Chapter 4

Factors That Affect Research, Development, and Commercialization

While the development of new industrial crops and uses of traditional crops potentially could benefit society, such development is not a simple matter. It involves technical change, the complex process by which economies change over time with respect to the products produced, and the processes used to produce them (22). New ideas, models, products, and processes must be conceptualized and research conducted to develop promising products and processes for commercial use. New processes and products must be adopted by firms and spread throughout an industry to achieve maximum impacts. Governments can affect the rate of technical change by influencing the general economic environment (fiscal and monetary policy as well as regulatory policy can enhance or inhibit technical change), and by specific policies designed to encourage technical change.

U.S. technical policy focuses predominantly on the research to develop new ideas. Federal and State governments, and the private sector, have numerous programs and provide billions of dollars to support such research. Commercialization is generally the responsibility of the private sector, although the Federal and State Governments have passed legislation and developed some programs to encourage technology transfer from public-sector research to the private sector. Many of these programs are of recent origin and have limited funding. The process of adoption of new technologies, with a few notable exceptions, receives little public-sector attention.

For new industrial crops and uses of traditional crops to be commercialized, many technical and economic constraints must be overcome. Involvement of the public and private sectors is needed. The extent of this involvement, and the speed at which new technologies will be developed and commercialized will be influenced by many factors. This chapter analyzes many of these factors, and describes some Federal and State programs available to encourage the research, development, and commercialization of new technologies. Chapter 5 will discuss important factors involved in the adoption of new technologies.

Research and Development

It is one of the myths of technical change that the process proceeds in a linear manner from basic to applied research, to development, to marketing, and to dissemination. In fact, a more accurate description might be one where science- and technology-oriented research follow two parallel but interacting paths. The two paths are connected by a common pool of scientific knowledge that feeds and draws from each research path. While personal insight, professional curiosity, and the state of the science all play a role, the speed and direction of technical change is highly influenced by the interaction of economic and institutional factors.

Private-sector research and development is motivated by profit-seeking and will tend to occur whenever profit and risk conditions create comparatively attractive investment opportunities. Firms undertake research and development to reduce the unit costs of production (generally through process development), and/or to stimulate demand for outputs (new product development). Firms develop new processes to reduce the use of production inputs that are, in the future, expected to become relatively more expensive than other inputs (i.e., firms minimize the present discounted value of expected future costs). The resources allocated to a particular line of research will also be influenced by the cost and productivity of the research. New product research resources are usually concentrated on products that are expected to have the highest prices and largest markets, and development efforts are accelerated for such new products. Development activities are slower for new products that substitute for existing, profitable products (2,10,22,24).

Public-sector research can be active or passive. The public sector, in response to actual, anticipated, or perceived needs, can take an active stance by setting its own research priorities and providing adequate resources to meet established goals. The public sector can take a passive approach by following the research priority agenda determined by interest groups. Interest groups demand public-sector funding for research that they believe will bring a payoff to themselves. They commit their own resources in a similar fashion. Federal fiscal constraints tend to reinforce the passive approach to public research by intensifying the search by scientists and research administrators for private research monies and competitive grants (16).

With the possible exceptions of guayule and ethanol derived from cornstarch, Federal policy concerning new industrial crop and use development has been relatively passive. Interest groups, for the most part, have not demanded this type of public-sector research, and the private sector has not invested in public-sector research of this type. The private sector has shown interest in new industrial crops and uses that have relatively clear potential to substitute for inputs whose cost is increasing (relative to the cost of other inputs), or whose market is affected by regulation. Situations where these factors are not so obvious have not elicited substantial private-sector interest.

The new industrial crops *Vernonia* and *Cuphea* illustrate these points. Lauric-acid containing oils (coconut and palm kernel oil) and petroleum-derived ethylene can be used to produced surfactants for use in detergents, emulsifiers, and wetting agents. The new crop *Cuphea also* produces oil containing lauric acid, and could be used in place of coconut and palm kernel oil or ethylene in many detergents. Raw material costs in the detergent industry are a small portion of total product cost and have little impact on profitability. Additionally, supplies of coconut and palm kernel oil are expected to at least double within the next decade as recently planted, high-yielding palms begin to mature (1,7). The detergent industry provides limited funding for *Cuphea*. Industry interest in developing *Vernonia is* increasing. Stricter volatile organic emission standards are forcing the reformulation of many paints and coatings. Preliminary results show that use of *Vernonia oil* as a diluent in place of organic solvents can reduce volatile emissions. The paint and coatings industry is increasing its support for research on *Vernonia (19).*

Industrial Use Research Funding and Institutional Involvement

The Federal institution most involved in agricultural research is the U.S. Department of Agriculture (USDA). Research funds are allocated through the Cooperative State Research Service (CSRS) and the Agricultural Research Service (ARS). Research funds awarded to the State Agricultural Experiment Stations located within the Land Grant Universities are administered through CSRS. Funding includes formula funds (Hatch, Evans-Allen, McIntyre-Stennis, Animal Health, etc.), special grants, education and facilities grants, and competitive grants. Total CSRS funding to the State Experiment Stations for fiscal year 1990 was approximately $344 million. It is estimated that approximately $5 million is allocated to research and development of new crops and uses of traditional crops ($2 million for new crop research and $3 million for new use research) (12). Universities have performed most of the agronomic research and some utilization research on new crops and industrial uses.

The fiscal year 1990 budget for the ARS was approximately $609 million. Of this amount, it is estimated that expenditures for industrial-use research were $15.5 million. Much of this funding, however, focused on more traditional uses of cotton fibers and not new uses. An estimated $2.7 million was allocated to new crop research. Additionally, another $6.7 million was spent on research that could indirectly enhance industrial uses (12, 17). The primary ARS center for research on new crops and industrial uses is the Northern Regional Research Center in Peoria, Illinois, which focuses primarily on utilization research.

The Critical Agricultural Materials Act established the Office of Critical Materials (OCM) located within USDA. This office serves as ‘‘a central location where USDA can address research and development with respect to agricultural crops that have the potential of producing critical materials for strategic and industrial purposes.” A Joint Commission on Research and Development of Critical Agricultural Materials, which includes representatives from the Department of Agriculture, the Department of Commerce, the Bureau of Indian Affairs, the National Science Foundation, the Department of State, the Department of Defense, and the Federal Emergency Management Agency, oversees the activities of the Office of Critical Materials. This office is trying to commercialize many of the new industrial crops discussed in this report. Commercialization efforts have been greatest for guayule, kenaf, jojoba, *Crambe*, and industrial rapeseed. Some efforts have been made to commercialize meadowfoam and *Lesquerella. The* 1990 Farm Bill reauthorized the Critical Agricultural

Materials Act through FY 1995, and Congress appropriated $1,968,000 for FY 1991 to fund research on guayule ($668,000), *Crambe* and rapeseed ($500,000), and other unspecified research ($800,000).

In addition to ARS and CSRS activities, other USDA agencies such as the Forest Service also support research on industrial uses of forest products. Other Federal agencies such as the Department of Defense (DoD), the Department of Commerce, the Department of Energy, the National Science Foundation, and the Agency for International Development provide some funding for industrial uses of agricultural commodities. The States, as well as the private sector also provide some funding, as do commodity organizations, such as the National and State Corn Growers Associations.

Funding Levels for Specific New Crops and Industrial Uses

USDA expenditures for selected new crops for fiscal year 1989 are summarized in table 4-1. To put these funding levels in perspective, USDA and the State Agricultural Experiment stations annually spend, on average, an estimated $120 million for corn, wheat, and soybean research.

The $325,000 being spent by USDA on *Crambe* and winter rapeseed supports an eight State consortium that is attempting to commercialize these two crops. The eight States involved are Missouri, Kansas, New Mexico, Idaho, Iowa, Nebraska, North Dakota, and Illinois. It is estimated that these States are receiving an additional $2 in State support for every $1 of Federal support (12).

Guayule is the new crop most heavily supported, as mandated by the Native Latex Act and later the Critical Agricultural Materials Act. Much of the funding has come from DoD and USDA. Table 4-2 summarizes known expenditures for guayule development. Private-sector expenditures on guayule research are estimated to be three to four times USDA levels (12).

Kenaf is also receiving public- and private-sector attention. The Joint Kenaf Task Force (JKTF) composed of Kenaf International, CIP Inc., and Combustion Engineering's Sprout-Bauer Division, in cooperation with USDA, is attempting to commercialize kenaf. The program consists of three phases. Phase I, begun in 1986, involved agronomic and papermaking research. Phase II, begun in 1987, focused on commercial trials. Phase III, currently in progress, is focusing on agronomic and utilization research. Table 4-3 summarizes expenditures for kenaf research. It is estimated that private-sector support is three to four times the USDA expenditures (3,1 1,12).

Table 4-l—USDA Fiscal Year 1989 Expenditures for Selected New Crops (dollars)

Crop	Amount
Cuphea	$100,000
Meadowfoam	350,000
Lesquerella	20,000
Crambe/rapeseed	325,000
Guayule	1,168,000
Kenaf	675,000
Total	2.638,000

SOURCE: Office of Critical Materials, U.S. Department of Agriculture Cooperative State Research Service, 1990.

Table 4-2—Expenditures for Guayule Research (millions of dollars)

Year	Amount	Agency
1978-86	$13.1	Department of Defense
	13.2	U.S. Department of Agriculture
	2.9	Other Federal
	2.7	Firestone Tire & Rubber
1987-88	15.0	Department of Defense
	4.3	U.S. Department of Agriculture
1989	1.168	U.S. Departrnent of Agriculture
1989-96 estimated	38.0	

SOURCE: Office of Critical Materials, U.S. Department of Agriculture Cooperative State Research Service, 1990.

The California South Coast Air Quality Management District, the State of Michigan, the U.S. Agency for International Development, and Paint Research Associates (an industry-financed research group) have committed $425,000 for *Vernonia* research (19). The Tennessee Valley Authority, in cooperation with the Department of Energy, conducts research on the conversion of lignocellulose to chemicals. Funding levels for other crops are unavailable, but the amounts seem to be small. (See *Appendix A: Selected New Industrial Crops* for more specific information concerning each individual crop.)

Research and development of new uses for traditional crops is also conducted by the public and private sectors. The General Accounting Office has evaluated the extent of Federal support for degradable plastic research (28). Their findings for fiscal year 1988 are summarized in table 4-4. Several private firms are also interested in degradable

Table 4-3—Expenditures for Kenaf Research (dollars)

Research	Amount	Agency
Phase I	141,000	U.S. Department of Agriculture
	263,000	Joint Kenaf Task Force
Phase II	300,000	U.S. Department of Agriculture
	644,000	Joint Kenaf Task Force
Phase III	675,000	U.S. Department of Agriculture

SOURCE: Office of Critical Materials, U.S. Department of Agriculture Cooperative State Research Service, 1990.

Table 4-4-1988 Federal Expenditures for Degradable Plastic Research

Agency	No. of projects	Funding
U.S. Department of Agriculture . .	4	$ 941,000
Department of Defense	4	575,000
Department of Energy	3	150,000
National Science Foundation	1	63,000
Total	12	$1,729,000

SOURCE: U.S. Congress, General Accounting Office, "Degradable Plastics: Standards, Research and Development," RCED-88-208 (Gaithersburg, MD: September 1988).

plastics, and have products on the market, many of which use cornstarch.

Funding for ethanol desulfurization of coal has been provided by the Illinois State Geological Society, Southern Illinois University-Carbondale, Illinois Department of Energy and Natural Resources, the Illinois and Ohio Corn Marketing Boards, and the U.S. Department of Energy. Expenditures of approximately $2.85 million have been allocated for 1987 through 1991 (33).

Funding levels for other uses are unavailable. (See *Appendix B: Selected New Industrial Uses for Traditional Crops* for more specific information on each use.) In addition to the United States, other countries have expressed interest in developing new industrial crops and uses for traditional crops. For example, Japan is currently in the second year of a 7-year, $100 million program to develop degradable plastics (21). The European Community has also begun funding a program to develop new industrial crops and uses of traditional crops (box 4-A).

Commercialization

New products and processes developed in Federal laboratories or universities will not be in the form of a fully developed, marketable product. Commercialization will require considerable research and development effort on the part of companies. For new crops and uses, commercial-scale extraction, separation, purification, and chemical transformation mechanisms that are economically competitive will need to be developed. For chemicals used in strategic applications, reliability and performance characteristics will be of paramount importance. Consistent quality control procedures must be developed, and for many uses, performance standards must be established. In some situations, waste disposal procedures must be developed. Commercialization efforts by private firms will follow their research and development efforts and will be driven by the same economic factors.

Cooperation and technology transfer between the public and private sectors will be a key component of the commercialization effort. Technology transfer is the process by which technology, knowledge, and/or information developed in one organization, in one area, or for one purpose is applied and used in another organization, in another area, or for another purpose. Technology transfer can include the transfer of legal rights and the informal movement of information, knowledge, and skills. Private-sector awareness, interest, and capacity to utilize public-sector research effectively will be critical to the successful commercialization of new uses of agricultural commodities.

Industrial Interest in Public-Sector Research

A critical component of technology transfer is the interest of industry, without which institutions to transfer technology will be ineffective. Industrial interest has frequently been lacking in the past; industries have not wanted to use technologies not developed in their own laboratories (29). Industry has felt that it can get little value from cooperative agreements and has not encouraged them. Small firms have often felt that this is a big company game that they are ill-equipped to play (13). These attitudes may be changing, primarily because of industry's need to respond to rapidly changing markets, and because of legislation that has made licensing and collaborative R&D with Federal laboratories easier (23).

Economics will play a major role in the private-sector demand for technology developed in the public sector. Many new crops being developed are intended to substitute for chemicals that are currently either imported or derived from petroleum, and which may be widely accepted and available. It is unlikely that any single company will commit

Box 4-A—European Research Program To Develop New Industrial Crops and Uses of Traditional Crops

In addition to the United States, the European Community (EC) is exploring alternative crops and uses as a means of alleviating their agricultural problems. The EC has initiated a program called the European Collaborative Linkage of Agriculture and Industry Through Research (ECLAIR), to improve the interface between industry and agriculture. ECLAIR is being administered through the Science, Research and Development Directorate. ECLAIR has been funded for $80 million over 3 years. All grants require matching finds from an industrial partner. Awards are decided on a peer-reviewed basis. The program is divided into four sectors:

1. Production of Biological Resources, which includes many agronomic features;
2. Harvesting and Conditioning, which includes transportation, classification, and storage;
3. Fractionation and/or Extraction; and
4. Methods of Transformation and their control.

Preference will be given to large, interdisciplinary projects, to proposals utilizing advanced technologies such as biotechnology, to projects that potentially can improve the competitiveness of European agriculture and/or have positive environmental impacts (Other social goals are not explicitly considered, unlike U.S. proposals that place heavy emphasis on technology applicability to small-scale farms and potential rural job creation) (5). The ECLAIR program requires projects to involve participants from at least two member countries. U.S. proposals can accommodate multidisciplinary, regional projects, but these are not explicit requirements. Like the U.S. proposals, the ECLAIR program requires matching funds from the industrial partner, and is peer-reviewed.

The ECLAIR program, unlike U.S. proposals, does not attempt to commercialize products. It is designed to carry out research necessary before commercialization can be contemplated, and focuses strictly on precompetitive research and development. Precompetitive research is considered to be beyond the stage of basic research, but the results of the research will still require further development to be marketable.

Commercialization will be attempted in another program currently in the planning stages. Current projections for this commercialization program are about $160 million for 3 to 4 years. Additionally, each member country of the EC carries out its own agricultural research and some funds maybe available for alternative crops through each country's research (15).

Interest has been shown in Europe for utilizing crops for fuel production and for industrial uses. Crops for which some interest has been expressed include jojoba, *Crambe, Lesquerella, Cuphea, Euphorbia,* sunflowers, *Vernonia,* and *Stokesia (18).* A sister program called FLAIR (Food-Linked Agro-Industrial Research) focuses on food technologies; there are no U.S. proposals to develop new food uses.

resources to develop new alternative supplies in anticipation of future hypothetical shortages (30). This may be particularly true for development of renewable resources, which vary frequently and widely in price and supply.

Economic factors that will affect private-sector interest in using agricultural commodities as inputs include price, quality, performance, and reliability of supply. Price is determined largely by the current and expected trends in supply and demand, the number of substitutes available, transportation, processing, and storage costs, and exchange rates for internationally traded products. Short-run supplies are most affected by environmental or political factors, such as adverse weather, embargoes and commodity cartels. Long-run supply trends are affected by technological change and institutional factors (e.g., Federal agricultural programs), and the quality, price, and quantity of the resources (primarily land and labor) needed to produce the commodities (27).

Demand for agricultural products results from food and feed, industrial, and on-farm uses. Crops that have multiple uses for primary products and byproducts will have more marketing options. Demand for commodities will be highly price sensitive if numerous substitutes are available. Proximity of crop production locations to processing plants, distance of processing plants to markets, method of transport (i.e., air, land, or water), and special transport requirements will affect transportation costs. Processing costs will be affected by techniques used, purification requirements, waste disposal, and volume. Frequently there are returns to scale in the processing of agricultural commodities, which leads to lower per-unit processing costs for high-volume commodities. Fiscal and monetary policies will affect exchange rates, which in turn, affect the price of imported and exported commodities.

The major production cost for many new uses is the price of the commodity itself. The net cost of using a commodity for industrial uses is the price paid for the commodity minus any credits received for the sale of byproducts. In many cases, increasing the use of an agricultural commodity will increase the price of the raw commodity and decrease the price of the byproducts, effectively raising the cost of using the agricultural commodity (25,31). Demand for food and livestock feed exerts pressure on the price of many commodities, and variability in the commodity and byproduct markets leads to wide price fluctuations. These factors make it difficult for agricultural commodities to be price competitive in many uses. Ethanol derived from cornstarch illustrates these points. In recent years, the net cost of corn (price of corn minus credit for byproducts) has ranged from 10 to 79 cents per gallon of ethanol produced. Additionally, as ethanol production increases, the price of corn increases and the value of the byproducts decreases (oil, protein meals), effectively raising the net cost of using corn for ethanol production (31).

In addition to price, the quality of a commodity will affect its competitiveness. A premium can be expected to be paid for crops that have many useful compounds, or compounds whose chemical structure is such that they yield superior performance relative to chemicals they could replace. Superior performance will be important if costly product or process reformulations are needed to use the new crop, and could improve the attractiveness of a new use, even if it is more expensive. As an example, soybean oil-based printing inks are more expensive than petroleum-based inks but are beginning to capture part of the market, particularly in color printing, because they give better colors and resist rub-off (20).

Reliability of supply is an important consideration for manufacturers. Crops that have few producers, or that are produced in few geographical regions, are more susceptible to supply shocks from weather or political factors. Development of alternative supplies might help to ensure supply availability and reduce price variability. Given a more reliable supply and less price variability, manufacturers may be more willing to increase their use of agricultural commodities as a source of chemicals. An example that illustrates this concept is the use of lauric acid-containing vegetable oils in the detergent industry. Coconut oil and petroleum-derived compounds can be used to manufacture detergents, but because of the high price variability and unreliability of supply of coconut oil, petroleum-derived products have been preferred. The maturation of high-yielding palms that produce palm and palm kernel oil is expected to double world supply of lauric acid oils by 1995. The prospect of a larger and more diversified source of supply and less price variability, has stimulated the detergent industry to increase capacity to utilize natural oils (7). Although, many traditional crops are in surplus and supplies for industrial use are available, supply fluctuations affect the cost of using these crops in industrial applications.

An understanding of these economic factors is essential to any market strategy for new industrial crops and uses of traditional crops. Factors within the production process that are now expensive or that are expected to become expensive relative to other production factors are good candidates for substitution through the development of new processes or products. Other good candidates include production inputs whose supply is highly variable, and products or processes that meet only minimal performance standards. Convenience and quality considerations are particularly pertinent to the development of consumer products. New industrial crops and uses of traditional crops that fill well-defined market needs are those most likely to succeed.

Private-Sector Access to Public-Sector Information

A major obstacle to the transfer of technology is the difficulty of learning about or accessing pertinent information (23). Research that might be of value to industry is conducted in numerous Federal and university laboratories in the United States and in other countries. Keeping up to date on this research is a massive undertaking even for large companies with substantial research budgets. For small fins, it is nearly impossible. Industry ability to access research data on new industrial crops and uses of traditional crops may be a serious constraint because firms that are likely to commercialize the new technologies may not historically have had extensive dealings with the Agricultural Research Service or with university Colleges of Agriculture. Mechanisms that aid in the exchange of information and reduce the time and cost involved in searching for information will enhance the opportunity for technology transfer.

The Federal Laboratory Consortium (FLC), consisting of a small central staff and volunteer representatives from at least 300 Federal labs, functions as a single source of entry for firms into the Federal laboratory system. It promotes communication with industry and shows firms where to go for help on a particular problem within the Federal laboratory system. The FLC also maintains computerized general-purpose databases on technologies of possible interest to industry.[1] In conjunction with groups such as the Industrial Research Institute, the FLC holds Federal laboratory-industry conferences to identify possible areas of collaboration. The number of industry participants has been growing. These conferences, which bring industry and Federal laboratory representatives together, provide economical means for companies to search for technologies that fit their needs. This program is clearly not devoted strictly to the development of industrial crops and uses. However, USDA is a member of the consortium, and this link can serve as a mechanism for firms to find out about ARS research activities (29). The FLC currently receives about $1 million per year, with funding due to expire in fiscal year 1991.[2]

In addition to establishing the Office of Critical Materials, the Critical Agricultural Materials Act also provided for the establishment of a database on industrial crops to be housed in the National Agricultural Library (NAL). The NAL, in cooperation with the Arid Lands Information Center at the University of Arizona, collects published material on industrial crops. Bibliographies of several crops are available. The information is also available through AGRICOLA, the Library's computerized database system relating to agricultural research. The CRIS and TEKTRAN databases also contain information about ARS and university agricultural research (32).

Many universities also have established offices that aid in disseminating research information to industry. These university offices are not devoted exclusively to developing new industrial crops and uses, but can direct interested firms to researchers performing this type of research within the university.

Technology Transfer Mechanisms

Technology transfer between Federal and university laboratories and industry can be facilitated in many ways, including personnel exchange between laboratories and industry, private-firm use of specialized laboratory facilities, and the granting of licenses to firms to commercialize technologies patented by the public sector.

Cooperative agreements between industry and public-sector research institutions are designed to create new technology that the firm can then commercialize, rather than to transfer preexisting technologies. With risk and expense sharing, industry is better able to take on large and long-term projects with uncertain payoffs. These types of arrangements can be difficult because they may require a fundamental reorientation on both sides. Issues of conflicts of interest, fairness to fins, national security, and proprietary information can create obstacles. Nonetheless, collaborative agreements exist between Federal laboratories and industry, and between universities and industry. The cooperative agreements that seem to be most effective are those made at a scientist-to-scientist level, rather than at the administrative level (13).

Incentives for collaboration in Federal laboratories are sometimes weak or even negative. Technology-transfer activities sometimes do not count in a researcher's performance evaluation even though the law specifies that it should. Researchers may view collaborative agreements unattractive if the work is proprietary and cannot be published as the researcher's own. Sabbaticals in industry are often not counted as pensionable. Only recently have researchers and their laboratories been permitted to keep portions of patent royalties for their inventions. It is not possible to copyright material developed in whole or part by government employees (29).

Slow negotiations and delays can cause deals to collapse as a fro's strategic situation changes. Startups are especially vulnerable. Many delays

[1]The J+&@ Research in Progress Database (FEDRIP) contains information on federally funded research projects.

[2]The Consortium is funded by a set-aside of 0.005 percent of theR&D budgets of the Federal laboratories.

revolve around a company's desire for exclusive rights to help recover the cost of expensive R&D efforts, which may require the Federal laboratory to waive its patent rights. Until recently, industry collaboration has been impeded by the possibility of data and information release under the Freedom of Information Act (FOIA). The National Competitiveness Technology Transfer Act of 1989 largely removed this obstacle by exempting the results of collaborative R&D from release under FOIA for 5 years (29).

Personnel exchange between private- and public-sector researchers is possible; however, it is uncommon for industry researchers to take visiting positions, particularly at Federal laboratories. The reverse is also quite rare. In the place of formal personnel exchange, visitor programs of just a few hours or days can provide an informal technology-transfer mechanism. Such programs provide opportunities for firms to stay in touch with the latest developments, particularly those in the government laboratories (29).

Startup firms are new firms established specifically to commercialize new technologies. The process can be aided by having the parent laboratory grant scientists entrepreneurial leave, with the right to return to old jobs within a stated time. However, this option does have problems, foremost among them the potential for conflicts of interest and brain drain. Some laboratories have established their own corporations to encourage startups, and provide services to entrepreneurs including office and laboratory space and help in forming business plans and incorporation. They also contribute capital in return for a minority interest in the firm (29). Other methods of technology transfer include allowing firms to use a Federal laboratory's specialized facilities and publication of semitechnical brochures to acquaint industry with technologies that may be of interest.

The Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480) and the Federal Technology Transfer Act of 1986 (Public Law 99-502) were enacted to facilitate technology transfer between Federal laboratories and industry. The Stevenson-Wydler Act provided Federal laboratories with a mandate to undertake technology transfer activities, while the Technology Transfer Act created an organizational structure to meet this mandate.

Federal laboratories are allowed to participate in cooperative R&D agreements and to grant exclusive licenses for resulting patents to the private businesses with which they cooperate. Each Federal department with one or more laboratories must allocate at least 0.5 percent of its existing research budget for technology transfer activities; additional funding for these activities was not provided. Identifying technologies with commercial possibilities, patenting, finding firms that might be interested, and exchanging information with those firms takes time, effort, and substantial funding. In some cases, startup firms will require support in the form of office space, help in writing a business plan, access to venture capital, etc.

Successful technology transfer requires a full-time staff, and a sustained financial commitment. Firms may hesitate to pledge themselves to multi-year projects when the government will commit funds only year by year. Given the financial constraints that already exist in many Federal research laboratories, it is perhaps not surprising that progress has been slow (29). However, cooperative agreements between industries and Federal laboratories are occurring. According to the USDA, the Agricultural Research Service has entered into 127 cooperative research and development agreements with industrial firms since 1986, and is in the process of negotiating 34 more agreements (32). Several of these agreements are for the purpose of commercializing new crops or uses of traditional crops.

Financial Assistance

Sometimes firms are interested in developing a new technology or product but the cost of the research and development needed to commercialize the technology exceeds the budget of the firm. This is a particular problem for small firms or startups. Federal and State programs are available to provide financial assistance to small firms.

Small Business Innovation Research Program

The Small Business Development Act was passed in 1982. Part of the Act required all Federal agencies that provide external research funds to establish a Small Business Innovation Research (SBIR) program modeled after a National Science Foundation program begun in 1977. Funding for each agency's SBIR program is equal to 1.25 percent of the agency's total external research funding budget. The total annual SBIR budget is approximately $350 million. Eligibility is restricted to small firms of fewer than 500 employees.

Grants provide finding for research from an idea to a prototype in three phases. Phase I grants are for $50,000 for 6 **months** and are used to determine technical feasibility, determine that sufficient progress has been made before larger funding takes place, and determine whether the firm can do high-quality research. Phase II involves the principal research. Grants last 1 to 2 years at levels up to $500,000 depending on the agency. Phase I studies accounted for about $109 million in 1987, and phase II accounted for $241 million. Phase III involves finding follow-on private funding to pursue commercial application (SBIR does not fund the final stages of bringing a product to market, but the Small Business Administration does help firms find private financing for commercialization).

USDA is one of the Federal agencies that has an SBIR program. The budget for USDA-SBIR for fiscal year 1989 was approximately $4 million. The USDA-SBIR program is divided into eight topic areas. New crop proposals generally fit into the Plant Production and Protection section. A new section on Industrial Applications has been established for fiscal year 1991. USDA-SBIR has received a small number of grant applications for new industrial crop projects, but they were not funded.

In addition to the USDA-SBIR program, funding for industrial uses of agricultural commodities is provided by the SBIR programs of other Federal agencies. One of the original projects funded by the National Science Foundation SBIR program in 1977, was a project to study the *Feasibility of Introducing Food Crops Better Adapted to Environmental Stress.* Emphasis was placed on food crops, but some new industrial crops, including many of those discussed in this report, were also evaluated. This study played a role in the establishment of Kenaf International, a private company working with the USDA Office of Critical Materials to commercialize kenaf. NSF-SBIR has funded research on milkweed among other crops, although this crop has not been successfully commercialized (4,26).

College and University Innovation Research (CUIR) Program

This program is being proposed by the National Science Foundation. It would function in a reamer similar to the SBIR program, but applications for funding would come from universities, not industry. The intention of the program is to allow university researchers to pursue commercialization of their research results without having to leave their university positions as has happened in many cases. Initial funding requests for fiscal year 1991 are $420,000 (8).

State Programs

Fourteen States (California, Connecticut, Indiana, Louisiana, Maine, Maryland, Michigan, Minnesota, Mississippi, Missouri, Montana, New Jersey, Vermont, and Virginia) have loan guarantee programs that are intended to stimulate business activity. Loan guarantee programs are more attractive than loan programs because they are lower cost and share the risk between the public and private sector. The State programs are generally aimed at manufacturing firms and are open to rural and urban businesses. At least 10 States (Connecticut, Indiana, Kansas, Maine, Massachusetts, Michigan, Minnesota, Montana, New York, and Wisconsin) have venture capital programs although none are aimed specifically at rural businesses. The Minnesota program (Greater Minnesota Corp.) may have the strongest rural component (6, 9).

Other Federal Programs

The Small Business Administration (SBA) makes direct and guaranteed loans to small businesses. It is not aimed at rural businesses, but because of the size of the program, it is a significant financial resource for rural businesses. In addition to the loan programs, SBA also supports small businesses through programs that support small business development corporations (SBDC) and small business investment corporations (SBIC). The SBDC program makes long-term capital available to emerging small businesses. The SBIC program encourages investors to make equity capital available to eligible small businesses (14).

The USDA Farmers Home Administration (FmHA) also operates a business and industrial loan program, which provides loan guarantees aimed at rural businesses. Eligible firms can be of any size and as a result loans made under this program tend to be large (14). Additionally, rural development programs provide funding for firms located in rural areas. None of these programs is geared toward commercializing new crops or uses of traditional crops, but firms involved in these activities may be eligible for these programs.

Summary and Conclusions

The foregoing analysis has several implications for development of policies to encourage technical change. Technical change involves research and development, commercialization, and adoption of new products and processes. Constraints, impediments, and opportunities in all three components must be addressed. This chapter has focused on research and development, and commercialization. The factors involved in the adoption of new technologies will be discussed in chapter 5.

The United States has several policies and programs to encourage research and development. Currently, public- and private-sector funding and research for new industrial crops and uses of traditional crops is limited. If new crops and uses are to be commercialized, adequate resources over a sustained period of time will be needed. A new industrial crops and use research and development policy must recognize the role that institutions and economics will play. It is clear that chemicals derived from agricultural commodities can be used for a broad range of industrial applications, and many are technically promising. Technical feasibility, however, will not be sufficient. Chemicals derived from agricultural commodities must be less expensive than those currently available, or provide a superior product in terms of quality, performance, supply reliability, or environmental benefits. Products and processes that fill specific market needs and provide superior quality and performance, and/or lower costs will be more attractive to industry, and it is in those technologies that industry interest will be highest. Research needs for technology development are generally framed within the context of the chemical, physical, or biological sciences. Attention to institutional structure and economic and social analysis is often lacking. This lack of market and economic analysis is a glaring deficiency and a severe constraint to the intelligent allocation of research funding for new crop and new use development. Research policy should include research for social science research as well as for chemical and biological research.

There has been a recent increase in attention to the problems of commercialization. Several programs, although not specific to new industrial crops and uses of traditional crops, are available to aid technology transfer from Federal laboratories to the private sector. However, these programs tend to treat firms homogeneously. Policy must be flexible enough to be able to offer a wide range of assistance options. Research, development, and commercialization efforts face different constraints and proceed in different ways in response to industry structure. Industries characterized by many small, highly innovative firms will have different needs than industries composed of very large fins, or small to medium-size firms lacking research capacity. For example, small, innovative firms may need financial help. Lack of information and inexperience with technology transfer from Federal laboratories may be a more serious constraint for large firms that have large research budgets. Finding additional ways to help industry minimize the search costs for information could prove quite beneficial. A successful policy must be able to address these differing needs.

Chapter 4 References

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