Chapter 5

Factors Involved in the Adoption of New Technologies by Industry and Agricultural Producers

Many new technologies involving agricultural commodities will not be final consumer products, rather they will be inputs into the manufacture of other products. The new technologies may be new manufacturing processes (to accommodate a new raw material), or intermediate products that will be used in the production of other products (e.g., plastics are used to manufacture final consumer products). Adoption and incorporation of new materials, processes, and technologies into the manufacturing procedures of firms is a key component to the success of newly developed and commercialized technologies that use agricultural commodities.

Economic factors play a major role in industry adoption of new technologies. Industrial use of a new material or technology may require new equipment, design, manufacturing, and operating changes, and worker training. New materials and technologies are unlikely to be adopted unless they provide cost and/or performance advantages relative to technologies already in use. Many of the economic considerations that influence a firm to allocate resources to the research and development of a new product, will influence the adoption of new technologies by firms (see ch. 4).

The adoption of new agricultural technologies by farmers, in addition to manufacturers, must also be considered, because in some cases, new industrial uses will involve crops not currently grown in the United States. Again, economic considerations will play a key role. This chapter examines factors involved in adoption of new technologies and crops by manufacturers and farmers, as well as programs to assist technology adoption.

Adoption of New Technologies by Industry

Industrial adoption of new technology will depend on industry's interest in, knowledge of, and ability to use effectively the new technology. The cost and effectiveness of the search for information about new technologies will influence the speed of adoption. In general, industries characterized by high labor intensity, rapid growth, and competition within the industry, and industries composed of firms of similar size and profitability are more rapid adopters of new technologies (15).

Firms will consider the profitability, the risk and uncertainty of use, and the cost of any necessary management and production changes when evaluating the possible adoption of a new technology (11). New technologies must be cost competitive with current technologies, or offer clear performance advantages. Sometimes, the price of an intermediate material, even if expensive, represents a srnall percentage of the total cost of the final product, and thus even large price increases for intermediate materials may not be sufficient to encourage the adoption of a substitute material. Use of a new process or intermediate material may require the purchase of new equipment or new worker skills that require additional training. Product design, operating procedures, and manufacturing processes may be needed to use a new technology. The expense of making these changes is an integral part of the decision to adopt a new technology.

Confidence in the performance characteristics of a new material or process is critical to new technology use in strategic applications where acceptable performance variation is narrowly limited. Intermediate materials containing agriculturally derived rather than petroleum-derived chemicals, for example, may have slightly altered chemical characteristics and behave differently in the same manufacturing procedure. Lack of familiarity with this variation is a significant constraint to use in strategic applications, and new materials and processes may first be adopted by firms for use in non-strategic applications. Confidence for strategic applications may be increased if new intermediate material and process standards are developed. However, testing and standard-setting are often done on a volunteer basis by professional societies who have neither the time or resources to make this a priority, or are undertaken by individual firms and are proprietary (18).

The commercialization of biodegradable plastics demonstrates some of these points. The plastics industry is composed of a few major resin producers and several small and medium-sized companies that make plastic products. A few major producers make biodegradable starch-based masterbatch (primarily firms whose major businesses involve corn or starch) and several small to medium-sized firms make biodegradable products such as grocery and trash bags. However, most of the large resin manufacturers who produce degradable resins, produce photodegradable rather than biodegradable plastics[1] (13). This is because of cost considerations associated with methods of production: photodegradable materials can be made by simply adding photosensitive agents or forming copolymers with photosynthetic groups. The characteristics of the materials do not change substantially, so they can easily be processed with existing equipment. Starch-based materials on the other hand, can cost about 25 percent more to produce than photodegradable materials, in large part because high levels of starch require new equipment and processing procedures (13). This cost differential explains why the frost commercially available biodegradable plastic products contained 6 to 7 percent starch; that amount of starch can be incorporated into plastics without significant processing and equipment changes (12). Thus, even firms that adopted the starch-based master batch to produce biodegradable plastic products, did so in a way that did not substantially alter their production methods.

Products using agricultural commodities that can easily and cost-effectively fit into existing production procedures are those that will be adopted frost. Products that have clear cost or quality advantages, even if new procedures are needed, may also be adopted relatively quickly. Products or processes for which the advantages are not as obvious, will be more slowly adopted if at all. However, even if a new process or product has clear economic benefits, it may still be adopted slowly because firms that could use these new technologies are either not aware of them, or unsure of the type of equipment or training needed to utilize the new products and processes. For these firms, access to accurate information that is specific to their needs can determine whether or not they adopt a new technology. A good technical assistance program could be invaluable in such cases.

Federal technology policy has, for the most part, focused on the research, development, and commercialization of new technologies; technology adoption is generally not given high priority. Federal programs generally encourage the development of cutting-edge technologies and the establishment of new innovative firms to commercialize these technologies. Only limited attention is paid to upgrading the technology and skill levels in existing fins, particularly those lacking research capacity. The potential users of new agricultural commodity-based technologies in many cases will be firms that already exist; some of which may need assistance in learning about and adopting these new technologies. Technology extension programs may be able to offer this assistance.

Technology Extension and Assistance

Technical extension programs generally consist of an accessible office staffed with engineers or experienced industrial personnel who can provide help in solving problems for manufacturing fins. Effective programs make on-site diagnoses, provide customized client reports, and work one-on-one with firms to implement recommendations made by the service and accepted by the fro's manager. These programs help fins, particularly small manufacturers, choose and manage new technologies and equipment, and provide advice on training requirements. Industrial extension services do not provide funds for capital investment or operating expenses; they give technical, not financial assistance. They can, however, financially help small firms via their diagnoses, which may reveal that the problem is one of management, not funding. They can also direct firms to sources of funds, such as State and Federal loan programs for small businesses, and can support firms in their dealings with banks (17).

The Omnibus Trade and Competitiveness Act of 1988 gave the Bureau of Standards (now the National Institute of Standards and Technology, NIST) new responsibilities for technology transfer to manufacturing. The Act directed NIST to create and support non-profit regional centers for the transfer of manufacturing technology, especially to small and medium-size firms. The tasks of the

[1]Photodegradable plastics are those that have organometallic or metal compounds added, or that have photosensitive functional groups incorporated within the polymer chains so that the plastics degrade in response to ultra-violet light. An example of a photodegradable plastic product is most degradable six-pack beverage rings. Biodegradable plastics are those that have been modified to disintegrate under biological actions. The most common approach has been to blend the plastic polymer with starch, so that under the appropriate environmental conditions, microorganisms will digest the starch, breaking the plastic into small pieces.

Manufacturing Technology Centers are to transfer technologies developed at NIST to manufacturing companies, make new manufacturing technologies usable to smaller firms, actively provide technical and management information to these firms, demonstrate advanced production technologies, and make short-term loans of advanced manufacturing equipment to firms with fewer than 100 employees. Three such centers currently exist (funded at $4.5 million) and three more are planned. The Centers expect to concentrate more on off-the-shelf, best-practice technologies than on high-technology, cutting-edge systems. The primary service offered will be modernization plans customized to fit the needs of individual fins. The Act also authorized $1.3 million for fiscal year 1990 to expand State technology extension programs (17).

The Small Business Administration, primarily through the Small Business Development Centers located mostly on university campuses, use faculty and students to provide business management and marketing advice, and to advise on particular problems, some of which maybe technical. There are 53 such centers nationwide in all but four States, funded by State and Federal Governments and universities (17).

At least 40 States have programs to promote technology, but most of their effort and funding goes for research and development in universities and high-technology startup ventures, not to help existing firms adopt best-practice technology. Only 14 programs in 10 States have technology extension programs whose main purpose is direct consultation with manufacturers on the use of technology. In 1988, States spent approximately $57 million for technology transfer and technology managerial assistance (17). Specialists in rural development recognize the importance of technical assistance, and some studies even suggest that lack of appropriate technical assistance is at least as significant a problem for rural firms as finance availability (2,4,9).

Neither the State extension programs nor the NIST programs are specific for industrial crops or uses of traditional crops. However, for small firms to use new crops in their manufacturing processes, or to develop new products using agricultural commodities, the purchase of new equipment and development of new operating procedures may be required. Technology extension programs may be able to provide some assistance in these areas.

Adoption of New Technologies by Agricultural Producers

In addition to industry adoption of new technologies using agricultural commodities, farmers must grow the commodities to provide the raw materials. The adoption of new industrial crops by farmers will be more problematic than the development of new uses of traditional crops. Farmers have accepted and are growing traditional crops. New crops, however, will be riskier for farmers to grow because they lack experience producing these new crops. Factors that affect farmer adoption of new crops will be significant in terms of the overall success of developing new industrial uses for these crops. Economic factors and agricultural commodity programs will influence the attractiveness of new crops relative to traditional crops. Many technical, economic, and institutional constraints need to be resolved before new crops are ready to be commercially grown.

Technical Considerations

Many of the new industrial crops are in the early stages of development and agronomic research is needed before they can be produced. Some problems yet to be overcome for one or more of the new crops include low germination rates and seedling vigor, asynchronous flowering, seed shattering, self-pollination, low yields, and photoperiodism (5,7). Seed dormancy (lack of germination) and poor seedling vigor not only are undesirable agricultural qualities, but diminish the opportunities for scientists to continue research on that species. Asynchronous flowering (flowering of individual plants at different times) allows a wild plant species to survive periods of adverse weather, but in commercial crops may necessitate multiple harvesting, which greatly increases cost. Seed shattering (the inability of a plant to retain its seed after maturation) is also a useful survival tactic in the wild, but greatly decreases the ability to capture the yield from a commercialized plant. Self-pollinating plants are generally preferred to cross-pollinating plants because of improved control. Photoperiodism is important in determining the length of the growing season and will affect the potential for double cropping and the geographic regions where the crop can be grown. Examples of potential new crops that must overcome one or more of these constraints include meadowfoam (insect pollination), *Cuphea* (seed shattering, seed dormancy), *Vernonia* (photoperiodism), and *Lesquerella* (seed dormancy, seed shattering). Sufficient time and resources devoted to research will likely overcome these problems, but lack of germplasm could slow progress.

New crops will be more readily adopted if they do not require large capital investments or major adjustments in the management style of the farm. New crops that do not require purchase of new machinery or equipment, and which complement traditional crops in terms of planting and harvesting time, are likely to be more attractive than new crops that cannot be so readily incorporated into existing farm procedures. Major changes in the plant's physical structure, such as altering plant height, density and degree of branching, and changing the position and structure of the ovule containing the seeds, may be needed to allow use of farm equipment. Additionally, new crops that can play several on-farm roles and present multiple management options may be more attractive. Oats, for example, are still planted in significant quantities because in addition to providing positive net returns, oats use existing farm equipment, are used in crop rotation schemes, provide good ground cover for erosion control, and can be grown for forage and livestock feed.

Economic Considerations

Farmer decisions involving crop mix are based on many factors, including income-leisure tradeoffs, food and occupational safety, and environmental quality. However, a major driving force is the desire to achieve highest expected net returns for the farm enterprise (21). To be accepted by farmers, a new crop must be competitive with other crops that a farmer can produce with the same resources. Crops compete for the same acreage and production resources; the types and quantities chosen for production will be those for which farm profits are greatest. The expected net returns will be influenced by market conditions and agricultural programs.

Role of Net Returns

Production costs include fried and variable costs. Fixed costs must be paid regardless of whether production occurs, and in the short run, are not the major determinant of crop mix. Variable costs differ depending on what crop is grown, and play an important role in crop-choice decisions. Variable costs include the costs of labor, machinery and fuel, chemicals, seeds, irrigation, etc. Production costs for the same crops can vary widely among geographic regions, leading to geographical specialization in the production of certain crops (21).

Low production costs and positive net returns are not always sufficient to guarantee widespread adoption of a new crop. The net returns of one crop relative to those of another crop will, in large part, determine the extent of adoption. For example, average variable costs of oats in the Corn Belt are about $50 per acre, with receipts of about $102 per acre, yielding a net return of about $52 per acre. Net returns for corn are approximately $227 per acre (receipts of $363 and costs of $136) and are about $162 per acre for soybeans (receipts of $216 and costs of $54). Oats have lower production costs than corn or soybeans, and are profitable, but in 1987,6.9 million acres of oats were planted in Illinois, Indiana, and Iowa, whereas 24.4 million acres of corn and 20.9 million acres of soybeans were planted. The most acreage was planted to the crops with the highest net returns (3,19,21).

Risk will play a role in a farmer's perception of net returns. A great deal of uncertainty exists surrounding the production of a new crop. Culturing and harvesting practices, handling procedures, markets etc. are not well-established. This uncertainty increases a farmer's risk, making it likely that farmers will discount the expected price of a new crop. Even if the expected net returns of a new crop are comparable to those of a traditional crop, the farmer may **not** plant the new crop. Because of the discounting for the added risk, anew crop may need to have higher expected net returns than traditional crops to be attractive to farmers.

Role of Agricultural Commodity Programs

Agricultural commodity programs will also affect the potential adoption of new crops. A loan rate is established for crops covered by commodity programs. At harvest time, farmers enrolled in commodity programs have the option of selling the crop on the market and paying back the loan rate (if the market price is greater than the loan rate), or of accepting the loan rate and forfeiting the crop as payment (if the market price is lower than the loan rate). Some commodities (i.e., corn, wheat, cotton, rice, barley, sorghum, and oats) have target prices in addition to the loan rate. The difference between the target price and the market price or loan rate (whichever is higher) is called the deficiency payment. Deficiency payments are made on a certain percent of the base acres and yields of the eligible commodities. Because some of the eligible commodities are in surplus, receipt of the deficiency payments requires a mandatory set-aside of base acres (Acreage Reduction Program and Paid Land Diversion). No crops can be grown for market on set-aside acres (l).

Acreage Reduction Programs have a large impact on crop-mix decisions. Two examples illustrate this point. In some areas of the Southeast,. Delta, and Southern Corn Belt regions, double-cropping of soybeans after harvesting winter wheat is a common practice. If a farmer participates in the wheat program, the farmer can plant soybeans only on that acreage previously planted to wheat. If a large acreage reduction requirement is in effect, the amount of land eligible for double cropping soybeans is significantly reduced (20). In the Corn Belt, the two major crops grown are corn and soybeans. An acreage reduction requirement for corn has a substantial impact on soybean acreage. In the presence of an acreage reduction program, corn acreage changes more in response to a price change than it does under free market conditions. However, in the presence of an acreage reduction program for corn, changes in soybean acreage (in response to a change in the price of soybeans) are lower than would occur under free market conditions. Additionally, changes in soybean acreage in response to a change in the price of corn are higher in the presence of a corn acreage reduction program relative to free market conditions. Thus, the effect of acreage reduction programs on farmer response to the relative prices of crops leads to a different allocation of farm acreage than would occur under free market conditions. Specifically, the presence of corn acreage reduction programs magnifies the impact of corn prices, and diminishes the impact of soybean prices on a farmer's decisions regarding the number of soybean acres to plant (8,21). It is reasonable to assume that new crops competing for acreage with crops that are subject to acreage reduction programs will experience similar impacts. This has significant implications for the adoption of new crops.

Commodity program restrictions that prohibit growing crops other than program crops on base acreage, inhibit crop diversification. However, even if this constraint is relaxed somewhat, acreage of other crops may not increase significantly because of the loss of deficiency payments. Under the Food Security Act of 1985, and the Food Security Improvement Act of 1986, soybeans and sunflowers cannot be planted on underplanted base acreage of commodity program crops without losing those base acres. The Disaster Assistance Act of 1988 relaxes this provision and allows plantings of sunflowers and soybeans on 10 to 25 percent of permitted acreage for major program crops without loss of base acreage, provided that the increased planting does not depress the expected soybean prices below 115 percent of the loan rate for the previous year. Using net returns, and including the deficiency payments received for corn, cotton, spring wheat, and barley, the impact of the program on soybean acres and sunflower acres was estimated. The results indicate that even though base acreage is not lost, the loss of deficiency payments is sufficient to require higher-than-expected soybean prices to encourage farmers to plant soybeans on base acreage instead of corn in the Corn Belt, and instead of cotton in the Delta region. Likewise, it is estimated that there will not be much of an increase in sunflower production relative to spring wheat or barley production in the Plains States. Hence, even if alternative crops are allowed to be planted on base acres of commodity program crops without loss of the base acreage, the expected price of the alternate crop must be high to offset the deficiency payment (21).

As this report was going to press, Congress passed the 1990 Farm Bill. The Bill addressed some of these issues by adopting a Triple Base Option, to begin in 1992. Under this option, base acreage is divided into three categories: acreage reduction program (ARP), program acreage (permitted acres), and flexible acreage. The ARP acres and 15 percent of the base acres are ineligible for deficiency payments. Designated crops may be planted on up to 25 percent of the base (flexible acres).[2]

To demonstrate how the program works, assume that a farmer has a 100-acre corn base and a 10 percent ARP is in effect. Under these conditions, 10 acres (ARP) are idled, leaving 90 acres on which crops can be grown. Any designated crop can be grown on 15 acres but will receive market prices

[2]Designated crops include grains covered by commodity programs, oilseeds, and other crops designated by the Secretary of Agriculture, possibly including many of the industrial crops discussed in this report. Fruits, vegetables, and dry edible beans are excluded.

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only (i.e., no deficiency payments).[3] The remaining 75 acres (permitted acres) can be planted to corn and are eligible for deficiency payments. An additional option offered to farmers is that 10 of these 75 acres can be planted to designated crops other than corn without a loss of base acres. Thus a total of 25 acres (25 percent of base) could potentially be planted to crops other than corn and still maintain the 100 acre corn base (flexible acres), but only a maximum of 75 acres will be eligible for deficiency payments.

Additionally, target prices have been nominally frozen at 1990 levels, but changes in the way deficiency payments are calculated may effectively reduce target prices. These changes are expected to increase planting flexibility and to remove some of the institutional constraints to the adoption of new industrial crops. New industrial crops will still need to compete with traditional crops in terms of profitability on the flexible acreage, but profitability will be based more on market prices than on commodity program prices.

Role of Multiple Uses

Multiple uses of primary products and byproducts derived from new crops will improve their commercial prospects. Soybeans illustrate this point. Two major products are derived from soybeans: oil and a high protein meal that remains after oil extraction. Soybean oil is used primarily for edible purposes (70 to 75 percent of the U.S. edible oil use), but also has industrial uses. The meal is used primarily as livestock feed. On average, the price of a pound of soybean oil is about three times the price of a pound of meal. However, the value of the meal accounts for 60 to 65 percent of the value of a bushel of soybeans because soybeans are only 18 percent oil (10). Production of soybeans solely for oil appears unlikely to result in a farm price high enough to make soybeans an attractive crop. Many new crops being developed for the industrial use of one primary product (i.e., the oil from oilseed crops, rubber from guayule, etc.) will likely face a similar situation. Combined food and nonfood uses of the primary product may not result in prices that are favorable for the new crops. Markets for byproducts will need to be developed. Simultaneous development of multiple markets for new crop products is imperative.

Use of Existing Infrastructure

Adoption of new industrial crops will be facilitated if the new crop can readily be accommodated, with minor adjustment, by existing transportation, storage, processing, and marketing infrastructure. Individuals or firms maybe unwilling to make large capital investments for a crop that may be low volume (at least initially) and for which the market is not secure. The commercial development of soybeans illustrates many of the concepts discussed in this chapter (see box 5-A).

Agricultural Extension

The largest Federal program to aid in the adoption of new technologies is the Agricultural Extension Service (AES). Funding is approximately $1.2 billion (31 percent Federal) per year. There are offices in nearly every county in all 50 States, with a staff of 9,650 county agents and 4,650 scientific and technical specialists. The AES conducts educational programs to help farmers and agribusiness firms use the results of agricultural research. Historically, it has been successful in helping farmers adopt new technologies, and will continue to play a substantial role in educating farmers about new industrial crops. Recently, the AES has identified as high priority, the development of strategic marketing approaches to market agricultural commodities. This approach is needed to aid development of new industrial crops and uses of traditional crops. It is too early to judge how successful the AES will be in establishing this approach (16).

Policy Implications

Policy to develop a reliable supply of new industrial crops and uses of traditional crops must consider constraints and opportunities in all phases of technical change. In addition to policies that encourage research, development, and commercialization, there must also be policies that address the adoption of new technologies by industry and farmers (see ch. 6).

A strategic approach is needed to develop new industrial crops and uses of traditional crops. Subsector constraints must be identified and linkages established between the producers of the crops, and the manufacturers and consumers who will use the crops (14). A framework to aid in the identification

[3] These crops may be eligible for nonrecourse and marketing loans.

Box 5-A-Commercialization of Soybeans

Soybeans are frequently cited as an example of the successful commercialization of a new crop. The history of soybean commercialization shows that considerable time may be required for widespread adoption and use of new crops. Soybeans were introduced into the United States in the early 1800s but were grown primarily for hay and had little economic importance for decades. Imported soybeans were not processed in the United States until around 1910; U.S.-produced beans were first processed in 1914, but commercial processing did not begin until 1922. Processing of soybeans occurred in cottonseed mills that had been adapted to accommodate soybeans, and early production was in areas where processing facilities already existed. Thus soybean production and processing adjusted to existing industry structure; new industries were not created to accommodate soybeans. Once soybeans became firmly established as an important crop, new processing and poultry production facilities located in soybean production regions (10).

Prior to World War II, U.S. production of soybeans was insufficient to meet demand, and the United States imported 40 percent of the fats and oils it used. Soybean production increased following World War II in response to several simultaneous events. First, demand for meat products increased, which placed a premium on high-quality livestock feeds; soybean meal was uniquely suited (because of its high protein and lysine content) to fill that demand Second, tractors continued to replace horses (decreasing the demand for oats) and new synthetic fibers began to replace cotton, resulting in decreased prices for these commodities. Increasing soybean prices coupled with decreasing oats and cotton prices made soybeans relatively more attractive than these crops and acreage was shifted from producing cotton and oats to soybean production. Third, the Federal Government not only supported research to develop and improve soybeans and processing technologies, but offered production supports as well. Programs for feed grains, cotton, and wheat have often allowed soybeans to be substituted without loss of allotted acreage, and at times, grain farmers have been paid to plant soybeans on that acreage. With the exception of 1975, soybeans have been covered by commodity-loan programs every year since 1941. Historically, large amounts of soybeans have often been placed under price supports, but acquisitions by the Commodity Credit Corporation have been relatively small. Soybean producers use the loan program as a financial mechanism to obtain cash, and then redeem the loans prior to maturity to take advantage of higher market prices (10).

By 1950, the United States was planting 15.6 million acres to soybeans. In 1987, about 57.4 million acres were planted. Highest acreage planted was 71.4 million acres in 1979. Between 1%7 and 1%9 the United States produced 74 percent of the world's soybeans. By 1984 to 1986, that level had dropped to 56 percent. Nations other than the United States responded to favorable soybean prices and their production increased. Other countries also increased their processing and refining capacity, which helps to constrain U.S. exports of oil and meal compared to beans. In the 1980s, the United States exported 42 percent of the beans, 25 percent of the meal, and 15 percent of the oil it produced (10,18).

Soybeans have never been widely used for industrial purposes. In 1%0, about 6 percent of the oil produced was used industrially, while today's level is about 2 percent (10). From a farmer's point of view, soybean prices may be low, but from a manufacturing point of view, soybeans are expensive because of their food and feed uses. Also, higher quality, less expensive alternatives are available. Some new crops and uses of traditional crops may also face this situation (6).

of subsector constraints is the Production-Maketing-Consumption (PMC) system developed by the University of Missouri.[4]

The long history and extensive influence of agricultural commodity programs significantly affects the competitiveness of new industrial crops, and possibly new uses of traditional crops. Changes in agricultural commodity programs may help to remove some of the disincentives to new industrial crops.

Chapter 5 References

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4Some of the subsectors identified in this framework include the agricultural research and extension system; the production input supply system; systems that affect resource allocation, such as Federal or State programs that affect land and water use; the credit system, and the marketing system, which includes the collection, transportation, storage and processing of the commodity, and the distribution and promotion of the products made from the commodity.

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