 2000 under the no-new-technology environment. Historical trend lines of the performance measures of crop and livestock production were provided to the participants as a basis for their projections. Through the Delphi process, participants collectively projected the performance measures for each of nine commodities for 1990 and 2000 (app. A, table A-5). The nine commodities included corn, cotton, rice, soybeans, wheat, beef cattle, dairy cattle, poultry, and swine.

Based on those estimates and on the information obtained from the presentations and from discussions with the authors of the commissioned papers, participants then jointly projected the net increases in crop yields, animal feed efficiencies, and other performance measures that could be expected if specific packages of technologies were commercially available and fully adopted by farmers. Generally, the 28 areas of technologies were grouped in "packages" according to their probable impacts on a commodity. Each package was further categorized as a 1990 version of the package or a 2000 version of the package, thus delineating those technologies that are expected to be introduced by 1990 and 2000, respectively. The packages of technologies are described further in appendix A.

Through the Delphi process, OTA obtained estimates for each package of technologies on each of the nine commodities under the three alternative environments. The results are shown in tables 3-1 and 3-2. In soybean production, for example, if technology package 1990A—which includes genetic engineering, enhancement of photosynthetic efficiency, plant growth regulators, plant disease and nematode control, and multiple cropping—is adopted by soybean producers, yields are predicted to increase 2.2 percent under the most likely environment, 15.2 percent under the more-new-technology environment, and only 1.2 percent under the less-new-technology environment. If package 2000A is adopted, soybean yields are predicted to increase 22.1 percent under the most likely environment, 23.9 percent under the more-new-technology environment, and 14.9 percent under the less-new-technology environment. Package 2000A increases soybean yields substantially more than package 1990A because it includes such major technologies as genetically engineered soybean plants, photosynthetic molecular biology and genetics, and genetically engineered pest-resistant plants, all of which would

Table 3-1 .—Estimated Percentage Change in Crop Yield

Crop	Technology package	Technology environments: Less-new-technology 2000	Most likely 2000	More-new-technology 2000
Corn	Package A	15.6°\o	21 .5%0	28.50/o
	B	8.8	14.4	20.8
	c	–31.2	–28.8	–28.0
Cotton.	Package A	5.4	9.0	12.0
	B	2.3	2.8	3.1
	c	0	0	0
Rice.	Package A	8.4	12.4	15.6
	B	8.8	14.4	18.6
Soybean	Package A	14.9	22.1	23.9
	B	4.9	7.2	7.5
	c	3.7	4.6	5.5
Wheat	Package A	24.0	24.0	24.0
	B	1.5	1.5	1.5
	c	5.0	5.0	5.0

SOURCE: Office of Technology Assessment.

Table 3-2.—Estimated Percentage Change in Animal Feed and Reproductive Efficiency

			Technology environments		
Animal	Technology package	Efficiency measure	Less-new-technology 2000	Most likely 2000	More-new-technology 2000
Beef	Package A	Pounds meat per lb feed	o	22.4%	30.4%
		Calves per cow	o	0	28.4
	B	Pounds meat per lb feed	5.8%	10.4	12.4
		Calves per cow	1.2	5.2	6.4
	C	Pounds meat per lb feed	1.8	4.5	5.8
		Calves per cow	1.2	2.0	3.2
	D	Pounds meat per lb feed	0.1	1.2	1.7
		Calves per cow	o	0.3	0.9
	E	Pounds meat per lb feed	1.4	2.8	3.3
		Calves per cow	2.3	5.3	6.6
	F	Pounds meat per lb feed	o	1.1	1.5
		Calves per cow	o	0	0
Dairy	Package A	Pounds milk per lb feed	5.8	13.2	15.2
		Pounds milk per cow	6.8	12.2	15.2
	B	Pounds milk per lb feed	7,6	11.0	13.0
		Pounds milk per cow	9.4	12.2	14.6
	C	Pounds milk per lb feed	7.8	12.4	15.2
		Pounds milk per cow	15.0	21.3	24.3
	D	Pounds milk per lb feed		25.6	25.6
		Pounds milk per cow		25.6	25.6
Poultry	Package A	Pounds meat per lb feed	7.3	9.2	11.3
		Eggs per layer per year	4.6	5.8	7.1
	B	Pounds meat per lb feed	2.5	3.1	3.9
		Eggs per layer per year	4.0	5.0	6.2
	C	Pounds meat per lb feed	1.3	1.6	2.0
		Eggs per layer per year	1.6	2.0	2.5
Swine	Package A	Pounds meat per lb feed	4.8	12.6	15.0
		Pigs per sow per year	14.4	27.6	50.0
	B	Pounds meat per lb feed	2.8	4.0	
		Pigs per sow per year	14.4	20.8	
	C	Pounds meat per lb feed		2.1	2.1
		Pigs per sow per year		0.8	2.4

SOURCE' Office of Technology Assessment.

not be ready for commercial adoption until after 1990.

Note that technology package C for corn production, which consists of only organic farming, received very low marks from the Delphi panel. If fully adopted, this technology will result in yield reductions ranging from 23 to 28 percent. Some organic farming specialists feel that the panel overestimated the negative impact. Harwood (1985) indicates that the best estimate from the published reports is about a 10-percent reduction. Since the cost of organic farming is lower, the economic efficiency for organic farming may be higher than that for conventional farming.

Adoption Profiles

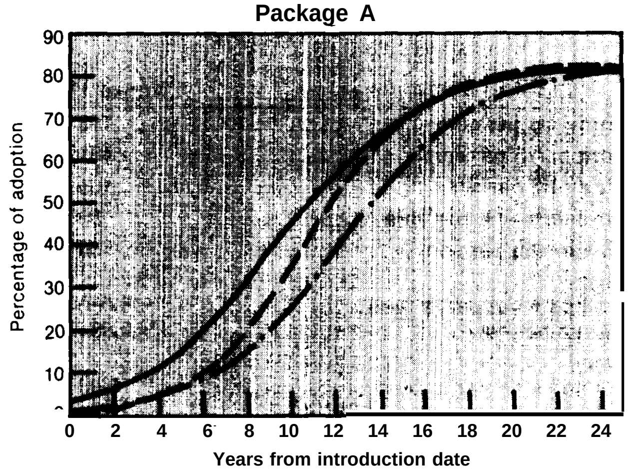
The primary impacts estimated above assume that the technologies will be fully adopted by farmers and put into agricultural production. But when a new technology is introduced for commercial adoption, only a small number of farms, mostly the large and innovative ones, will adopt the technology initially because the possible payoff of the new technology is uncertain and because the potential adopters need time to learn how to use the new technology and to evaluate its worth. As early adopters benefit from using a new technology, more and more farmers will be attracted to it, increasing the speed of adoption exponentially. Eventually, as most potential adopters adopt a new technology, the percentage of adoption will level off and approach a maximum; thus, the adoption profile follows an S-shaped curve (Lu, 1983).

To derive an adoption profile of each package of technologies for each commodity under different economic environments, participants were divided into commodity groups according to their expertise in a particular commodity. There were four groups in the animal technology workshop (beef, swine, dairy, and poultry) and five in the plant, soil, and water technology workshop (wheat, corn, cotton, soybean, and rice). The participants were then asked the question, "If a specific package of technologies is introduced in the market today, how long will it take for farmers to have it adopted?" Based on their collective experience, the participants estimated the following for each package of technologies:

1. The maximum percentage of adoption.
2. The number of years it would take to reach 20)-percent adoption.
3. The number of years it would take to reach 50-percent adoption.

Based on information from the commodity groups, a logistic curve was fitted for each package of technologies applied to each of the nine commodities under different scenarios. Figure 3-1 shows the estimated adoption curves for package A corn technologies, which consist of plant genetic engineering, plant disease and nematode control, management of insects and mites, water and soil-water-plant relations,

Figure 3-1.—Logistic Adoption Curves for Corn, Package A



— More-new-technology environment

.—— Less-new-technology environment

—— Most likely environment

Source. Office of Technology Assessment

communication and information management, monitoring and control, and telecommunications. The participants estimated that it would take 8 years to reach 20-percent adoption under the most likely environment, while it would take only 6 years to reach it under the more-new-technology environment, where the economic environment is more favorable for technology adoption. To reach 50-percent adoption, it would take 11 years under the most likely environment and 10 years under the more-new-technology environment. The maximum adoption rate projected is 80 percent under both environments.

PROJECTION OF PER-UNIT CROP YIELDS AND LIVESTOCK FEED EFFICENCIES

Based on the information obtained from the workshops on: 1) the years of commercial introduction, 2) the primary impacts, and 3)the adoption profiles, OTA computed the efficiency measurements for all animals and the average yield and percentage of planted acreage for all crops in 1990 and 2000 under alternative environments. The results are presented in tables 3-3 and 3-4.[3]

Under the most likely environment, feed efficiency in animal agriculture will increase at a

[3]For ease of presentation, the less-new-technology environment is not presented. Its estimates fall between the no-new-technology and most likely environments.

Table 3-3.—Estimates of Crop Yield and Animal Production Efficiency

	Actual 1962	No-new-technology environment 2000	Most likely environment 2000	More-new-technology environment 2000
Corn—bu per acre	113	124	139	150
Cotton—lb per acre	481[a]	511	554	571
Rice—bu per acre	105	109	124	134
Soybeans—bu per acre	30[a]	35	37	37
Wheat—bu per acre	36	41	45	46
Beef:				
Pounds meat per lb feed	0.070	0.066	0.072	0.073
Calves per cow	0.88	0.96	1.0	1.04
Dairy:				
Pounds milk per lb feed	0.99	0.95	1.03	1.11
Milk per cow per year[b] (1,000 lb)	12.3	15.7	24.7	26.1
Poultry:				
Pounds meat per lb feed	0.40	0.53	0.57	0.58
Eggs per layer per year	243	260	275	281
Swine:				
Pounds meat per lb feed	0.157	0.17	0.176	0.18
Pigs per sow per year	14.4	15.7	17.4	17.8

[a]Not actual—based on estimate from trend line.
[b]These estimates differ from those in table 2.2 of the first report from this study because of changes made at a later date by workshop participants in the adoption rate of some of the dairy technology packages.

SOURCE: Office of Technology Assessment.

Table 3-4.-Historical and Projected Rates of Annual Growth in Crop Yield

		1982-2000		
	1960-82	No-new-technology environment	Most likely environment	More-new-technology environment
Corn	2.6%	0.5%	1.2%	1.6%
Cotton	0.1	0.3	0.7	1.0
Rice	1.2	0.2	0.9	1.4
Soybean	1.2	0.8	1.2	1.2
Wheat	1.6	0.7	1.2	1.4

SOURCE: Office of Technology Assessment.

rate of from 0.2 percent per year for beef to 1.4 percent for poultry. In addition, reproduction efficiency will also increase, at an annual rate ranging from 0.6 percent, for beef cattle, to 1.1 percent, for swine. Milk production per cow per year will increase at 3.9 percent per year, from 12,300 pounds to 24,730 pounds per cow, in the period 1982-2000.

Major crop yields are estimated to increase from 1982 until 2000 at a rate ranging from 0.7 percent per year, for cotton, to 1.2 percent per year, for wheat and soybeans. Wheat yield, for example, is projected to increase at the rate of 0.7 percent per year, from 36 bushels per acre in 1982 to 41 bushels per acre in 2000, assuming no new technologies will become available before 2000. Under the most likely environment, wheat yields will increase at the rate of 1.2 percent per year to 45 bushels per acre. The difference in wheat yield between the two environments, 4 bushels per acre, represents the impact of new technologies under the most likely environment.

How do these rates of increase compare with historical trends? Will emerging technologies significantly change the trends? By far the most drastic increases in productivity will be in milk production, primarily because the products of genetic engineering will soon be available for commercial adoption by the dairy industry. One of the proteinaceous pharmaceuticals, bovine growth hormone, is alone expected to increase milk yields between 20 to 40 percent almost overnight via daily injections of the hormone into cattle.

From 1960 to 1982 milk production increased 2.6 percent per year, from 7,029 pounds per cow per year to 12,316 pounds. If no new technology is available from now until 2000, this rate of increase would not be maintained. Under such an environment milk production per cow per year is expected to increase at only 1.4 percent per year, from 12,316 pounds in 1982 to 15,700 pounds in 2000. However, if new technologies are adopted, the rate of increase in milk production would far surpass the historical rate, under the remaining technology environments. Under the more-new-technology environment, milk production is expected to reach 26,080 pounds in 2000, at an annual rate of 4.2 percent.

Application and adoption of new technologies will also increase the feed efficiency of other animals. Poultry feed efficiency has been increasing at 1.2 percent per year for the last 15 years, Under the most likely environment, feed efficiency will increase at 1.4 percent per year through 2000.

The feed efficiencies for beef and swine have not increased for the last 15 years. Beef feed efficiency declined from 0.093 pounds of beef per pound of feed in 1965 to 0.065 pounds in 1973 and then maintained at about 0.070 pounds in recent years, The introduction of new technologies will increase feed efficiencies. Under the most likely environment, the feed efficiency is projected to increase at an annual rate of 0.2 percent, reaching 0.072 pounds of beef per pound of feed in 2000. Swine feed efficiency has declined steadily from 0.19 pounds of pork per pound of feed in 1974 to 0.15 pounds in 1980. Under the most likely environment, feed efficiency will increase to 0.18 pounds of pork per pound of feed in 2000, at the rate of 0.4 percent per year,

Efficiencies in crop production will be less dramatic than those in animal production, primarily because development of biotechnology for plants is far behind that for animals, Most of the major plant biotechnologies will not be commercially available before 2000. Therefore, it will be difficult to maintain historical trends without infusion of new technologies. As shown in table 3-4, all major crops included in this study, except for cotton, have experienced phenomenal growth during the past 20 years. The average annual rates of growth range from 1.2 percent, for rice and soybeans (and 1.6 percent for wheat), to 2.6 percent for corn. Without new technologies, these trends cannot continue. Under the no-new-technology environment, the yields of major crops are expected to grow only at 0.2 percent per year for rice, to 0.8 percent, for soybeans. Even under the most likely environment, corn and wheat yields still could not keep up with past growth. Under the more-new-technology environment, the annual rates of growth of all major crops, except for corn and wheat, are expected to equal or exceed historical rates of growth. The growth rate of corn yields under the most favorable environment is expected to be 1.6 percent, which is far short of the historical rate of 2.6 percent per year.

New technologies could have a significant impact on cotton and rice yields. Cotton yields have not increased much during the last two decades. Instead, they have been fluctuating around the trend line, which has increased at the rate of only 0.1 percent per year from 1960 to 1982. Adoption of new technologies could shift the trend upward. Under the most likely environment, cotton yields are projected to increase at 0.7 percent per year, and under the more-new-technology environment, 1.0 percent per year.

Although rice yields have increased at an average of 1.2 percent per year since 1960, the yield curve has been flattened since 1967. During the 1960-67 period, rice yields increased at 4.1 percent per year, but the rate of growth has declined to only 0.2 percent per year since 1967. Introduction of new technologies into rice production could turn the yield curve upward. Under the most likely environment, rice yields are expected to increase 0.9 percent per year, and under the more-new-technology environment, 1.4 percent. This is the highest rate of growth estimated among all major crops.

PROJECTIONS OF AGGREGATE CROP AND LIVESTOCK PRODUCTION

OTA used the projected crop yields and percent of planted acres harvested for major crops, and the projected feed and reproductive efficiencies of livestock, to assess the collected impacts of the 28 areas of emerging technologies on the total production of various crop and livestock products. The primary tool used in the analysis was an econometric model which is an annual, partial equilibrium model consisting of a crop sector, a livestock sector, and a financial sector.[4] The model is a partial equilibrium model in that a general equilibrium solution is solved within the agricultural sector while a specified set of conditions are assumed to exist within the rest of the economy, such as population growth, income growth, export demand, and interest rates. The model was used in a 20-year simulation projecting the effects of technological change on the various crop and livestock commodities previously discussed. The results appear below.

IThe model used was the Iowa State University econometric model developed by Earl Heady.

crop Production

Applications of new technologies will increase aggregate crop production throughout the projection period—from 1981 to 2000. Table 3-5 shows projections to year 2000 of increased production for five major crops. Total U.S. crop production was determined by average crop yields and acres of crops harvested. Crop yields were projected to 2000 under the three technology environments from the results of the technology workshop. The projections took into account the timing, adoption profiles, and primary impacts of emerging technologies. Acres of crops harvested were determined by the model, based on expected returns from crop production, diversion payments, and other crop-specific considerations.

Although there will be a drop in the number of acres of corn planted, projected yield increases and increases in the proportion of planted acres actually harvested will cause corn production to increase over time under each environment. The increase will be greatest under the more-new-technology environment, a

Table 3-5.—Projections of Crop Production

			2000		
crop	Unit	1984	No-new-technology environment	Most likely environment	More-new-technology environment
Corn?					
Production	Billion bu	7.7	8.6	9.3	9.7
Growth rate.	Percent		0.7	1.2	1.5
Cotton:					
Production	Billion lb	6.2	6.4	6.9	7.2
Growth rate.	Percent		0.1	0.7	0.9
Rice:					
Production	Million cwt	137.0	153.6	163.4	169.2
Growth rate.	Percent		0.7	1.1	1.3
Soybean.[a]					
Production	Billion bu	1.9	3.0	3.2	3.3
Growth rate.	Percent		3.1	3.4	3.6
Wheat?					
Production	Billion bu	2.6	3.3	3.5	3.5
Growth rate.	Percent		1.5	1.9	2.0

[a]Projections shown for this commodity differ from those in table 2-3 of the first report from this study because the Previous figures were preliminary.

SOURCE: Office of Technology Assessment.

situation that is also true for the other crops analyzed.

Unlike planted acres of corn, planted acres of soybeans will increase during the projection period. Increases in yields and increases in harvested acres will cause total U.S. soybean production to increase significantly over the 1982 through 2000 projection period, Because yields, planted acres, and proportion of planted acres harvested vary little across different environments, production increases do not vary much across environments. The rate of increase ranges from 3.1 to 3.6 percent per year for the no-new-technology and more-new-technology environments, respectively.

Planted acres of wheat are projected to increase under the no-new-technology environment but to decrease under the most likely and more-new-technology environments, Increases in average wheat yields will cause wheat production to increase over the projection period.

As shown in table 3-4, cotton yields are projected to increase relatively less than corn, soybean, and wheat yields. Planted acres of cotton are projected to increase under each of the technology environments, with only slight differences across environments. Increases in both yields and harvested acres will cause total U.S. cotton production to increase,

Planted acres of rice are also projected to increase under each technology environment. As shown in table 3-4, rice yields are projected to increase over time for each environment. Increasing yields and increasing harvested acres will cause total rice production to increase over time.

Livestock and Milk Production

Technology impacts are felt in the livestock sector through calving rate changes for beef and through feed input price differentials for beef and other livestock. Higher feed efficiencies and crop production levels under the more-new-technology compared with the no-new-technology environments result in lower corn, soybean meal, and wheat prices, The lower prices of these feed inputs cause livestock production to increase generally. The higher calving rates under the more-new-technology environment also tend to increase beef production. Increased production tends to depress livestock and meat prices if demand for livestock and meat does not increase proportionately.

The production of prime beef is determined by the number of feeder cattle slaughtered, the average fed cattle weight at slaughter, and the conversion ratio of live weight to carcass weight (dressing percentages).

As shown in table 3-6, prime beef production decreases over time for all technology environments. Due to higher calving rates and lower feed costs, beef production is highest under the more-new-technology environment. Under the most likely environment, beef production is projected to decline from 1984 to 2000 based on a weakness in consumer demand caused by changes in income levels, shifts in taste, and concern over potential health problems associated with the consumption of red meat, among other factors.

The impacts of technology on pork production are reflected only through differences in feed input prices. Differences in farrowing rates are not accounted for across environments, As shown in table 3-6, pork production is projected downward for all technology environments, The downward trend is attributed to higher feed input prices and higher retail pork prices resulting from lower production. Pork production under the most likely environment is projected to drop 15 percent from 1984 to 2000.

Chicken production is projected to increase over time for all technology environments, and the differences across the various environments are minimal.

Total milk production is determined by multiplying milk yield times milk cow numbers. Milk yield, as indicated earlier, is projected to increase through 2000, owing in large part to the anticipated emergence and adoption of biotechnologies in the dairy industry, Cow numbers are determined in the model as a positive function of the ratio of the blend price of Grade A and Grade B milk over the average ration cost

Table 3.6.—Projections of Animal Production

			2000		
Livestock	Unit	1984	No-new-technology environment	Most likely environment	More-new-technology environment
Prime beef:					
Production	Billion lb	16.0	12.5	14.1	15.7
Growth rate	Percent		– 1.5	–0.8	–0.2
Poultry:					
Production	Billion lb	13.5	16.8	16.7	16.7
Growth rate	Percent		1.4	1.3	1.3
Pork:					
Production	Billion lb	13.8	10.7	11.7	13.0
Growth rate	Percent		– 1.6	– 1.0	–0.4
Milk:					
Production	Billion lb	135.4	126.1	192.1	201.8
Growth rate	Percent		–0.4	2.2	2.5

SOURCE: Office of Technology Assessment

and a negative function of the cull price of dairy cows. The blend price falls slightly for each environment over the projection period. The average ration cost and cull cow price are exogenously projected to increase over the 1983-2000 period. As a result, cow numbers are projected to decline by at least 30 percent over the period, with only small differences across the environments.

Given the increases in milk productivity and the decreases in cow numbers, what will happen to total milk production over time? As shown in table 3-6, under the no-new-technology environment, milk production will fall at 0,4 percent per year from 1982 through 2000 because reductions in cow numbers more than offset increases in milk yield. Under the other two environments, milk production will increase despite the reductions in numbers of cows. The largest increases are projected to occur before 1990.

In the world agricultural marketplace, available information points to a periodic series of surpluses and deficits over the next two decades (Mellor, 1983; Resources for the Future, 1983). A Resources for the Future (RFF) study indicates that the global balance between cereal production and population will remain quite close until year 2000, indicating vulnerability to annual shortfalls resulting from weather, wars, or mistakes in policy, Over the next 20 years the world will become even more dependent on trade, There will be increasing competition for U.S. farmers in international markets. Much of this increased competition will come from developing countries selling farm commodities as a source of exchange to pay for imports such as oil. Despite this increased competition, exports of grain from North America are projected nearly to double by year 2000.

On the other hand, there is another school of thought that believes current studies such as that by RFF have not properly assessed the magnitude and impact of emerging technologies on farm production. Technologies such as genetic engineering and electronic information technology that are available now in various forms could mean rapid increases in yields and productivity. While such changes may improve the competitive position of American agriculture, they might create surpluses and major structural change—favoring, for example, larger, more industrialized farms.

Any conclusion regarding the balance of global supply and demand requires many assumptions about the quantity and quality of resources available to agriculture in the future. Land, water, and technology will be the limiting factors to agriculture's future productivity.

Agricultural land that does not require irrigation is becoming an increasingly limited resource. In the next 20 years, out of a predicted 1.8-percent annual increase in production to meet world demand, only 0.3 percent will come from an increase in quantity of land used in production (RFF, 1983). The other 1.5 percent will have to come from increases in yields–mainly from new technology. Thus, to a very large extent, research that produces new technologies will determine the future world supply / demand balance and the amount of pressure placed on the world's limited resources.

The OTA results indicate that with continuous inflow of new technologies into the agricultural production system, U.S. agriculture will be able not only to meet domestic demand but also to contribute significantly to meeting world demand in the next 20 years. This does not necessarily mean that the United States will be competitive or have the economic incentive to produce. It means only that the United States will have the technology and resources available to provide the production increases needed to export for the rest of this century.

SUMMARY AND CONCLUSIONS

OTA finds that emerging agricultural technologies, if fully adopted, will produce significant impacts on the performance of plant and animal agriculture. The most dramatic impacts will first be felt in the dairy industry, where new genetically engineered pharmaceuticals (such as bovine growth hormones and feed additives) and information management systems will soon be introduced commercially. New technologies adopted by the dairy industry will increase milk production far beyond the 2.6-percent annual rate of growth of the past 20 years. Under the most likely environment, milk production per cow is expected to increase at an annual rate of 3.9 percent. Applications of new technologies will also increase the feed efficiency and reproductive efficiency of other agricultural animals.

Because development of biotechnology for plant agriculture is lagging behind that for animal agriculture, significant impacts from such technology will not be felt in plant agriculture before the turn of the century. The development and adoption of the new technologies under the most favorable environment will, in the short run, increase the rates of growth of major crop yields, except for corn, at about the level of the historical rates of growth. However, the impacts of these technologies will be substantially greater for plant agriculture after 2000.

The OTA study indicates that, with a continued flow of new technologies into the agricultural production system, major crop yields will continue to grow and U.S. agriculture will continue to provide enough food to meet domestic and foreign demand as long as agricultural research is adequately supported and economic and political environments are favorable.

CHAPTER 3 REFERENCES

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