Modernizing Manufacturing

New Policies to Build Industrial Extension Services

Philip Shapira

Economic Policy Institute

1730 Rhode Island Ave., N.W. Suite 812, Washington, D.C. 20036
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Philip Shapira is a research assistant professor at West Virginia University's Regional Research Institute, where he conducts research on industrial restructuring, economic and regional development, and technology diffusion in the United States and Japan. Dr. Shapira has frequently served as a consultant to state and local economic development agencies and was previously a congressional fellow and analyst with the Office of Technology Assessment of the U.S. Congress (OTA).

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ECONOMIC POLICY INSTITUTE
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Suite 812
Washington, DC 20036

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Executive Summary

Compared with their major international competitors, U.S. firms have been slow to upgrade their manufacturing capabilities. The modernization problem is most acute among small and midsized firms with fewer than 500 workers. Most are not using available modern manufacturing technologies and are slow to implement quality control methods and to improve workforce training.

Smaller firms frequently lack sufficient expertise, money, and time to improve current operations and bring in new technologies and methods.

There are about 355,000 of these smaller firms in the United States, producing more than one-half of all value-added in manufacturing. Since many of them supply larger firms, this failure to modernize adversely affects the whole industrial base.

In the coming decade, smaller U.S. manufacturers will face tremendous competitive pressures. To meet this challenge, smaller manufacturers will have to upgrade their production systems, enhance design capability, improve products, seek new markets, and invest in improving workforce skills.

Unfortunately, smaller firms frequently lack sufficient expertise, money, and time to improve current operations and bring in new technologies and methods. This is particularly true for firms in rural areas.

Some states and state universities have initiated industrial extension programs, similar to the nation's agricultural extension service which, since the beginning of the century, has been transferring modern agricultural techniques to farmers. These industrial extension programs assist small and midsized firms to solve production problems, boost productivity and quality, introduce new technology, and improve training. In general, industrial extension programs have demonstrated that they can stimulate smaller firms to upgrade their manufacturing proficiency.

The pattern of industrial technology assistance in the U.S. is more fragmented and less developed than in Japan and in several European countries.

At the federal level, a handful of regional centers for the transfer of manufacturing technology have been sponsored, along with a small program to support state industrial extension and technology transfer efforts.

But overall, the pattern of industrial technology assistance in the U.S. is more fragmented and less developed than in Japan and in several European countries. Many states offer no programs. At the federal level, assistance strategies are not well coordinated and there is often too much emphasis on sophisticated technologies which smaller firms cannot absorb. At both the state and federal levels, the resources allocated are far too small, especially given the number of smaller firms that need assistance.

An increase in federal support (which would not need to be large, compared with other high technology projects) and better federal coordination could help states stimulate a considerably larger number of smaller manufacturers to modernize their manufacturing technologies. An effective industrial extension program would strengthen U.S. manufacturing capabilities, provide high-quality, cost-effective inputs to other manufacturers, and contribute to reducing the U.S. trade deficit.

An increase in federal support...and better federal coordination could help states stimulate a considerably larger number of smaller manufacturers to modernize their manufacturing technologies.

To move toward this end, the federal government needs to:

- Develop a strong federal policy commitment to work with the states in modernizing small and midsized manufacturers.
- Encourage the development of industrial extension services throughout the country, especially in poorer states and rural areas.
- Increase federal resources allocated to industrial extension and technology deployment.
- Strengthen intensive field service programs as well as establish new technology centers.
- Improve the linkages between industrial extension programs and public training programs.
- Help smaller manufacturers overcome the financial barriers to industrial modernization.
- Provide training and other services for state-level staff and support independent research and evaluation to guide program development.
- Encourage regional and industry-based collaboration and networking initiatives.
- Encourage larger customers to strengthen collaboration with suppliers.

An effective industrial extension program would strengthen U.S. manufacturing capabilities, provide high-quality, cost-effective inputs to other manufacturers, and contribute to reducing the U.S. trade deficit.

Introduction

The United States has a long history of technological ingenuity. American scientists have expanded the frontiers of knowledge and invented many new technologies. However, there has been much less success in recent years in transferring and applying this knowledge and technology to achieve commercial success in manufacturing. Although U.S. scientists and technologists pioneered products like color televisions, videocassette recorders, and machine tool centers, U.S. manufacturers have only small shares of the markets for these products today (*Business Week*, 1989). Similar trends are evident in semiconductors and computers. Inadequate macroeconomic and trade policies have certainly played a role, but one of the most critical reasons why many U.S. firms have lost market share has been because they have fallen behind foreign firms in design, engineering, and manufacturing (Dertouzos, Lester, and Solow, 1989). It is no longer sufficient to be the first to develop a new technology or even the first to commercialize it; rather, in today's global economy, preserving and building product market share, retaining high-wage jobs in industry and related services, and maintaining control of technology increasingly depend on proficiency at manufacturing (Cohen and Zysman, 1987).

One of the most critical reasons why many U.S. firms have lost market share has been because they have fallen behind foreign firms in design, engineering, and manufacturing.

Unfortunately, compared with major international competitors, U.S. firms have failed to devote enough attention to improving manufacturing technology (President's Commission on Industrial Competitiveness, 1985). In the 1970s and 1980s, fixed capital investment in manufacturing (as a share of manufacturing output) was 1.5 times higher in Japan than in the United States.[1] In developing new products and processes, Japanese firms allocate to tooling and equipment almost double the share of total project costs as the amount spent by American companies (Mansfield, 1988).[2] Over three-fifths of U.S. machine tools are ten or more years old, while more than one-quarter are twenty or more years old (American Machinist, 1989). Proportionately, Japan now uses numerically controlled (NC) machine tools at 1.5 times the rate in the U.S.—27 per thousand manufacturing workers compared with 18 per thousand in the United States.[3] Japan also employs about 7 times as many industrial robots per thousand workers as does the U.S. Several other countries, including Sweden and West Germany, have higher industrial robot densities than the U.S. (Tani, 1989).

U.S. firms have failed to devote enough attention to improving manufacturing technology.

However, the problem is not simply that U.S. companies have underinvested in new manufacturing technologies. In addition, and more fundamentally, U.S. manufacturers have lagged in product development methods, design, quality control, shop floor organization, inventory management, and workforce training. This means that U.S. firms are missing opportunities to improve quality and increase the productivity of their existing plants and equipment. It also means that when new machine technologies are introduced, they are often not used to full potential. For example, using similar flexible manufacturing systems, U.S. firms produce a less varied mix of parts, make fewer parts each day, introduce fewer new parts, and have less machine up-time than comparable Japanese firms (Jaikumar, 1986).

Many U.S. firms continue to pursue manufacturing strategies more suited to the 1950s than the 1990s.

There are, of course, American firms who have continued to upgrade their manufacturing capabilities and who are using new technologies well. But many U.S. firms continue to pursue manufacturing strategies more suited to the 1950s than the 1990s. U.S. firms which do not modernize run the very real danger of seeing their markets taken over by firms which are better at manufacturing. In today's international economy, these better manufacturers are likely to be European, Japanese, and Korean, rather than American.

The poor performance of U.S. manufacturers in upgrading their technologies and methods is a cause for concern because of the indispensable nature of manufacturing in an advanced economy. International trade is dominated by manufactured goods; manufacturing still provides much well-paid employment, there are many related service jobs which depend on manufacturing, and the manufacturing sector continues to support a large share of basic research in the United States (Cohen and Zysman, 1987; U.S. Congress, 1988). Enhancement of the manufacturing capabilities of U.S. firms is therefore not only important for their own survival, it is also important for the U.S. as a whole in order to reduce the trade deficit in manufactured goods, strengthen employment and living standards, and generate the resources to support continued research and technology development.

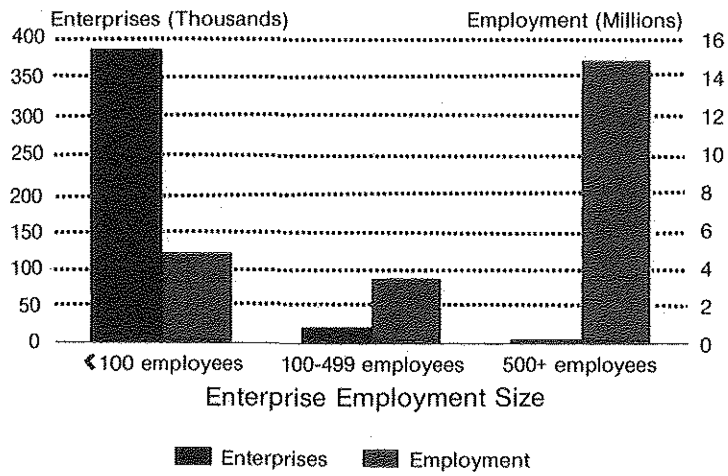
The problem of industrial modernization is most acute for small and midsized manufacturing enterprises with fewer than 500 workers.

The problem of industrial modernization is most acute for small and midsized manufacturing enterprises with fewer than 500 workers. There are about 355,000 of these smaller firms in the United States, directly employing more than eight million workers (U.S. Small Business Administration, 1988) (see Figure 1). These small and midsized manufacturing firms form a crucial part of the U.S. industrial base, producing more than one-half of value-added in manufacturing (U.S. Department of Commerce, 1985). Since many smaller manufacturers supply larger firms, the failure of smaller U.S. manufacturers to modernize adversely affects the performance of the industrial base as a whole. However, smaller firms frequently do not have sufficient expertise, money, and time to assess and improve their current operations and bring in new technologies and methods to upgrade quality and productivity. In some cases, customers, suppliers, equipment vendors, and private sector consultants can provide assistance. But many times, these sources are unavailable, inappropriate, inadequate, or too expensive.

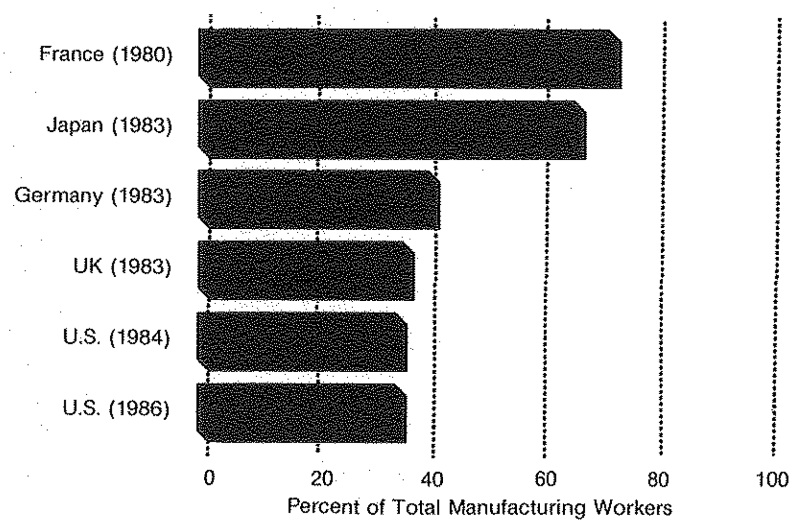
The failure of smaller U.S. manufacturers to modernize adversely affects the performance of the industrial base as a whole.

FIGURE 1

U.S. Manufacturing Enterprises and Employment, by Enterprise Size, 1986



Percent of Manufacturing Employment in Enterprises With Under 500 Employees



Sources: U.S. Small Business Administration (1989) and Storey & Johnson (1987).

Manufacturers in rural areas face additional modernization difficulties. Firms are generally more remote from customers, vendors, and other private assistance sources. Networks of manufacturers that exchange information (and provide peer pressure) are less dense. It is also harder to attract and keep technically qualified staff, while workforce training and skills are less developed in rural locations. Additionally, universities and other public sources of technology assistance are less accessible for rural firms.

Manufacturers in rural areas face additional modernization difficulties.

The barriers faced by small and midsized manufacturers present both needs and opportunities for government and public institutions (such as universities) to supplement private sector resources and to develop effective ways of helping small and midsized manufacturers to modernize. There is a role for the public sector akin to that played by the nation's agricultural extension service which, since the beginning of the century, has been transferring technology and modern agricultural techniques to farmers. A number of states and universities have recognized this and have initiated *industrial extension* programs to assist firms to modernize, solve production problems, boost productivity and quality, introduce new technology, and improve training.

There is a role for the public sector akin to that played by the nation's agricultural extension service.

Several of these existing state and university industrial extension programs have demonstrated that they can effectively stimulate smaller firms to upgrade their manufacturing proficiency (see Clifton, *et. al.*, 1989). The best programs do this by placing industrially experienced professionals in the field to diagnose and solve manufacturing problems and assess manufacturing technology needs and opportunities. Field service is supplemented by a range of other services, including workshops, technical information provisions, and demonstrations. State programs have found that highly sophisticated technologies are not necessarily the answer to the problems of smaller manufacturers. These firms can often achieve significant gains by adopting existing "off-the-shelf" technologies and by improving training and shop floor organization. More sophisticated approaches can then build on this base. Industrial extension programs succeed in helping firms pursue modernization by providing independent and qualified advice, developing customized yet workable solutions, and assisting firms with implementation. Extension program staff bring to firms a wide range of talents, including organizational, training, and interpersonal skills as well as technological and industrial expertise.

In addition to these state efforts, the federal government has now entered the picture. The 1988 Omnibus Trade Act gave the U.S. Department of Commerce and its National Institute of Standards and Technology (formerly the National

Bureau of Standards) new responsibilities for industrial modernization. A handful of federally sponsored regional centers for the transfer of manufacturing technology have been established, along with a small program to support existing state industrial extension and technology transfer efforts. Other agencies, such as the National Science Foundation, the Federal Laboratories, and the Department of Defense, are also paying more attention to improving manufacturing technology and methods, although their efforts are often directed toward larger firms.

Federal support for industrial extension needs to be refocused and increased.

While the increasing federal interest is a welcome development, there are also significant problems: assistance strategies are not well coordinated; there is a danger of too much emphasis being placed on sophisticated technologies which smaller firms cannot absorb; and the level of resources allocated is far too small, especially given the number of smaller firms that need assistance. In short, federal support for industrial extension needs to be refocused and increased. While several states offer industrial extension programs, not all states do. Even in states with programs, resources are frequently insufficient and services are inadequate. The federal government has a vital role to play in strengthening existing and new state programs and in providing improved leadership and coordination.

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Federal technology policy tends to give priority to high-technology, prestige projects which usually benefit larger firms and are often very expensive, too. Industrial extension, perhaps because it is low-tech and less glamorous, tends to be overlooked. But with an increase in federal support (which would not need to be large compared with other high-technology projects) and with better federal coordination, state programs could be leveraged to stimulate a considerable number of smaller manufacturers to modernize their manufacturing technologies. The payoffs for the nation's industrial competitiveness would be high. An effective industrial extension program would strengthen the nation's base of smaller manufacturers, accelerate the diffusion of modern manufacturing technologies and practices, help upgrade manufacturing skills, and bolster the economies of urban and rural manufacturing regions.

PART I. THE INDUSTRIAL MODERNIZATION PROBLEM

Most smaller firms face considerable barriers in technology upgrading and are not investing in modern manufacturing technologies and methods.

In the coming decade, smaller manufacturers will face tremendous competitive pressures. Foreign competition will continue to intensify. At home, large corporations are already transforming their relationships with smaller suppliers, reducing the number of suppliers and requiring better quality. At the same time, new opportunities will develop for regional networks of small firms adept at flexible production. Are U.S. smaller firms ready for these challenges? Have they made adequate investments in manufacturing technology and training? Is there a support infrastructure in place to assist smaller firms in improving their manufacturing skills and responding to changing technological, customer, and market requirements?

By and large, as Part I of this paper shows, the answers to these questions are not comforting. Most smaller firms face considerable barriers in technology upgrading and are not investing in modern manufacturing technologies and methods. In addition, the public and private sources that might be expected to help smaller firms generally do not provide adequate manufacturing technology assistance.

The Changing Role of Small and Midsized Manufacturers

To meet the competitive challenge which will intensify during the next decade, smaller firms must upgrade their technological capabilities.

Small and midsized manufacturers will have an increasingly important role in the economy, but many of these smaller firms are currently operating at levels far below their full potential. To meet the competitive challenge which will intensify during the next decade, smaller firms must upgrade their technological capabilities.

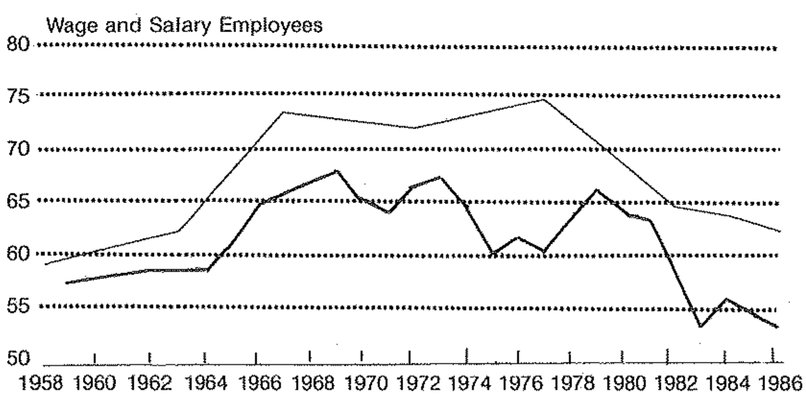
The 1980s have seen not only a decline in total manufacturing employment in the United States, but also changes in the structure of firms which comprise the industrial base. Many large manufacturing firms have massively restructured employment, closing or shrinking plants in the U.S. as they have lost market share, shifted out of product lines, introduced new technologies, or moved production overseas. Many large industrial corporations have divested themselves of businesses or parts of the production process they no longer consider to be essential, a process which has been called de-glomeration (Carlsson, 1989). Between 1980 and 1986, the net effect of these changes was an employment decline of 10.8 percent, or nearly 1.8 million jobs, among manufacturing enterprises employing 500 or more employees (U.S. Small Business Administration, 1988).

Among midsized manufacturers, the decline in employment has been less dramatic. Employment in midsized manufacturing enterprises employing 100 to 499 workers fell by 2.4 percent, or 83,000 workers, between 1980 and 1986. However, small manufacturers employing less than 100 workers added 326,000 jobs, an increase of 7.5 percent. As would be expected from combining these trends, the proportion of U.S. manufacturing jobs in small and midsized manufacturers employing less than 500 workers has grown, increasing from 32 percent in 1980 to 35 percent in 1986. Similarly, after increasing in the 1950s and 1960s, the average employment in U.S. manufacturing enterprises has declined from about 75 workers in 1977 to under 64 in 1986. The average size of manufacturing establishments also declined from 60 workers in 1977 to 54 in 1986 (see Figure 2).[4]

The proportion of U.S. manufacturing jobs in small and midsized manufacturers employing less than 500 workers has grown, increasing from 32 percent in 1980 to 35 percent in 1986.

FIGURE 2

Average Employment in U.S. Manufacturing Enterprises and Establishments, 1958-86



Sources: U.S. Small Business Administration, U.S. Enterprise Statistics, and County Business Patterns.

Despite the increase in jobs in small firms and the trend toward smaller manufacturing enterprises and establishments, the U.S. has a much smaller proportion of employment and value-added in enterprises with less than 500 employees than does Japan and some European countries (Storey and Johnson, 1987, see also Figure 1). In Japan, despite popular myths about the dominance of large corporations, the share of employment and value-added in small and midsized manufacturers has risen dramatically since the 1950s to about 60 percent today. It has been suggested

The U.S. has a much smaller proportion of employment and value-added in enterprises with less than 500 employees than does Japan and some European countries.

that the innovativeness and flexibility of these small manufacturers has contributed greatly to Japan's industrial development (Friedman, 1988). In contrast, the U.S. production structure has emphasized stable product lines and economies of scale, which, outside of a few high-technology sectors, have resulted in a less dynamic and less innovative small-firm manufacturing sector. For example, in 1967 average productivity (value-added per employee) in U.S. establishments with 20-49 workers was 75 percent of that in establishments with 500 or more employees. By 1982, the most recent year for which data are available, average productivity in 20-49 employee establishments had dropped to 63 percent of the level of plants with 500 or more employees (Luria, 1989). In other words, not only has the productivity of smaller U.S. plants lagged behind large ones, but the gap has grown.

The innovativeness and flexibility of small [Japanese] manufacturers has contributed greatly to Japan's industrial development.

In the coming decade, smaller U.S. manufacturers will face tremendous pressure to improve their performance. International competition is likely to intensify, coming from Korea, Taiwan, Brazil, and perhaps Eastern Europe, as well as from Western Europe and Japan. U.S.-based customers will also place considerable pressure on smaller firms. Large U.S. corporations have already begun to transform their relationships with smaller U.S. suppliers. Numerous smaller manufacturers have lost contracts as customers have closed U.S. operations or switched to global sourcing. At the same time, large U.S. firms maintaining their manufacturing capacity in the U.S. are increasingly requiring contractors to pay greater attention to quality and on-time delivery. This is true, too, for the growing number of Japanese and European firms investing in the U.S. In some cases, suppliers are being given more responsibility for design and subassembly.

Some observers believe that we are rapidly leaving the era of large-company, standardized mass production and are moving into a new period of industrial disintegration.

More fundamentally, some observers believe that we are rapidly leaving the era of large-company, standardized mass production and are moving into a new period of industrial disintegration. In this new phase, advantage will accrue not to the old industrial giants but to networks of small, innovative, flexible, specialized, and geographically linked production complexes (Piore and Sabel, 1984; Scott, 1988). In these small-firm production complexes, competition gives way to cooperation, external economies supplant internal economies, and the locus of production is the region as much as the firm, leading to a flexible, networked system of firms (Saxenian 1989). Examples of innovative, small-firm complexes are already evident in some U.S. regions such as California's Silicon Valley and in regions of Europe and Japan.[5]

The key question is: how well are U.S. smaller manufacturers able to deal with these structural changes? One way U.S. smaller manufacturers can adapt (besides going out of business) is to bid down wages and working conditions to sweat-shop levels. This is already happening in Los Angeles, New York, and other parts of the country where there has been a proliferation of small-firm, low-wage employment in sectors like apparel, electronics, and metalworking (Harrison and Bluestone, 1988; Sassen, 1989; Teitz and Shapira, 1989). A better approach is for smaller manufacturers to upgrade their production systems, improve products, enhance design capability, invest in workforce skills, and develop new customers and markets in the U.S. and in foreign countries. This strategy is one which is more likely to maintain high-wage jobs (at least in the aggregate), strengthen U.S. technological capabilities, provide high-quality inputs to other manufacturers, and contribute to reducing the U.S. trade deficit.

Smaller manufacturers... [must] improve products, enhance design capability, invest in workforce skills, and develop new customers and markets in the U.S. and in foreign countries.

Technology Diffusion in Small and Midsized Manufacturers

Despite the increasing demands being placed on smaller firms and their growing importance in the national economy, smaller manufacturers are not using available technologies that would allow them to improve quality, raise productivity, and increase their ability to respond to changing market conditions. There are many small and midsized U.S. manufacturers with the ability to generate and apply state-of-the art manufacturing technologies. Unfortunately, there are also a great number of smaller firms which lag in their use of modern manufacturing technologies and methods. This has been documented in a series of studies over the last few years.

Despite the increasing demands being placed on smaller firms and their growing importance in the national economy, smaller manufacturers are not using available technologies.

Rees, Briggs, and Oakey (1984) looked at the use of eight new technologies in U.S. metalworking industries and found that single plant firms had much lower adoption rates than multiplant firms, while smaller plants showed lower adoption rates than larger plants. For single plant firms, the adoption rate of numerically controlled (NC) tools was less than half the rate in multiplant firms. Similarly, only 10 percent of plants with fewer than 19 employees used NC tools, compared with 83 percent in plants employing more than 1,000 workers. The Industrial Technology Institute (1987), surveying the adoption of automation in durable goods firms in six Great Lakes states, found that large establishments (250 employees or more) adopted more than three times as many different technologies on average than small establishments with 10-49 employees. Another survey of U.S. metalworking plants, by Kelley and Brooks (1988), established that small, single-plant firms with fewer than 50 employees were far less likely to adopt programmable automation technologies than were large plants with 500 or more employees and a multiplant corporate parent.

Smaller plants are less likely than larger plants to use modern technologies.

The U.S. Department of Commerce (1989), in the largest survey to date of technology adoption in U.S. manufacturing, again confirmed that smaller plants are less likely than larger plants to use modern technologies. In this survey, the Bureau of the Census asked nearly ten thousand companies in fabricated metals, industrial machinery and equipment, electronics and electrical equipment, transportation equipment, and instruments about their use of 17 advanced manufacturing technologies. The technologies were grouped into five areas: design and engineering, fabrication/machining and assembly, automated material handling, automated sensor-based inspection and/or testing, and communication and control. In every technological area, larger plants with more than 500 employees had much higher adoption rates than smaller plants with 20-99 employees. The larger plants were twice as likely to be users of numerically controlled/ computer numerically controlled technology than the smaller plants, nine times as likely to use lasers to work materials, and sixteen times more likely to use pick and place robots (see Table 1).

It would be comforting to learn that smaller companies were projecting significant increases in their use of new technologies in the near future. Unfortunately, this is not the case.

It would be comforting to learn that smaller companies were projecting significant increases in their use of new technologies in the near future. Unfortunately, this is not the case. Kelley and Brooks show that only a small proportion of small, single-plant firms in metalworking not currently using programmable automation planned to invest in the technology. Similarly, nearly one-half of smaller plants employing 20-99 workers using none of the new technologies surveyed by the Bureau of the Census had no plans to acquire any of these technologies within 5 years. For those smaller plants using one technology, nearly 60 percent had no plans to add any others within the next 5 years.

While smaller firms and plants clearly have low adoption rates of new manufacturing technology, this might give less cause for concern if other, people-based "soft technologies" were being well used. Indeed, for many manufacturers, introducing new machine-based "hard" technology is not always the first or best way of enhancing productivity and quality. Much improvement can usually be gained through softer methods like statistical process control, just-in-time manufacturing, or greater attention to manufacturability in design stages. Soft technologies have the advantage of being less capital intensive, although they may involve training

TABLE 1

Percent of U.S. Establishments Using Selected New Manufacturing Technologies in 1988, by Size of Establishment

Technology	Employment Size 20-99	100-499	500+	[C]/[A]	[C]/[B]
	Used in operations Percent of establishments				
	[A]	[B]	[C]		
Design and engineering:					
Computer-aided design (CAD) or computer-aided engineering	29.8	54.4	82.6	2.8	1.5
CAD output used to control manufacturing machines	14.0	19.5	39.9	2.9	2.0
Digital representation of CAD output used in procurement	7.5	12.2	29.2	3.9	2.4
Fabrication/machining and assembly:					
Flexible manufacturing cells or systems	6.5	16.2	35.9	5.5	2.2
Numerically controlled/computer numerically controlled machine tools	35.9	50.0	69.8	1.9	1.4
Materials working lasers	2.4	5.8	21.6	9.0	3.7
Pick-and-place robots	2.7	13.4	43.3	16.0	3.2
Other robots	2.4	8.1	35.0	14.6	4.3
Automated material handling:					
Automatic storage and retrieval systems	1.2	3.7	24.4	20.3	6.6
Automatic guided vehicle systems	0.5	1.7	13.1	26.2	7.7
Automated sensor based inspection and testing:					
Automated sensor based inspection or testing of incoming or in-process materials	5.8	14.2	41.5	7.2	2.9
Automated sensor based inspection or testing of final products	8.0	17.4	44.3	5.5	2.5
Communication and control:					
Local area network for technical data	13.1	25.9	58.6	4.5	2.3
Local area network for factory use	11.0	22.9	50.7	4.6	2.2
Intercompany computer network linking plant to subcontractors, suppliers, or customers	9.7	22.7	41.8	4.3	1.8
Programmable controllers	22.5	48.1	77.8	3.5	1.6
Computers used for control on the factory floor	18.9	41.0	68.0	3.6	1.7
N	27,369	9,903	2,284		

Source: U.S. Department of Commerce, Bureau of the Census, Current Industrial Reports, Manufacturing Technology 1988, SMT(88)-1, Washington, D.C., May 1989.
Note: Based on sample survey of establishments in Standard Industrial Classification (SIC) Major Groups 34 - 38.

and other management costs. They can also be very effective. Although Japanese manufacturers are effective users of hard technology, their success has been based not just on machines and automation but also on common sense or simple development and manufacturing practices, such as closely coordinating design and tooling, manual systems of inventory control (*kanban*), and workplace quality control methods which reduce the need for separate inspections (Abegglen and Stalk, 1985).

Smaller U.S. firms are lagging as well in their use of...soft technologies.

However, it appears that smaller U.S. firms are lagging as well in their use of such soft technologies. In a survey of West Virginia durable goods manufacturers, only 14 percent of plants with 20-99 employees used statistical process control (SPC) compared with 78 percent of plants with more than 250 workers (Shapira and Geiger, 1990). A similar result was found among the durable goods firms surveyed by the Industrial Technology Institute, with SPC used by only 18 percent of firms with 10-49 employees compared with 60 percent of firms with more than 250 employees. The survey noted that most companies adopting advanced hard technologies started by using soft technologies, such as SPC—in other words, by first reorganizing the management of their manufacturing process. After successfully using soft technologies to make their existing operations more efficient, firms were then in a position to bring in more automation. Hence, the slow pace at which smaller firms adopt new soft technologies is a critical problem.

Workforce training is another area of weakness.

Workforce training is another area of weakness. Smaller manufacturers rarely provide formal training or skill upgrading programs for their workers. For example, among West Virginia manufacturers, workforce training was provided by 76 percent of establishments with more than 250 workers, but by only 20 percent of establishments with 100-249 employees, and only 6 percent of establishments with 20-99 employees. No establishment with fewer than 20 employees was found to provide workforce training (Shapira and Geiger, 1990). Similar findings have been reported in other national studies (see Osterman, 1989). Additionally, smaller manufacturers tend not to participate in public training programs, in part because public training programs are usually not well geared to meet the needs of smaller firms. The lack of training, combined with fewer internal promotion opportunities, means that smaller manufacturers are often unable to develop and retain the skilled labor needed to absorb and effectively operate new manufacturing technologies.

Barriers to Technology Upgrading in Smaller Firms

Small and midsized manufacturers face a series of barriers to modernization. Lack of financing to underwrite the cost of upgrading production systems is a major problem. Additionally, insufficient "hands on" opportunities for smaller firms to gain familiarity with technologies and methods to upgrade their shops (Lyons, 1988); lack of awareness about available and proven technologies; fear of change; insufficient time to study and implement changes; and shortcomings of skill and training among technical, engineering, and production workers—these factors all make technological upgrading difficult for smaller firms, particularly in rural areas.[6]

Lack of financing to underwrite the cost of upgrading production systems is a major problem.

In part, the problems facing smaller firms result from differences in the technical and operational characteristics of new manufacturing technologies contrasted with earlier generations of equipment. Whereas older equipment was based on mechanical and electrical technologies, today's machines frequently use sophisticated electronic technologies and computer control. Thus, a small machining shop may have years of experience in metalworking, but know little about the electronics and software programming needed to maintain and run computer-aided design (CAD) or computer-controlled manufacturing systems. Management may not know how best to select an equipment vendor, let alone define equipment specifications; workforce training is likely to be inadequate; and the likelihood of making mistakes, or of putting off the modernization decision entirely, is high.

While previous generations of equipment could often be used (and justified) on a stand-alone basis, new manufacturing technology increasingly needs to be used in an integrated way to work most effectively.

Moreover, while previous generations of equipment could often be used (and justified) on a stand-alone basis, new manufacturing technology increasingly needs to be used in an integrated way to work most effectively. For example, the introduction of CAD not only requires workforce retraining in new programming skills, but may also involve changes in parts specifications and inventory systems. Using CAD's ability to rapidly design and redesign parts may also lead to changes in manufacturing procedures, involving perhaps smaller batch sizes and manufacturing to order rather than to stock. Similarly, increased use of flexible production technologies puts new demands on a firm's ability to coordinate production by reducing planning horizons, magnifying the effects of errors, and requiring faster management response times (Schoenberger 1989). In other words, the introduction of new technology can have ramifications throughout the manufacturing and nonmanufacturing operations of a firm.

However, smaller firms often have limited capabilities to understand these new technologies and prepare for and deal with the consequences of their implementation. Managers and owners of smaller firms are usually preoccupied with the day-to-day problems of running their business (often single-handedly), keeping delivery schedules, and meeting payrolls. In these conditions, it is hard to find the time to learn about new manufacturing methods or evaluate complex new technologies. A related hurdle is the lack of in-house engineering and technical skills in smaller firms. For instance, in West Virginia, half of all durable-goods establishments with 20-99 employees have no manufacturing or process engineers and almost three-fifths lack new product design and development staff, too. Among manufacturers with fewer than 20 workers, two-thirds of establishments have no manufacturing or process engineers (Shapira and Geiger, 1990).

Smaller firms often have limited capabilities to understand these new technologies and prepare for and deal with the consequences of their implementation.

In addition to shortcomings in technical skills, managers of smaller firms (and also larger ones) frequently use inadequate methods to evaluate investments in modern manufacturing technologies and practices. Traditionally, U.S. firms justify investment in new equipment by examining labor savings and improvements in labor productivity. But, on average, direct labor now comprises only 15 percent of U.S. manufacturing costs, materials comprise 53 percent, while overhead costs account for 32 percent (Howell, *et. al.*, 1987). Focusing too narrowly on labor costs leads firms to ignore much larger opportunities to improve their performance in nonlabor-related areas. The benefits from upgrading manufacturing systems frequently include improved quality and reliability, greater manufacturing flexibility, reduced inventory, shorter product development cycles, less machine downtime, reduced materials wastage, smaller batch sizes, and better delivery schedules. However, in many firms, while direct labor costs are tracked avidly, there is often less awareness and information about the costs imposed by inadequate or outdated manufacturing methods. The costs of failing to modernize, and the range of benefits that would accrue from modernization, are thus poorly appreciated.[7] Equally important, when firms do decide to invest in new technology, they frequently fail to consider the full range of the technology's costs and requirements. In particular, the training time and costs involved in making new technologies work well are often underestimated.

Managers of smaller firms...frequently use inadequate methods to evaluate investments in modern manufacturing technologies and practices.

Smaller firms may also inadequately recognize the benefits that can be generated by improved manufacturing methods and procedures which do not require large capital investments. For example, in a traditional factory, similar machines are often grouped together on the shop floor. These separate groups of machines may be operated in isolation, leading to high levels of in-process inventory, poor quality control, and difficulties in accurately costing final products. However, rearranging equipment into "cells" with different machines integrated into a sequential or synchronous manufacturing process can reduce material handling time and in-process inventory, and improve quality control. Workforce morale may increase as a result of multiple job responsibilities and direct product costs can be easier to determine.[8] Again, even if managers were aware of the possible alternative ways of organizing the shop floor, since this rearrangement would have little impact on direct labor costs, a narrow focus on labor would probably fail to identify sufficient benefits to justify the costs of rearranging the machinery.

Another barrier to modernization of small manufacturers is prior bad experiences with new technologies.

Another barrier to modernization of small manufacturers is prior bad experiences with new technologies. Sometimes, vendors sell smaller firms technologies that the firm is never able to operate effectively. This may be because the firm made a poor technology selection through inexperience, the vendor "oversold" the capabilities or ease of use of the technology and failed to follow-up with after-sales training, or the firm failed to train its own workers in the use of the technology. In such situations, an attitude of "once bitten, twice shy" is understandable and may lead to reluctance among smaller firms to make further investments. These smaller firms will fail to move up the "learning curve" to positions where they can effectively select, absorb, use, and profit from new manufacturing technology.

In many rural areas, geographical isolation constrains contact with the technological and educational resources usually available in urban areas.

Additional problems of modernization are faced by small and midsized manufacturers in rural areas. Partly because of shifts by U.S. industry out of traditional manufacturing cities, manufacturing comprises around 30 percent of non-metropolitan, non-farm employment, compared with 25 percent in metropolitan areas (U.S. Department of Commerce, 1986 [1982 data]). However, in many rural areas, geographical isolation constrains contact with the technological and educational resources usually available in urban areas. For example, rural areas generally lack clusters of employment in technology- and research-intensive industries; much of the rural industrial base rests on labor-intensive industries (Rosenfeld, Malizia, and Dugan, 1988). Research centers, universities, and other information resources are less accessible. Networks of scientists, engineers, and technical consultants are less dense, and customers and vendors are farther away. Local economic development agencies tend to have few, if any, paid professional engineers or technical staff. Managers and owners tend to be conservative and not inclined to change established practices, workers skilled in new technologies are hard to find, and training programs may be poorly developed. Rural banks tend to be unwilling to lend money for technologies they do not understand. All of these problems apply to independently owned rural firms; but most are also applicable to rural branch plants which are distant from corporate technical resources. Ironically, manufacturers who located plants in rural areas in the 1960s and 1970s to employ a cheaper, non-union workforce may now find that they have cut some of the links to the technological infrastructure necessary to maintain competitiveness in the internationalized economy of the 1990s.

Rural banks tend to be unwilling to lend money for technologies they do not understand.

Conventional Sources of Technology Assistance: A Flawed System?

Technologies are available which could improve the performance of smaller firms, but lack of knowledge, financing, and skills obstructs the implementation of these useful technologies. Resources to help smaller firms overcome these deficiencies are not readily available, especially in rural areas.

One of the most obvious places a smaller firm might turn for assistance in upgrading its operations is a larger customer. Indeed, it would seem to be in the interest of larger firms to deploy some of their engineering staff to improve the productivity and technology of small suppliers. The vertical linkages between suppliers and customers can be critical pathways for transferring technology and know-how (Dertouzos, Lester, and Solow, 1989). Unfortunately, large U.S. manufacturing corporations have typically maintained an adversarial relationship with their small suppliers focusing primarily on short-term cost considerations. Parts have customarily been designed in-house, with contracts awarded to suppliers able to meet those specifications at the lowest cost. Contracts are moved at short-notice to other low-cost suppliers or terminated during business downturns.

Unfortunately, large U.S. manufacturing corporations have typically maintained an adversarial relationship with their small suppliers focusing primarily on short-term cost considerations.

The relationships between larger and smaller firms in the United States contrasts with the situation in Japan. Large Japanese corporations maintain close long-term links with their smaller suppliers and subcontractors, facilitating a high degree of knowledge and technology sharing between prime manufacturers and small and midsized firms (Trevor and Christie, 1988). The complex linkages between large Japanese corporations and their dense network of suppliers have been called "relational contracting," to distinguish them from the "spot contracting" more common in the United States (Dore, 1986, 1987). Moreover, in addition to benefiting from technology sharing, the Japanese style of subcontracting provides smaller firms with the stability and security to make long-term investments in new technology. For example, interviews with small and medium-sized Japanese suppliers of steelmaking equipment indicate that the long-term relationships developed over as many as 70 years with their large customers created a stable environment where considerable resources could be invested in process and product technology.[9] In contrast, U.S. small firms point to the uncertainty of demand as an important obstacle to investment in technological modernization.[10] Over the last few years, an increased concern with quality has caused many U.S. firms to restructure relationships with suppliers, in some cases making them more long-term. But, instances of large U.S. firms intensively reaching out to help their small suppliers modernize are still the exception rather than the rule.

Instances of large U.S. firms intensively reaching out to help their small suppliers modernize are still the exception rather than the rule.

Universities are another potential source of assistance. However, universities place their highest priorities on research and teaching; with some exceptions, universities have generally allocated few resources to assist technology upgrading in manufacturing. Most university faculty have little industrial experience. Moreover, faculty are generally more interested in working on advancing research frontiers than applying what is already known. Faculty are usually rewarded for their research record, publications, and success in obtaining funding, not for assisting small manufacturing shops solve problems or improve technology (although, at times, there is an overlap). When universities work collaboratively with industry, it is usually with larger firms who have both technical and financial resources to share with faculty researchers (see Shapira, 1988).

Most of the federal government's budget for supporting research and development in private companies goes to the nation's very largest firms.

The federal government has traditionally devoted few resources to helping small and midsized firms upgrade their manufacturing technologies and production systems. There are a handful of assistance programs, such as the U.S. Department of Commerce's Trade Adjustment Assistance (TAA) program which sponsors consultants to guide product- and process-technology improvements in firms adversely affected by import competition. Unfortunately, TAA certification requirements are laborious, funding is limited, and only a few hundred firms are assisted each year (U.S. Congress, 1987). There are set-asides (such as the Small Business Innovation Research program) to increase small business access to federal research dollars. Nonetheless, most of the federal government's budget for supporting research and development in private companies goes to the nation's very largest firms, those with more than twenty-five thousand employees.[11] Moreover, such programs usually support the development of innovative prototype technologies rather than applying current, commercially proven technologies to exist-

Less than $500 million, or 0.8 percent of [the federal R&D]...budget, is allocated to technology transfer and this is mostly for product rather than process technology.

U.S. equipment and software vendors, another potential source of private sector assistance, frequently give short-shrift to smaller firms.

ing manufacturing operations (U.S. General Accounting Office, 1987, 1989). Indeed, advancing basic knowledge and developing new technologies has long been the primary goal of almost all the federal government's research and development budget, which totaled $63 billion in 1989. Less than $500 million, or 0.8 percent of that budget, is allocated to technology transfer and this is mostly for product rather than process technology (Office of Management and Budget, 1989). Almost two-thirds of federal R&D spending, or $41.3 billion, goes to the Defense Department, largely for sophisticated and specialized technologies which rarely have commercial applications in the average small manufacturing shop.

U.S. small manufacturers do not fare well with other potential sources of private-sector assistance. In Europe, trade associations, especially at the regional level, have helped bring together groups of smaller firms in cooperative arrangements to introduce new technologies and improve design, marketing, and training (Plosila, 1989). For example, the Italian Confederazione Nazionale Dell'Artigianato (National Confederation of Artisans or CNA) organizes small firms with fewer than 20 employees, providing financing, marketing, information about new technology, and assistance with training, subcontracting, and networking. CNA has participated with regional governments in creating industry service centers to provide clusters of firms with testing, design, information, new technology, research, and training assistance (Rosenfeld, 1989). Similar examples of collaboration among smaller manufacturers and between associations of smaller firms and government are found in Denmark, Germany, Sweden, and elsewhere in Europe. In contrast, U.S. manufacturing trade associations are most commonly found pursuing legislative agendas in Washington and state capitols. At the local level, chambers of commerce and manufacturing groups often address community, economic development, education, and tax issues, but they rarely serve as resources for substantive manufacturing technology assistance.

U.S. equipment and software vendors, another potential source of private sector assistance, frequently give short-shrift to smaller firms. Vendors want to sell products, but their products do not always deliver as promised and they often fail to follow-up with after-sales training, especially for smaller firms. Vendors are generally not regarded as providers of objective advice. In this respect, private consultants might appear more promising. But smaller manufacturers may not know what kind of consultant they need. A not infrequent example is a manufacturer who faces a shortage of warehouse space. The manufacturer could hire an architect and contractor to build a new warehouse. However, the real problem might be that the firm is carrying too much in-process and finished inventory. What the firm might really need is an engineering consultant to help the firm restructure its manufacturing and delivery operations to reduce inventories. However, even when a firm realizes it needs a manufacturing consultant, it can be hard to determine whether the consultant will be good. Smaller manufacturers are very familiar with tales of expensive private consultants who delivered little. There are exceptions, of course: some trade associations do provide good technical assistance to members and there are many excellent vendors and consultants. There are also good university and state technology programs (some of which are discussed later). But it is still very much a hit-or-miss affair, and a large enough proportion of U.S. smaller manufacturers are missing out or lagging on industrial modernization to make this a cause for national concern.

Smaller manufacturers are very familiar with tales of expensive private consultants who delivered little.

PART II. POLICY STRATEGIES AND APPROACHES

If the federal government is to play an effective role [it must]...learn from the experiences of existing agricultural extension programs and state industrial technology assistance programs.

The interrelated problems of lagging modernization among small and midsized manufacturers and an inadequate system of public and private support cannot be ignored. Manufacturing is too important for the nation's regions, the overall economy, and our technological future. Many institutions and individuals must be involved in developing and implementing appropriate, corrective strategies, including state governments, educational and training institutions, industry associations and labor groups, customers, equipment vendors, and financial institutions, as well as small manufacturers themselves. But most critically, the federal government needs to be involved to ensure that national resources and leadership are applied to this nationwide problem.

If the federal government is to play an effective role, it needs not only to recognize the technology problems and needs of small and midsized manufacturers, but also to learn from the experiences of existing agricultural extension programs and state industrial technology assistance programs. The following sections discuss lessons from these programs and also raise some problems. This leads to a discussion of current federal policies and of new federal policy options to stimulate smaller firm modernization.

Lessons from Agricultural Extension

The nation's agricultural extension service frequently has been seen as a model for a new federal program to aid the small and midsized manufacturing industry.

As concern has grown about lagging modernization among smaller U.S. manufacturing firms, the nation's agricultural extension service frequently has been seen as a model for a new federal program to aid the small and midsized manufacturing industry. Established at the beginning of the century, agricultural extension is a comprehensive, nationwide system which helps farmers apply modern agricultural practices and technologies. More than 9,600 full-time county extension agents work closely with farmers to disseminate information, demonstrate new techniques, and provide technical assistance. These agents are backed up by 4,600 land-grant university specialists. The U.S. Department of Agriculture (USDA) cooperates with the state land-grant universities and state and local governments in operating and supporting the system. In 1988, the USDA provided 30 percent of agricultural extension's $1.1 billion budget, the states supplied 48 percent, counties provided 18 percent, and the balance came from private sources (Rasmussen, 1989). Agricultural extension is acknowledged to have played a significant role in the dramatic growth of U.S. agricultural productivity during the twentieth century. In 1910, more than one-third of the U.S. population lived on farms and each farmworker fed seven people. Today, less than two percent of Americans live on farms, but each farmworker feeds 83 people.[12]

Agricultural extension offers important lessons for an industrial extension service. Agricultural extension is a unified, national system of technology transfer that links publicly sponsored research in universities and USDA laboratories with individual farmers. It offers technologies with clear payoffs, rewards research geared toward utilization, is designed for local/user control, and is a stable and evolved system (Tornatzky, et.al, 1983). It is also a people-intensive system, with a ratio of about one extension staff member for every 150 farmers. This allows a high level of one-on-one contact between agents and farmers, enabling agents to develop good working relationships, provide hands-on assistance, and stimulate change.

Agricultural extension...offers technologies with clear payoffs, rewards research geared toward utilization, [and] is designed for local/user control.

However, it would be difficult and undesirable to develop a new federal industrial extension program based simply on duplicating the agricultural extension model, for two reasons. First, compared with farmers, manufacturers often face a more varied set of problems and conditions. In a given region, farmers usually share common soil, water, crop, climate, and market conditions. Their needs can be met by a single, university-based extension service. However, a region's small and medium-sized manufacturers can have widely differing technologies, products and processes, material needs, and markets. Interregional differences in manufacturing are also considerable. Thus, no single approach to manufacturing extension is likely to serve all needs; rather, a variety of models and approaches may be justified, depending on the particular characteristics of the manufacturers and regions being served. Adaptations of the agricultural extension model of university-based research and county-based field agents may meet some manufacturing needs. But other, perhaps quite different approaches to manufacturing technology dissemination may be needed.

No single approach to manufacturing extension is likely to serve all needs; rather, a variety of models and approaches may be justified.

Second, the federal government would encounter great difficulties today if it tried to establish a unified industrial extension service in the same way that the national agricultural extension system was founded in 1914. Current budget constraints are but one obstacle. In addition, several states are already running their own industrial extension and technology transfer programs. These programs assist firms in various ways, including technology deployment, product development, work organization, and workforce training. The federal government is thus making a late arrival into industrial extension. Rather than establishing its own independent programs, the federal government should supplement and support existing and new state-sponsored efforts. In other words, the federal government should not seek to unilaterally develop its own industrial extension system, but should build upon the experience and programs developed by the states. These state programs are considered in the following section and Part II concludes with recommendations for federal policy and action.

The federal government should not seek to unilaterally develop its own industrial extension system, but should build upon the experience and programs developed by the states.

Industrial Extension in the States

Some states have recognized the needs of smaller manufacturers and the benefits to be gained from improving the small manufacturing base of the economy. These states have developed industrial extension programs to help smaller firms upgrade their technology. The experience of these programs can provide invaluable guidance to other states and to federal policymakers.

However, while some states have developed effective industrial extension programs, all too often, helping existing manufacturers better use technology and modernize their production methods falls between the cracks of state economic development strategies. States have long played the economic development game of "smokestack chasing" to snare a footloose manufacturing branch plant. This strategy usually results in expensive tax breaks and other subsidies to large corporations, but does little for small manufacturers. Over the last decade, many states have started programs to "grow" new, start-up firms with business planning support, incubator space, and access to low-cost financing. But these small business development programs usually do not offer assistance on engineering problems and manufacturing technology.

While some states have developed effective industrial extension programs, all too often, helping existing manufacturers better use technology and modernize their production methods falls between the cracks of state economic development strategies.

States have also vastly expanded their spending on technology *development* programs, through initiatives like Ohio's Thomas Edison Program and Pennsylvania's Ben Franklin Partnership (Osborne, 1987, 1988). One study showed that states spent more than $550 million on technology programs in 1988 (Minnesota Governor's Office of Science and Technology, 1988). But almost 70 percent of this money went to advanced technology research centers and to research grants—spending that, generally, does not help existing small manufacturers. Programs that focused on technology *transfer* and *management*, rather than technology development, received less state funding—a total of $57 million in 1988.

When states do sponsor technology transfer and management programs, the goals and missions are quite diverse.

Program clients may include services as well as manufacturers. Some programs also serve local governments, schools, and individual residents. Other programs provide technology services as part of their broader offerings. For example, a recent National Governors' Association (NGA) study of more than 200 business assistance programs supported by both state and federal governments found that 167 programs provide some form of technology assistance (Clarke and Dobson, 1989). But the scope and variety of programs in this survey was rather wide, and included small business assistance services, university technology research centers, research parks, and business incubators. Most of these programs do not, as a principal mission, provide substantive assistance for manufacturing technology improvement and deployment. Nonmanufacturers comprised about two-thirds of the firms served by the programs in the NGA survey.

Several states have multiple technology assistance and transfer programs, while some states...have no programs at all.

The picture at the state level is thus complicated, even confusing. Among the existing state programs, a variety of approaches is being tried, from technical information provision to intensive technology deployment programs which offer on-site engineering and training help (Wyckoff and Tornatzky, 1988). A large number of programs offer limited forms of assistance to a wide array of clients. A much smaller number of programs concentrate primarily on helping existing manufacturers to apply technology. State governments, federal agencies, universities, colleges, and nonprofit organizations all administer and fund programs. Some programs receive funding from industry or collect fees from clients. Several states have multiple technology assistance and transfer programs, while some states seem to have no programs at all.

The pattern of industrial technology assistance provision at the state level...reflect[s] uneven development, inconsistent specialization, and the lack of national leadership and coordination.

In short, the mix, scope, and density of technology programs and services offered varies considerably across states and even within states. In part, this diversity reflects differing needs and conditions in individual states and regions. It can also be difficult to neatly break out technology assistance from other types of business assistance or to separate technology diffusion from technology development. However, the pattern of industrial technology assistance provision at the state level also seems to reflect uneven development, inconsistent specialization, and the lack of national leadership and coordination.

That said, it is possible to identify a subset of state and university programs that do offer substantive assistance to small and midsized manufacturers in solving engineering problems, improving manufacturing practices, and upgrading manufacturing technology. A few states have been running industrial extension programs for two or three decades.

In the south, programs were begun by North Carolina in 1955 and Georgia in 1960. These programs, modeled after the agricultural extension service, used professional engineers based in regional field offices to assist industrial attraction strategies and help local firms resolve technical problems and improve their use of technology. In the mid-1960s, programs such as the Pennsylvania Technical Assistance Program (PENNTAP) were developed to diffuse technical information to industry and to solve problems by linking firms with technical specialists.[13] Finally, in the late 1970s and throughout the 1980s, new state industrial extension and technology transfer programs have been started in Maryland, Massachusetts, Michigan, New York, Ohio, Pennsylvania, Virginia, and several other states.

In the south, programs were begun by North Carolina in 1955 and Georgia in 1960.

To provide information on these programs and learn from their experience, a questionnaire survey was administered to 43 state-level programs that provide assistance in deploying industrial technology.[14] The survey asked a series of questions about services, clients, methods of operation, implementation, personnel, and funding. Replies were received from 35 programs, an 81 percent response rate. Of these programs, 14 are sponsored by state agencies, 14 by universities, 4 by federal agencies (but with sizable state and/or university support), and 3 by nonprofit corporations. Total funding for the programs exceeded $55 million dollars, of which 45 percent was directly provided by state government and another 14 percent through state-provided university funds. Federal sources provided 17 percent, program fee income 15 percent, other university funds 3 percent, and industry grants and other sources 6 percent. Fourteen of the programs (40 percent) serve manufacturers exclusively. Just under two-thirds of the clients served by the programs are manufacturers.

In the late 1970s and throughout the 1980s, new state industrial extension and technology transfer programs have been started in Maryland, Massachusetts, Michigan, New York, Ohio, Pennsylvania, Virginia, and several other states.

Clinics or House Calls

The programs pursue a range of approaches to providing services. Almost all programs provide technical information to manufacturers in response to specific questions, problems, and requests, and most made field visits to firms to deliver one-on-one, on-site assistance. Four-fifths of the programs mail out general materials and newsletters (mainly for program outreach), while three-quarters hold events such as seminars, workshops, and courses for manufacturers on new technology, productivity, and quality. More than half of the programs demonstrate new technologies to manufacturers and provide opportunities to test new technology equipment. All of the programs make referrals to other sources of assistance where this would be useful to client firms (see Table 2).

TABLE 2

Services Offered by Programs

	Programs offering service	Manufacturing clients served	
	Percent	Mean	Median
Mail out general materials/newsletters	79	3,643	1,550
Events: seminars, workshops, courses	76	918	273
Technical information provided by phone/mail	97	450	100
On-site field services	91	219	120
Referrals to sources of assistance	100	165	50
Demonstration of new technologies	55	58	15

Ranked by mean of clients receiving service

Source: Survey of state industrial extension and manufacturing technology programs (see text).

Individual programs vary in the emphasis they place on different methods of providing service.

However, while no program relies exclusively on a single method, individual programs vary in the emphasis they place on different methods of providing service. Some programs specialize in helping firms that call in with specific technical problems (the "clinic" approach). These programs typically deal with a high volume of requests, many of which are relatively uncomplicated problems that can be resolved with a telephone call or by referral to a specialized source of assistance. Other programs emphasize active on-site services to firms, making "house calls" with technically trained field personnel who not only solve problems but also conduct technology assessments and develop technology, training, and implementation strategies. Programs offering intensive field services generally assist fewer clients but provide more in-depth service of from two- to eight-days duration.

Programs...help companies better use the machinery and equipment they already have.

Types of Assistance

When programs work with firms, the most frequently provided assistance is to improve or solve a problem with *existing* production or process technology (see Table 3). In other words, programs are working to help companies better use the machinery and equipment they already have. Reflecting this, support for quality control and statistical proc-

TABLE 3

Types of Assistance Provided to Manufacturing Firms in the Last 12 Months

	NEVER 1	OCCASIONALLY 2	OFTEN 3	VERY FREQUENTLY 4	3+4
Improve/solve problem—existing production technology	3	21	52	24	76
Identify vendor of new technology/software	6	36	48	9	58
Specify new production/process technology	6	41	34	19	53
Refer to training source	9	41	38	13	50
Quality control/statistical process control	16	41	28	16	44
Improve existing plant/layout operations	16	41	28	16	44
Identify new markets	24	36	21	18	39
Waste management/environmental problems	19	44	13	25	38
Improve/debug an existing product	18	45	27	9	36
Improve customer/supplier linkages	19	47	28	6	34
Just-in-time production	19	53	16	13	28
Specify new plant expansion needs	13	59	19	9	28
Improve design capabilities for product development	18	55	12	15	27
Occupational health/safety problems	31	44	22	3	25
Identify training needs/curriculum development	24	52	21	3	24
Aid new product development	30	48	12	9	21
Directly provide training	56	25	13	6	19
Develop production teams/committees	38	47	16	0	16
Acquisition of finance to upgrade technology	48	39	12	0	12

Source: Survey of state industrial extension and manufacturing technology programs (see text).

ess control techniques, and for improving existing plant layout and operations, are also among the most frequently provided types of assistance (ranked fifth and sixth, respectively).

Where new production technologies are warranted, the programs help companies identify vendors and develop specifications, the second and third most common forms of assistance. Manufacturers typically rely on equipment vendors, articles in publications, customer recommendations, advertisements, trade show exhibits, and direct mail for information about new technology (Shapira and Geiger, 1990). For a small manufacturer, who is unfamiliar with a new technology or software, this can be a difficult and risky process with considerable likelihood of making the wrong choice. For example, vendors are naturally interested in selling their own technologies rather than their competitors' and so may not give wholly objective advice. Here, public industrial extension and technology assistance programs are able to offer independent assessments and guidance. Programs also help smaller firms assess the full range of benefits and costs associated with different approaches to upgrading manufacturing capability.

The programs help companies identify vendors and develop specifications.

Significantly, the technology which programs most frequently help firms to *implement* is personal computers for use off the manufacturing floor, for example, in accounting, inventory control, and other office work (see Table 4). The *manufacturing* technologies for which programs most frequently provide assistance include computer-aided design/computer-aided engineering and computer-integrated manufacturing/flexible manufacturing. Programs infrequently provide assistance on robotics or the use of microprocessors in products. Programs are somewhat more likely to help firms identify useful technology and select vendors than to help them implement technologies. Not all firms need implementation assistance; some may only need initial guidance and encouragement to identify the right path. The data also confirm that not all firms need to implement hard new technologies to achieve improvements. Introducing personal computers (a well-known, non-state-of-the-art technology) into the front office is often one of the most useful first steps toward modernizing small manufacturing companies.

The technology which programs most frequently help firms to implement is personal computers for use off the manufacturing floor.

Training is now recognized as one of the critical factors in improving manufacturing performance and making effective use of technology. This seems to be recognized by the programs surveyed, since making a referral to a training source is the fourth most frequently provided type of assistance. However, it is much less common for programs to identify specific training needs, develop training curricula, or directly

TABLE 4

Technologies that Programs Have Helped Firms to Implement in the Last 12 Months

	Never 1	Occasionally 2	Often 3	Very frequently 4	3+4
Personal computers, nonmanufacturing	24	33	39	3	42
Computer-aided design/ computer-aided engineering	9	55	24	12	36
Computer-integrated manufacturing/ flexible manufacturing	18	52	18	12	30
Numerical control/ computer numerical control	27	52	15	6	21
Programmable controllers	33	48	12	6	18
Shop floor computers	28	56	9	6	16
Automated material handling	30	55	15	0	15
Sensors/process monitoring/ automated inspection	33	52	15	0	15
Robots	27	64	9	0	9
Use of microprocessors in final product	55	39	6	0	6

Source: Survey of state industrial extension and manufacturing technology programs (see text).

Programs...never or only occasionally help firms acquire financing to upgrade technology.

provide training. With a few exceptions, manufacturing technology assistance programs do not have the resources to run training programs; they usually steer firms to state training programs, community colleges, and other training vendors.

Almost 90 percent of the programs included in the survey never or only occasionally help firms acquire financing to upgrade technology. This is a surprising finding given that lack of financing is listed by both program managers and firms as one of the most important obstacles to manufacturing modernization. Aiding new product development and improving design capabilities for product development (as opposed to improving process technology) are also never or only occasionally provided by most programs. Help with waste management and environmental problems is a frequently provided type of assistance. Often, eliminating and reducing the production of waste and hazardous materials leads directly back to improvements in the manufacturing process.

The Clientele

Most of the programs do not establish rigid eligibility criteria outside of requiring clients to be located in the state. Nevertheless, almost all (95 percent) of the manufacturers assisted had fewer than 500 employees. It has been argued that firms in the 20-499 employee-size range should be the critical target group for manufacturing extension and technology transfer programs, providing the best returns to publicly sponsored assistance (Luria, 1989). Firms larger than this usually have sufficient resources of their own to promote improvement, while smaller firms with fewer than 20 employees are less stable and often find it difficult to absorb new technologies. The manufacturing technology transfer programs in the study concentrate on 20-499 employee plants: this size group comprises over two-thirds of all manufacturers served.

Firms in the 20-499 employee-size range should be the critical target group for manufacturing extension and technology transfer programs.

However, the profile of clients served by programs is complicated by the fact that subsidiaries or branches of larger companies accounted for about 37 percent of all clients served. Smaller or separate units of larger corporations can find it difficult to get assistance from centralized corporate resources (such as corporate engineering departments or central laboratories), and so call upon state technology programs for help. This is particularly true for units which are geographically remote from corporate headquarters. Firms or facilities located in nonmetropolitan or rural areas comprise about one-quarter of all clients served, a slightly higher rate than the 21 percent of manufacturing establishments recorded in U.S. nonmetropolitan areas (U.S. Department of Commerce, 1986 [1982 data]).

Subsidiaries or branches of larger companies accounted for about 37 percent of all clients served.

Assessment Methods

The most common assessment method programs used to determine clients' problems or needs is to meet with company or plant management. Almost 90 percent of programs claim to very frequently or often hold such meetings. About two-thirds of the programs also claim to very frequently or often collect information by telephone and send an engineer for a plant visit. However, visits by training specialists are rather less common, used frequently or very often by just over one-third of programs. Only one-half of programs commonly develop a written analysis. The programs which do document their assessments and recommendations are generally those offering more intensive field services.

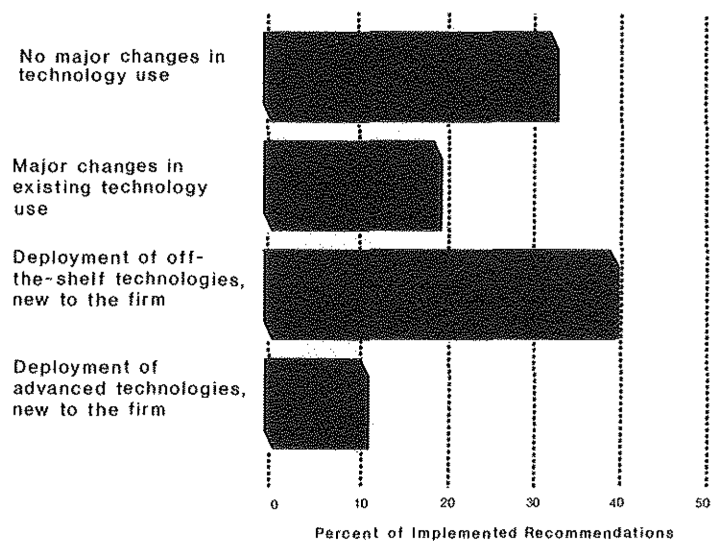
Unfortunately, almost three-quarters of programs never or only occasionally meet with workforce representatives. For programs that provide technical information over the telephone in response to management requests, this is understandable. But for programs with field service, the absence of dialogue with workers and (if unionized) their representatives weakens problem identification and strategy development. It is much more likely that problems will be correctly diagnosed and modernization strategies made successful if workers are involved in the process.

Unfortunately, almost three-quarters of programs never or only occasionally meet with workforce representatives.

Firms implement the recommendations of programs in about two-thirds of the cases, on average. Where firms implement program recommendations, these most often involve the deployment of off-the-shelf, familiar technologies (although new to the firm) or solutions to problems without any major technological changes (see Figure 3). Implementing recommendations for the use of advanced technologies is much less frequent. In the view of program respondents, the reasons firms do not implement recommended changes include the lack of financing and the expense of making changes. Management difficulties rank high on the list of reasons for nonimplementation, including the lack of man-

FIGURE 3

Role of Technology in Implemented Extension Program Recommendations



Source: Survey of Industrial Extension & Manufacturing Technology Programs agement commitment and time, management reluctance to change, and disagreement with the recommendations. It is not uncommon to find managers and owners with so many day-to-day problems in keeping a business going that they cannot consider—or are unwilling to consider—making changes in the way the firm operates, even if those changes will improve the firm's manufacturing performance.

Personnel

More than 90 percent of the programs [employ]... engineering staff, faculty, or consultants.

The success of a manufacturing technology program depends greatly on the quality and skill of its personnel. More than 90 percent of the programs engage engineering staff, faculty, or consultants. Regular staff engineers are employed by 80 percent of the programs; 37 percent of the programs (mainly those based in universities) use engineering faculty; and 34 percent use engineering consultants (results exceed 100 percent because some programs use two or all three staffing methods). Technical information and data specialists (mainly regular program staff) are used by about 80 percent of programs, while about 77 percent use business specialists (mostly regular staff, but sometimes business faculty, too). However, only 37 percent of programs employ training specialists. When training specialists are employed, they are usually regular staff or consultants.

The feedback linkages between programs and technology research do not seem well developed.

About two-thirds of the programs have sponsors or parent agencies which also conduct manufacturing technology research and development. In just more than half of these cases, the parent is a university. However, the feedback linkages between programs and technology research do not seem well developed. Only about one-third of programs often or very frequently demonstrate technologies developed by their parent institutions, while fewer than one-third transfer parent-developed technology at no cost (see Table 5). Program personnel infrequently participate as research team members or provide input or feedback for technologies under development.

Costs

The program cost per client varies quite widely, according to the range and intensity of services offered. The average (mean) cost per manufacturing client for the programs surveyed is just under $2,600 (the median cost is about $4,000).[15] These costs are not all public costs, since about half of the programs generate fee income. The lowest average cost per client (a few hundred dollars) is found among programs that mainly provide referrals and technical information, and serve most clients with less than four hours of staff time. Programs that provide intensive assessments,

TABLE 5

Research and Development Links With Parent Agencies or Sponsors

	NEVER 1	OCCASIONALLY 2	OFTEN 3	VERY FREQUENTLY 4	3+4
Demonstrated technologies developed by parent	33	33	19	14	33
Transferred at no cost technology developed by parent	33	38	19	10	29
Sold or licensed for a fee technology developed by parent	57	24	14	5	19
Used clients to test technologies under development by parent	48	33	14	5	19
Participated as technology research team members	42	42	5	11	16
Provided input/feedback for technologies under development	20	65	10	5	15

Source: Survey of state industrial extension and manufacturing technology programs (see text).

field service employing one or more professional engineers, and assistance extending to many days of service have much higher costs, ranging from about $5,000 to $20,000 (see also Shapira, 1990).

Technology broker programs disseminate and package technical information to firms and make referrals to other sources of information and assistance.

How Industrial Extension Programs Work

The diversity of activities and approaches among state programs makes any simple categorization scheme risky. However, it does seem that the programs fall roughly into four groups: technology brokers; university-based field office programs; technology centers and state-sponsored assessment, technology stimulation, and consulting services; and manufacturing network initiatives.[16]

1. *Technology broker programs* disseminate and package technical information to firms and make referrals to other sources of information and assistance. These programs typically handle a high volume of requests, allocating to each a small amount of time (usually less than a day on average).

Examples of programs in this group include the Pennsylvania Technical Assistance Program (PENNTAP), a program established in 1965 and based at Pennsylvania State University, which provides technology information and assistance services to industries and local governments in the state. Firms seeking information on a technical problem are assigned to one of the program's eight technical/engineering specialists. Most problems are resolved quickly. In some cases, a staff engineer makes a site visit. Program staff may refer to faculty, federal and private laboratories, computerized data bases, and library resources for assistance in resolving problems. PENNTAP also disseminates information about university and federal research. Most of PENNTAP's direct funding of $900,000 comes from the state. Requests from about 850 private firms and 450 other organizations are dealt with each year.

The Ohio Technology Transfer Organization [has]...a network of 34 agents based at community colleges in the state.

Among other technology broker programs is the Ohio Technology Transfer Organization (OTTO), which provides information services to businesses and other organizations through a network of 34 agents based at community colleges in the state. Only a few agents are engineers and not all of them are full time. Agents, especially in rural areas, spend a considerable amount of time on general economic development and business startup questions. OTTO also has 10 support staff, including a small group of research associates at Ohio State University who provide engineering consulting, reference and technical information services, and networking services for OTTO agents in the field. OTTO handled nearly 4,300 requests for information and assistance in 1988 from just more than 3,000 companies. Nearly one-half of the requests involved management and business questions, 19 percent involved questions about products or product development, and 16 percent involved production or production process subjects. One-third of the total requests came from manufacturing companies. In 1988, OTTO received $1.6 million from the state government.

University-based field office programs employ full-time engineers to work with local companies in their area.

2. *University-based field office programs* employ full-time engineers to work with local companies in their area. These programs tend to focus on problem-solving to help companies overcome specific difficulties. Problems involve a very wide range of technical areas, from process technologies to plant layouts. By virtue of university sponsorship (usually in an engineering college), they have closer links with faculty, service is free, and programs are fairly stable in terms of funding and personnel.

The largest university-based field program is run by the Georgia Institute of Technology with its network of 12 regional offices and 26 field staff to provide manufacturers and local communities in the state with information and technical assistance on new technology, management tools and techniques, and provide access to problem-solving engineering skills. Established in 1960, the industrial extension program is now part of the Economic Development Laboratory of the Georgia Tech Research Institute. The program's regional offices are all outside of Atlanta, in small cities and rural locations serving groups of counties. Through the industrial extension offices, firms are provided with two to five days of assistance by a field engineer. In FY 1988, the industrial extension program provided 960 firm-specific assists, mainly to rural manufacturers, and also helped with numerous other community economic development and information requests. About 70 percent of business problems are solved directly by field staff. For the rest, field engineers call upon, or refer clients to, resources available through the Economic Development Laboratory and other facilities at Georgia Tech. These facilities include the Georgia Productivity Center, which provides assistance of up to 15 days for firms trying to enhance productivity and improve technology, and the federally funded Trade Adjustment Assistance Center, which delivers very intensive assistance (up to 60-80 days) for qualified trade-impacted firms. Industrial extension's direct funding is about $2.5 million a year.

In FY 1988, the [Georgia Tech] industrial extension program provided 960 firm-specific assists, mainly to rural manufacturers.

Another program in this group is the University of Maryland's Technology Extension Service (TES) where six industrially experienced engineers staff five regional field offices. TES offices serve rural Western Maryland and the state's rural coastal areas, as well as Baltimore and the urban areas adjacent to Washington, D.C. Field engineers in these offices disseminate technical information and work with local companies to solve technical problems. Site visits are made by the engineers to forge personal relationships with companies, review the firm's technological capacity, and specify problems. In about 45 percent of the cases, the field engineer calls in a university faculty member to provide specialized assistance. Up to five days of free assistance can be provided per project per year. TES assists 250 to 300 firms each year and has a direct budget of $400-450,000. TES is located in the University's Engineering Research Center, providing access to other Center programs including productivity audits and joint university-industry applied research programs. TES was established in 1983.

Technology centers and state-sponsored consulting services [emphasize] technological modernization.

3. *Technology centers and state-sponsored consulting services*. Programs in this group are not directly part of university systems (although they may be linked with universities) and frequently employ consultants to provide services to firms. There is an emphasis on promoting technological modernization, i.e., providing firms with assessments on

how they can upgrade their technology and assisting firms with implementation, including training. Fee for service or cost sharing is common, although not universal. Funding, at least to date, is not always certain or stable.

An example of one of these programs is the Michigan Modernization Service (MMS), housed at the Industrial Technology Institute in Ann Arbor, Michigan. Funded by the state government, MMS focuses on Michigan's "foundation" firms, a tier of more than 5,000 metalworking companies, machinery manufacturers, and other small shops with 20-500 workers who provide about 400,000 jobs and a $10 billion annual payroll. These firms, survivors of the battering Michigan's economy received in the early 1980s, are seen as critical to the state's future as an international center for manufacturing complex, high value-added products. To help these firms modernize, MMS uses an intensive and sophisticated diagnostic process, makes on-site visits, and supplies a detailed package of technology and training recommendations through written and oral presentations. A team approach is used, with an industrially experienced field representative paired with a training specialist for each client. MMS also offers market analysis to help companies expand their markets, develop new products, and establish new linkages with customers. Each firm receives up to six days of free assistance. About 45 part-time/consultant field representatives and staff work in the program, equivalent, on a full-time basis, to about five or six technical field representatives and five or six training specialists. MMS served between 120 and 140 client firms in FY 1988 with a state budget of $2.8 million. In FY 1989, the number of clients served is slated to double with a budget of $3.9 million.

[The Michigan Modernization Service] also offers market analysis to help companies expand their markets, develop new products, and establish new linkages with customers.

The Pennsylvania Industrial Resource Centers (IRC) program is a second example of a program in this group. In 1988, the Commonwealth of Pennsylvania initiated the IRC program to provide technology and other kinds of assistance to small and midsized manufacturers. Under the IRC program, nine independent nonprofit centers have been established throughout Pennsylvania, serving urban and rural regions. Eight of these centers concentrate on assisting traditional manufacturing industries in their regions, providing specialized worker training and helping them to understand and implement modern manufacturing practices, adopt new technology, and improve quality.[17] Each of these centers differs in its operational approach and fee structure. The services provided by the IRCs include manufacturing assessments, research and technical information services, and education and training programs. Some centers use regular staff to directly provide assistance services. Other centers conduct initial technology assessments and then

The services provided by the [Pennsylvania Industrial Resource Centers] include manufacturing assessments, research and technical information services, and education and training programs.

help to underwrite part of the cost of an independent private consultant to help firms implement projects and solve problems. In such cases, IRCs qualify consultants and carefully match them with firms, thereby reducing the risk to the firm of choosing the wrong consultant. Some centers also provide low interest loans to help firms finance manufacturing improvement projects.

Pennsylvania will provide up to $10 million in state funds for three years to support the [IRCs].

Pennsylvania will provide up to $10 million in state funds for three years to support the program. Each center has to find equivalent matching funds. Eventually, the IRCs are expected to become self-supporting. In 1989, the IRCs garnered $1.5 million in fee income, $0.5 million in foundation support, and $3 million of in-kind income to match $5 million in state funds. The centers served about 500 manufacturing firms in 1989, all employing fewer than 500 people. Two-thirds of the firms served are in metalworking industries. About 50 staff are employed by the nine IRCs, including engineers and information, business, and training specialists.

4. *Manufacturing networks*. There is an emerging, fourth category of state programs that aim to develop production and manufacturing networks. In several states, efforts are now underway to build regional networks of firms which can cooperate on technology diffusion, training, design, finance, and marketing, influenced by the highly successful small-firm production networks of Northern Italy (Hatch, 1987). In Italy, networks of highly innovative and technologically advanced small firms have developed in industries like textiles and clothing, shoes, machine tools, food processing, and medical devices based on extensive linkages of shared production and subcontracting. The networks are often geographically clustered together by industry groups in industrial districts, which facilitates cooperation as well as competition. A series of quasi-public service centers sustains these networks, providing shared design services, training, management assistance, product development services, manufacturing assistance, and marketing. The centers are jointly sponsored by local and regional governments, trade associations, trade unions, and colleges.

In several states, efforts are now underway to build regional networks of firms which can cooperate on technology diffusion, training, design, finance, and marketing.

In the U.S., experiments to develop production networks based on the Italian experience are beginning in several states. The Southern Technology Council, a consortium of 14 southern states, has established two pilot networking projects in North Carolina and Arkansas. In these projects, community colleges, economic development groups, and local firms will attempt to develop collaborative networks for manufacturing, design, training, purchasing, and marketing. In Massachusetts, industry action projects have been established in the state's metalworking and needle trades regions to help clusters of smaller firms in these industries improve skills training and bring in new technology. The Massachusetts projects are notable for bringing together companies, unions, and local training institutions in collaborative networking efforts. Other states where networking projects are beginning or are underway include Indiana, Ohio, Michigan, West Virginia, and Oregon (see, for example, Hasler, 1988). Experiments are also being started in Pennsylvania, Virginia, and elsewhere to establish shared manufacturing facilities where smaller firms can join a consortium of manufacturers sharing a centralized advanced manufacturing facility, thereby gaining access to equipment and technical resources that they would otherwise not be able to afford or operate.

The Massachusetts projects are notable for bringing together companies, unions, and local training institutions in collaborative networking efforts.

Some Lessons From the States—and Some Problems

Although there are many variations in the organization of industrial extension services among states, there are some common factors. Based on the state survey, case studies, and firm interviews, this section considers some of the shared experiences and lessons of state-level programs and also highlights some problems.

First, it is clear that field service plays a critical role in the industrial modernization process. Helping small and midsized firms upgrade their manufacturing systems and introduce new technology is usually not a straightforward process. Recommendations must be tailored to the needs, capabilities, and resources of individual firms. Interpersonal as well as technical skills are needed, since the barriers to change can be organizational and psychological as well as financial and technological. The ability of professional staff to go out into the field and make "house calls" (on-site visits), make detailed assessments, and develop in-depth working relationships with firms, makes a real difference in stimulating technological upgrading. The other offerings of state programs, such as workshops, technical materials, or phone referrals, are useful in informing and guiding firms and can be essential program components. But, in solving substantive problems and stimulating firms to embark upon technological modernization, there seems to be no substitute for high-quality, active, one-on-one, field service assistance.

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Second, technology by itself is usually not enough. State programs have learned to take a broad view of technology needs, including the improvement of workforce training, quality control, shopfloor organization, management systems, and inventory control, as well as the use of machines. Indeed, without corresponding improvements throughout all aspects of the production and management process, new machines are rarely used effectively. Hard engineering assistance works best when it is combined with assistance on training and organizational changes in the firm. In many instances, such as when initiating statistical process control or a just-in-time inventory system, the most crucial step is to enhance workforce skills and flexibility, and to rethink workplace operating systems, not to invest in machinery. When new hard technologies are introduced (such as computers, computer numerical controlled machine tools, computer-aided design, or computer-assisted manufacture), training and organization assistance is vital to make most effective use of these technologies.

Hard engineering assistance works best when it is combined with assistance on training and organizational changes in the firm.

Third, technologies need to be approached pragmatically. When new manufacturing technology is discussed, images of state-of-the-art computer-integrated manufacturing systems and sophisticated robotized assembly lines are often presented. However, state programs have found that much improvement can be obtained in many small and midsized manufacturers through the use of off-the-shelf technologies rather than highly sophisticated, relatively untested, expensive, and complex new technologies. For example, computerization might best be introduced into a small manufacturing company by starting with tested computer-aided design software using readily available personal computer systems. Training for this system could be easily provided by a private vendor or a local college. At this time, most smaller firms are in a position where they cannot absorb highly sophisticated, leading-edge technologies, they cannot afford to make mistakes, and they usually cannot absorb too much technology at once. But they can readily use pragmatic technologies which have been well-tested and are readily procured, operated, and maintained. Most state programs are working to bring firms up to today's level of technology; subsequently, they can help with more sophisticated approaches.[18]

Much improvement can be obtained...through the use of off-the-shelf technologies rather than highly sophisticated, relatively untested, expensive, and complex new technologies.

Finally, effective industrial extension needs a long-term public commitment. Industrial extension is not a short-term jobs program. Rather, it works over the long-term to improve enterprise productivity and quality, technological capability and flexibility, and management and workforce skills. To do this, industrial extension programs need strong institutional support and stable public funding to develop and maintain the confidence of the business community, form long-term relationships with firms, and attract and retain first-rate technical staff. Some programs do charge fees for service, but it is not desirable, or likely, that fees can fully substitute for public funding.

Where programs charge fees or ask firms to cost-share, a substantive initial service is generally given without charge. Otherwise, there is the danger that an up-front fee will discourage smaller firms from seeking services. If programs become too dependent on fees, they risk losing their public service character. At the same time, firms are often willing to pay a fee for service as long as the service is of high quality. Programs sometimes resolve this problem by providing a first stage of service free, up to a specified number of days. After this, when a good program-client relationship has been established, a plan of further work is developed and a fee charged. In other cases, after providing an initial phase of assistance, programs refer the firm to qualified private consultants to implement the project. Here, programs serve to rationalize the private consulting market, significantly reducing the risk of a smaller firm choosing an unsuitable consultant.

A substantive initial service is generally given without charge.

The Problems

There are also some problems in the state programs that are worth highlighting. While the diversity of programs at the state level has strengths, there are also weaknesses. It is by no means clear that all programs are equally effective. In some state programs, choices have been made to provide limited levels of technology assistance to large numbers of firms. Other programs have chosen to aim a greater depth of resources at a smaller number of manufacturers. It is likely that these intensive approaches will prove more effective in upgrading the small and midsized firms' technology base. However, there is little hard evidence about the effectiveness of different methods. A few programs collect figures on the cost savings and jobs affected as a result of their activities, showing very positive results. But such traditional economic development criteria are not very good ways of measuring program effectiveness; better indicators are technologies implemented or manufacturing practices improved as a result of program intervention. However, to date, there has been no thorough national research evaluation of the state efforts.

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Although many of the state programs devote resources to maintaining offices and services in rural areas, it is not always easy to deliver effective *technology* services. In some cases, technology transfer agents in rural areas are not engineers and thus have a limited ability to resolve technical problems themselves. At the same time, many rural firms have low adoption rates of modern technology, lack financial and technical resources, and are very cautious about changing long-established ways of operating. This situation can create a circle of low demand for technology services and low capacity to stimulate technological change in rural areas that is hard to break.

While training is recognized to be an essential element in industrial modernization, many programs do little more than refer firms to training sources. This system can work if training and extension programs are well coordinated, but this is not always the case. Also, while lack of financing is a major concern, programs offer little assistance. Ideally for the firm, services should be seamless. After undergoing technology assessments and accepting action recommendations, firms should not have to face unnecessary bureaucratic hurdles to access training and financial help. A few programs have improved the coordination of services. For example, Michigan's Modernization Service uses teams of engineering and training consultants, the latter on leave from the community college system. In Massachusetts, the Industrial Services Program has developed an interagency approach where a single unit can provide training, financing, and technical consulting. But by and large, training and financing programs are not well integrated with technology services.

Ideally for the firm, services should be seamless.

The linkage between extension personnel and parent technology-research programs is another weak area. Researchers often prefer to develop innovative new products rather than improved process technology. Researchers also tend to view the problems of smaller, mature manufacturers as mundane and unglamorous. In part, this view reflects the lack of public research funding for work on applied technology. It also reflects the fact that most private research funding is provided by large corporations, not small ones. At the same time, full-time extension personnel rarely do research. Extension personnel are usually hired because of their practical industrial experience rather than academic research skills. Where links between research and extension exist, they are usually one-way with extension personnel demonstrating or licensing parent-developed technology. Possibilities for using extension professionals' field experience to improve the design and development of new applied manufacturing technologies are not well explored.[19]

The federal government has taken a series of steps in recent years toward strengthening the nation's technological base.

The Federal Role

With increasing concern about challenges to the U.S. technological position, the federal government has taken a series of steps in recent years toward strengthening the nation's technological base. Legislation has been enacted to improve technology transfer from federal laboratories. Cooperation between companies on joint research projects is now encouraged. And a number of industry, university, and government research consortia have been established, such as SEMATECH and the National Center for Manufacturing Sciences (both involving the Defense Department) and the National Science Foundation's Engineering Research Centers. These initiatives have been designed largely to keep the U.S. at the forefront in leading edge technologies such as next generation semiconductors, robotics, or advanced materials, a mission which does not serve the needs of smaller manufacturers which have yet to use today's available technologies.

Congress has started to define a federal role in helping smaller firms.

However, Congress has started to define a federal role in helping smaller firms. In the 1988 Omnibus Trade and Competitiveness Act, the Commerce Department was mandated to establish a Clearinghouse on State and Local Initiatives on Productivity, Technology, and Innovation to serve as an information center on state and local technology initiatives. Congress also strengthened policy coordination through a new Technology Administration in the Department of Commerce responsible for the National Institute of Standards and Technology, the National Technical Information Service, and related functions.

But the most significant Congressional action was to redesignate the old National Bureau of Standards as the National Institute of Standards and Technology (NIST). NIST is now charged with assisting industry to improve technology development; process modernization; product quality, reliability, and manufacturability; functionality; cost effectiveness; and commercialization. NIST is authorized to provide technical assistance to state and local industrial extension programs and serve as a link between these programs and other federal technology services. NIST is also sponsoring regional centers for the transfer of manufacturing technology. These centers will provide information and education for local small and midsized firms, demonstrate advanced technology, help firms evaluate their needs and implement new technologies, and support workforce training. NIST eventually hopes to initiate 12 regional centers. Three centers have been designated to date: the Advanced Manufacturing Program in Cleveland, Ohio; Rensselaer Polytechnic Institute in Troy, New York; and the University of South Carolina in Columbia, South Carolina. The centers will initially be supported with federal and state funds, but federal funding will decline in the fourth year and fall to zero in year six.

[The National Institute of Standards and Technology] is authorized to provide technical assistance to state and local industrial extension programs.

Yet, while an increased role for NIST is a welcome development, some caution is perhaps appropriate. NIST is a major center for developing and testing advanced manufacturing technologies (the Advanced Manufacturing Research

Facility is at its Maryland headquarters). But many, perhaps even the majority, of smaller U.S. firms, do not need or cannot use these state-of-the-art technologies which, besides being expensive, are often untested. For most smaller firms, the highest priority is to improve existing operations using proven, off-the-shelf technologies, and to strengthen quality, inventory control, design, training, and marketing. Here, the experience of existing state industrial extension programs in taking a pragmatic stance toward new technology for smaller firms should be taken as a helpful guide to NIST and its new centers.

For most smaller firms, the highest priority is to improve existing operations using proven, off-the-shelf technologies.

Federal Help Needed

With the NIST programs, the federal government is assuming greater responsibility for information sharing, federal coordination, and demonstration projects to help state efforts to modernize small manufacturers. This is good, as far as it goes. But the federal government needs to do much more. Even with NIST's new role, the federal government has not done enough to develop and promote a coherent and nationwide system of support for industrial modernization. In this respect, the U.S. continues to lag behind its international competitors.

The federal government has not done enough to develop and promote a coherent and nationwide system of support for industrial modernization.

For example, in addition to their relationships with larger customers, small and midsized Japanese companies have access to a nationwide public system of technological assistance. Japan has 169 consulting and research centers (*Kohsetsushi*), which provide research services, testing, and training for small and medium-sized enterprises (firms with fewer than 300 employees). The centers, sponsored by prefectures, have a total staff of 6,900 people, including 5,300 engineers and researchers. In FY 1988, *Kohsetsushi* provided technological guidance in 472,000 cases. In 25,000 cases, expert teams and advisers were sent to firms. Firms used *Kohsetsushi* analysis, test, and inspection services in a further 922,000 cases. The centers also provided employee training, conducted joint research projects with smaller enterprises, and supplied technological information. The central government establishes guidelines for *Kohsetsushi* and provides some funding. Total expenditures of the *Kohsetsushi* in FY 1988 amounted to ¥69.5 billion ($496 million at an exchange rate of 140 yen to the dollar).[20] There is also a national system for qualifying and registering private consultants who assist manufacturers. In 1989, there were 3,900 registered consultants (including those who work in mining as well as manufacturing) who could be called in by firms or *Kohsetsushi*. Other Japanese public agencies and cooperative organizations offer loans, credit guarantees, and equipment leasing programs to encourage small and midsized enterprise modernization (Small and Medium Enterprise Agency, 1989).

In Europe, national, regional, and local governments have established a growing network of technological assistance programs for smaller manufacturers. As noted earlier, Italy has developed a system of regional and industry service centers providing design, manufacturing, training, and marketing assistance in collaboration with clusters of firms and industry associations. Public agencies in Germany, Sweden, and Denmark have also initiated new collaborative programs to promote small enterprise technological upgrading. According to Rosenfeld (1989), an important feature of the European approach is a much higher degree of collaboration among businesses and between government and business than is usually seen in the United States. Government acts as a partner, not just as a provider of technology services. Rosenfeld also notes that European initiatives promote long-term working relationships between businesses and technology program personnel, foster linkages with market development and export promotion programs, and work closely with technical and vocational education systems.

In Europe, national, regional, and local governments have established a growing network of technological assistance programs for smaller manufacturers.

In the United States, fragments of the approaches found in Japan and Europe are seen in the best state programs and in the emerging federal initiatives. But, American industrial modernization efforts are, by and large, patchy, under-funded, and lacking in effective national leadership. If the U.S. wishes to maintain a vibrant and strong base of small and midsized manufacturers, this situation needs to be remedied. This does not mean the federal government should establish a new, centralized, federal system of industrial extension. In the absence of federal leadership of the kind that led to the nationwide system of extension service for agriculture, individual states have adopted diverse strategies for their own industrial technology programs. This is not necessarily bad since industrial conditions, geography, and sources of local technical expertise vary considerably between the states. Moreover, states are the right level of government to run programs that serve small manufacturing firms. But the states cannot do it all. Federal involvement is needed to provide a national policy framework, coordination, and additional resources to ensure the present system evolves into an effective, decentralized system for technological upgrading.

In the United States, fragments of the approaches found in Japan and Europe are seen in the best state programs and in the emerging federal initiatives.

Federal Support Needed

Given this strategic outlook, what should the federal government do? There are a series of policy and programmatic initiatives that could usefully be undertaken.

1. *The federal government should develop a strong policy commitment to work with the states to modernize small and midsized manufacturers—and then act on that commitment.* Industrial extension programs seek to stimulate changes within enterprises which upgrade productivity and quality, and increase the use of modern technology and manufacturing practices. Of course, such programs address only part of the problems facing U.S. industry. Other types of policy initiatives are needed in the areas of advanced technology development, trade, antitrust and acquisitions, infrastructure investment, and education and training, in addition to appropriate fiscal and monetary policies. Nonetheless, just as small and midsized firms form an important part of the manufacturing base, programs such as industrial extension can form an important part of a national strategy to revitalize U.S. manufacturing.

Programs such as industrial extension can form an important part of a national strategy to revitalize U.S. manufacturing.

It could be argued that the federal government has already moved in the right direction with the passage of the 1988 Trade and Competitiveness Act and by giving NIST new responsibilities to strengthen the nation's manufacturing technology base and support state technology extension programs. With hindsight, perhaps more fundamental changes were needed: a radically restructured Department of Commerce or a new Department of Trade and Industry (with Commerce abolished). But given that NIST now has its new mandate, there is a viable structure in place with the legislative authority to act. What NIST now needs are the resources to do the job. Unfortunately, this is the problem. NIST has not been given the resources necessary to fulfill its mandate. Effectively, the federal government and Congress are signaling to manufacturers and state governments that industrial modernization is <u>not</u> a priority. This needs to change. Not only does the federal government need a strong policy commitment to modernizing small and midsized manufacturers, it also needs to commit sufficient funds and to take a series of specific actions to make that policy commitment a reality.

With hindsight, perhaps more fundamental changes were needed: a radically restructured Department of Commerce or a new Department of Trade and Industry.

2. *Federal resources for industrial extension and technology deployment need to be substantially increased.* If the federal government is serious about improving the competitiveness of smaller manufacturing firms, sufficient resources need to be allocated to make a substantive difference. To date, the level of federal resources committed to industrial extension is much too small. In the FY 1990 budget, Congress appropriated $1.3 million for NIST to provide technology extension services to states. $7.5 million was appropriated for regional centers for manufacturing technology. Part of this funding will support the three existing centers. In the Department of Commerce, the Clearinghouse on State and

Local Initiatives on Productivity, Technology and Innovation will receive about $250,000.

Thus, direct federal financial support for industrial extension and manufacturing technology upgrading is under $10 million. Other federal funding indirectly going to state-level industrial extension programs is roughly estimated at $7-12 million.[21] But even if the upper figure is too low by half, the amount of direct and indirect federal funding for industrial extension is small. By contrast, agricultural extension has a $1.1 billion budget (and a staff complement of around sixteen thousand people), of which the federal government contributes about one-third. The low level of resources committed to manufacturing is all the more surprising given that, in 1986, the output of farm producers was about $76 billion (less than 2 percent of U.S. Gross Domestic Product or GDP), while manufacturers produced $824 billion (almost 20 percent of GDP).[22]

The amount of direct and indirect federal funding for industrial extension is small.

The 1991 budget proposal, released by the President in January 1990, allocated $5 million to fund two new regional centers, and $7.5 million to support the existing centers. Under this plan, a total of seven regional centers will have been initiated by the end of FY 1991. No funding was requested for NIST's state technology extension services.[23] It is likely, however, that Congress will reinstate funding for state extension services. But the real issue is not whether one or two million dollars should be restored to this program, but whether federal support should be increased by at least tenfold so that a very much larger number of small manufacturers throughout the country will receive the kind of assistance that will stimulate them to modernize.

The federal government in conjunction with the states should aim to assist, in depth, at least twenty-five thousand small and midsized manufacturers each year.

Rather than helping a few hundred or even a few thousand firms each year, the federal government in conjunction with the states should aim to assist, *in depth*, at least twenty-five thousand small and midsized manufacturers each year. This would mean that about half of U.S. manufacturing firms would be reached over a five-year period. Services provided to these firms would include technology assessments, problem solving, assistance with deploying new technology, and workforce training to implement new technology and improve productivity and quality. States should provide funds to match the federal support, as in agricultural extension. This means that the federal government needs to adjust the level of its support so as to leverage sufficient total system resources. At a one-third to one-half match, this might require federal support of approximately $75-125 million a year.

The federal government...[must] ensure that the industrial states with high concentrations of the nation's small suppliers have or develop effective modernization programs.

3. *The requirements of industrial states must be balanced with the need to provide assistance to poorer states and rural areas.* One of the problems with the existing arrangement of state programs is its uneven level of development. Several industrial states have established sophisticated programs. But in poorer states and even in rural areas within the industrial states, programs are less well-developed or nonexistent. For the federal government, a strategic concern is to ensure that the industrial states with high concentrations of the nation's small suppliers have or develop effective modernization programs. Core regional and industrial complexes of small and midsized firms should be identified and federal resources focused to strengthen state, regional, and sectoral initiatives to modernize these firms (see, for example, Industrial Technology Institute, 1989).

At the same time, the federal government also needs a strategy for developing effective programs in poorer states and rural areas with limited resources and few sources of technical expertise. In these areas, different kinds of programs may be needed which take into account the character of local industries and widely dispersed support institutions. Some states are too small to support a full range of technology development and deployment programs. The federal government needs to recognize this problem and develop a flexible approach. One possibility might be for the federal government to encourage greater interstate cooperation (see Tanski, 1989).

The federal government also needs a strategy for developing effective programs in poorer states and rural areas.

4. *The federal government must strengthen intensive, field service programs as well as establish new technology centers.* In the current federal strategy to support technological upgrading, the bulk of NIST's already limited resources are allocated to supporting regional centers for transferring manufacturing technology. One of the aims of the centers is to transfer the technology developed at NIST's Advanced Manufacturing Research Facility to industrial firms. However, this technology is sophisticated and complex, beyond what most smaller firms need or can absorb at this point. Too much emphasis on developing centers may lead to high overhead costs, and may divert or disrupt state programs as competition increases to attract federal resources and a prestigious center. Finally, the 12 centers envisaged in the 1988 Trade Act will never adequately serve the country. The number of centers that could be justified is much higher, but this would pose an impossible task if the federal government administered them all through what is essentially a categorical program.

This is not to disparage the center concept. Centers can provide valuable environments for demonstrating technology, providing training, focusing expertise, and linking research and development efforts. However, resources also need to be targeted toward decentralized, flexible programs with technical field staff able to visit firms in urban and rural areas. Additional resources are needed as well for new initiatives to encourage small firm networks, improve supplier-customer linkages and stimulate technology-focused industry associations. The federal government should encourage states to develop their own range of program initiatives appropriate to their industry and regional needs, using the most suitable combinations of state, university, college, nonprofit, and industry service providers. Federal support could be provided by an industrial extension block grant, to be matched by the states, to support state (and multistate) manufacturing modernization services. This block grant would encourage the provision of field services as well as support technology centers. A block-grant approach would lead to the development of a nationwide, state-operated, yet federally coordinated system.[24]

The federal government should encourage states to develop their own range of program initiatives.

5. *Linkages between industrial extension programs and public training programs must be improved.* A major problem for industrial extension services is training. Training is recognized as essential to manufacturing modernization, but many industrial extension programs lack staff who are capable of providing detailed assessments of manufacturing training needs and lack the resources to directly run training programs. Most frequently, extension programs only make referrals to other training providers. Considerable resources are already invested in community colleges, technical schools, and other training programs, which industrial extension programs do not have to duplicate. But it may be useful to increase the staff capacity of programs to help firms develop and implement specific training programs. NIST, the U.S. Department of Commerce, and the U.S. Department of Labor might also be encouraged to work together to develop better ways of linking training and extension services beginning, perhaps, with some interagency pilot programs.

A major problem for industrial extension services is training.

6. *Smaller manufacturers need assistance in overcoming the financial barriers to industrial modernization.* Federal financial support to smaller firms comes mostly in the form of new business start-up assistance and help with developing innovative new products (e.g., the Small Business Innovation Research program). There is much less support for manufacturing process improvement. Policy options here include equipment investment loans and guarantees, direct grants, tax incentives, depreciation allowances, and the promotion of equipment leasing. Each of these options has advantages and disadvantages. Federal policymakers, in conjunction with extension programs, small business finance

organizations, and private lending institutions, should weigh these options and develop strategies that will enable more smaller firms to afford the modernization of their manufacturing systems.

It would be valuable to establish national programs of training and updating for field staff and other industrial extension personnel.

7. *The federal government should provide training and other support services for state-level staff.* Congress has already assigned to the Department of Commerce the role of establishing a national clearinghouse on state and local technology initiatives. This is a very broad mandate that largely involves the exchange of information on a wide range of technology initiatives, including much that goes beyond manufacturing technology. But there is also a need to develop highly focused forms of support for primary industrial extension activities. For example, with the increasing number and intensity of state-level industrial extension programs, it would be valuable to establish national programs of training and updating for field staff and other industrial extension personnel. Such training might be seen as a one-time effort, extending over four or five years, to train a critical mass of extension personnel, or it could become an ongoing (and possibly fee-generating) in-service training program. NIST could sponsor this training activity as part of its mandate to support state industrial extension services and/or support experienced individual state programs (or consortia of state programs) to provide national and regional staff training.

Another important, although difficult, task is to improve the linkages between federal laboratories and state extension programs.

A few state programs, most notably the Michigan Modernization Service and its parent Industrial Technology Institute, have developed computerized technology diagnostic and assessment tools to assist in the analysis of manufacturers' technology problems and needs. A useful federal role (through NIST) would be to encourage the development, evaluation, and dissemination of such tools and to facilitate the training of state program staff in their use (again, either directly or through selected state programs). This step could help considerably in improving the "technology" of manufacturing technology assessment and deployment.

Another important, although difficult, task is to improve the linkages between federal laboratories and state extension programs. The nation's seven hundred federal laboratories, which have a $20 billion budget and employ one-sixth of U.S. scientists and technologists, are potentially a huge resource. However, in practice, the labs have had little involvement with small and midsized firms. Much of their work is defense or energy related, it is often concerned with knowledge development rather than commercial application, and considerable bureaucratic barriers plague technology transfer to industry. In recent years, labs have been encouraged to focus more on technology transfer. But outside a few model efforts, state programs infrequently see federal labs as a useful resource. Given the huge public investment in the labs and the role extension programs could play in linking the labs with smaller firms, continued federal efforts to encourage labs to develop better working relationships with state extension programs are justified.

8. *The federal government must support programmatic research and evaluation.* Effective programs need to be supported by insightful and continuous research to enable them to better target their services and approaches and measure program results. The federal government, through NIST and other agencies (such as the National Science Foundation), needs to ensure continuous research into manufacturing technology deployment and barriers to industrial modernization. A handful of surveys and research studies have been carried out, including the 1988 special survey of technology use by the Bureau of the Census, but a much richer information and analytical base on the diffusion of manufacturing technology is needed to guide program development.

Effective programs need to be supported by insightful and continuous research.

In addition, there is a need to support independent research evaluations of program effectiveness. Many state programs have no systematic evaluation procedures and there are few, if any, comparative evaluations of different types of programs. This is a difficult problem because programs have different missions and use different criteria of success, but it is not insurmountable. The National Science Foundation's Industry University Centers, which have an organized, independent, and ongoing evaluation component, provide a possible model.

9. *The federal government must encourage regional and industry-based collaboration and networking initiatives.* In addition to one-on-one efforts to modernize smaller U.S. firms, the federal government and the states jointly need to consider ways to improve the functioning of regional complexes of smaller firms, such as the concentration of automotive suppliers in the Midwest, the textile and apparel producers of the rural Southeast, or the high-technology firms of California and New England. One way to do this is by supporting emerging state efforts to develop regional production networks and shared manufacturing facilities. The barriers to developing production networks are as much organizational as technological, and can be overcome, in part, by fostering collaboration between smaller enterprises and developing new public-private industry linkages. Federal support, again matched by the states, for a series of model or pilot networking projects in a variety of industries and regions would be very helpful for finding ways to overcome these challenges, test the approach, and develop an experience base.

The federal government and the states jointly need to consider ways to improve the functioning of regional complexes of smaller firms.

A related federal task is to strengthen the framework of private technology assistance providers. Public industrial extension programs cannot, even with federal support, do the entire job of modernizing smaller manufacturers. Technology-focused regional industry and trade associations should be encouraged, as should initiatives by professional engineering associations, associations of manufacturing consultants, and national industry groups to improve the quality and depth of their assistance to smaller manufacturers. Collaboration between federal and state programs and private-sector technology assistance providers would strengthen regional networks of service, provide mutual support to all providers, and facilitate better cooperation between public and private services to ensure effective private-sector follow-up to public technology assistance.

Collaboration between federal and state programs and private-sector technology assistance providers would strengthen regional networks of service.

10. *The federal government should encourage large customers to strengthen the technological capabilities of their suppliers.* Large customers can be vital sources of technical information, assistance, and even financing to help smaller suppliers modernize. Consequently, promoting improved customer-supplier linkages should be an important policy goal (Kelley and Brooks, 1988). State extension programs should be encouraged to involve large customers in upgrading the technology of their smaller suppliers. This would not help in situations where smaller suppliers serve many customers (or only small customers), or where the larger company is seeking to reduce its number of small suppliers. But such collaboration would help, indeed it could be vital, in situations where there are well-defined customer-supplier relationships between small and large firms. The federal government should encourage state programs to make these linkages and urge the regional manufacturing technology transfer centers to develop model programs along these lines.

Industrial extension services could [help smaller defense contractors]...to diversify, re-equip, and adapt their manufacturing practices to commercial markets.

Moreover, the federal government is itself a huge customer for both defense and nondefense manufactured goods, and needs to consider how it can promote technological upgrading among its smaller contractors and subcontractors. At the same time, with the expected decline in defense spending in coming years, it is likely that many smaller contractors will lose defense business. Industrial extension services could play a significant role in helping such firms to diversify, re-equip, and adapt their manufacturing practices to commercial markets. Services to support supplier conversion should not be sponsored by the Defense Department which has little commercial experience and would be unlikely to give priority to this mission, but by NIST and existing/expanded state extension programs.

Conclusion: The Challenge To Move Forward

In the 1990s, U.S. small and medium-sized manufacturers will be challenged, as perhaps never before, by international competition, more demanding customer requirements, and relentlessly changing technologies. Smaller firms will need to be innovative and creative. They will also need to be highly proficient at manufacturing. This effort will require continuous upgrading of manufacturing equipment and practices, improved products, and training—and retraining—of workers. New relationships will need to be forged between suppliers and customers, vendors and users, and workers and managers. New forms of cooperation and support will have to develop among smaller firms and between these firms and government.

Existing state industrial extension programs have already shown that they can help...firms improve their manufacturing capabilities.

It would be comforting to know that U.S. smaller manufacturers, and federal and state governments, are ready to meet these challenges. Unfortunately, this is not the case. Most small firms are lagging in upgrading their manufacturing technologies, techniques, and workforce skills. Existing state industrial extension programs have already shown that they can help these firms improve their manufacturing capabilities. However, while some good state industrial extension programs and experimental networking projects are underway, by and large the public sector has failed to make the necessary commitment to modernizing the base of small and midsized manufacturing firms. The U.S. has yet to develop a nationwide and nationally supported system of industrial extension.

The way to move forward is to build on the experience of existing state industrial extension initiatives.

The way to move forward is to build on the experience of existing state industrial extension initiatives. Working closely with the states, the federal government needs to significantly increase the pace and breadth of small-firm modernization by strengthening exising state industrial extenion efforts, supportin the developme of new initiatives in states and rions lacking effective programs, and providing coordination and leadership. This investment will require an increased commitment of federal, state, and private funds. Yet, compared with current spending for agricultural extension, federal research and development, or publicly supported advanced technology projects, the level of resources needed is reasonable and justifiable. In all regions of the country, small and midsized manufacturers can be, and need to be, assisted and stimulated to improve their manufacturing capabilities. Industrial extension can provide the expertise and support to encourage modernization, leading to substantial benefits to small and midsized firms, their workers, industries, and regons, and American competitiveness.

Endnotes

1. Between 1973 and 1985, manufacturing gross fixed capital formation as a share of manufacturing gross domestic product averaged 12.4 percent in the United States and 19.1 percent in Japan, a ratio of 1.5 in Japan's favor. (Calculated from: Organization for Economic Cooperation and Development, Stocks and Flows of Fixed Capital, *1960-1985*, Paris: 1987; and OECD *National Accounts*, Detailed Tables, Vol II, 1973-85, Paris: 1987.) For additional analysis of the higher rate of manufacturing investment in Japan compared with the U.S., see U.S. Congress, Office of Technology Assessment, 1988.

2. Mansfield's study is based on a 1985 survey of 50 matched pairs of U.S. and Japanese manufacturers in the machinery, electrical and electronics, chemicals, and rubber and metals industries. Of the total costs for developing and introducing new products and processes, the percentages spent by U.S. [Japanese in brackets] firms were: research and development, 26 [21]; prototype or pilot plant, 17 [16]; tooling and equipment, 23 [44]; manufacturing start-up, 17 [10]; and marketing start-up, 17 [8].

3. U.S. density of numerical control (NC) tools calculated from "14th American Machinist Inventory," *American Machinist*, November 1989. This survey covers the U.S. durable goods industries of primary metals (iron, steel, and nonferrous metals), fabricated metal products, machinery except electrical, electrical and electronic machinery and equipment, transportation equipment, precision instruments, miscellaneous manufactures, and metal furniture and fixtures. The Japanese data are calculated from Ministry of International Trade and Industry, *Showa 62 nen dainanakai kosaku kikai setsubito tokei chosa hokokusho*, Tokyo: Tsusan tokei kyokai, 1988. (Report of the 7th Survey on Machine Tools Installation, Research and Statistics Department, Minister's Secretariat, Ministry of International Trade and Industry.) This survey covers the Japanese durable-goods industries of iron and steel, nonferrous metals, fabricated metals, general machinery (nonelectrical), electrical machinery and equipment (including electronics), transportation equipment, and precision instruments and machinery. The Japanese industry coverage is thus close to that of the U.S. survey. The U.S. data have been recalculated for establishments with 20 or more employees. The Japanese data are for establishments with 50 or more employees. This differ-

ence may slightly underestimate the ratio of Japanese to U.S. diffusion of the technology per thousand workers since usage of new technologies per thousand workers tends to be higher in small Japanese establishments than in larger ones (see the example of robotization given in Ishitani and Kaya, 1989).

4. Calculated from U.S. Small Business Administration data, U.S. Enterprise Statistics, and County Business Patterns (various years). An establishment is a single-location business unit and may be independent (a single-establishment enterprise) or owned by a parent enterprise. An enterprise is the aggregation of all establishments owned by a single parent company. Most manufacturing enterprises only operate one establishment. A smaller number of enterprises operate or own multiple establishments (often through subsidiaries and branches).

5. These agglomerations of small producers can be separate from or associated with larger producers and employ a variety of different production and interfirm relationships. For a discussion, see Storper and Harrison, 1990.

6. The analysis of the obstacles to upgrading manufacturing systems is based, in part, on personal field interviews with manufacturers in Georgia, Maryland, Michigan, North Carolina, Ohio, and Pennsylvania conducted in 1988 and 1989, covering about 20 firms; the questionnaire responses of 148 durable-goods manufacturers in West Virginia from a mail survey conducted in July 1989; and the questionnaire responses of 35 state industrial services and manufacturing technology programs from a national mail survey conducted in the fall of 1989.

7. Robert Kaplan (1986) has made the additional point that when firms consider investing in new technology, they typically fail to consider all the relevant alternatives. He notes that most investment decisions evaluate the new investment against the status quo, assuming that current market shares, selling prices, and costs will continue. This rarely happens. A better way is to assume declining cash flow, market share, and profit margins if no investment occurs. This is because once a new process technology is available, some companies will invest in it, putting noninvestors at a disadvantage (assuming, of course, the technology works effectively). Kaplan quotes Henry Ford on this point as

saying: "If you need a new machine and don't buy it, you pay for it without getting it."

8. This example is adapted from Howell, *et al.*, (1987), pp. 8-9.

9. Interviews with Isao Kimura, Senior Managing Director, Mishima-osan Co. and Takekazu Yamaguchi, Vice-President, IrieKohsan Co. Ltd, Kitakyushu City, Japan, July 11, 1989.

10 In the survey of West Virginia manufacturers, uncertain or insufficient demand was ranked as the fourth (out of 14) obstacles to increasing present plans for investment in new manufacturing technologies (Shapira and Geiger, 1990).

11. National Science Foundation data, reported in *The Economist*, "Out of the Ivory Tower," February 3, 1990.

12. Calculated from U.S. Department of Commerce, Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1970*, Washington, DC: U.S. Government Printing Office, 1975; and U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States, 1988*, Washington, DC: U.S. Government Printing Office, 1988.

13. The stimulus to start PENNTAP was the federal State Technical Services (STS) Act. The Act promoted the application of scientific and technological developments in industry through state programs of information dissemination, education, referral, problem solving, and demonstration. States pursued diverse responses to this mandate, including establishing science and technology foundations and developing university-based programs of technology diffusion. Funding for the program was terminated in 1969. However, some of the programs initiated by STS have survived (Arthur D. Little, 1969; U.S. Congress, 1984).

14. The programs included in the sample were selected from studies of state-level technology assistance programs produced by the National Institute of Standards and Technology and the Minnesota Governor's Office of Science and Technology. This information was supplemented and qualified through discussions with program managers and other federal and state officials. The survey was conducted in the fall of 1989. John Forrer (George Washington University) cooperated in

the design, sample selection, and administration of the survey.

15. Because some programs also serve nonmanufacturing clients, the budget for serving manufacturing clients is derived by adjusting the total program budget by the share of manufacturing clients out of all the clients served. The assumption here is that it costs the same to serve both manufacturing and nonmanufacturing clients.

16. The discussion of programs draws on visits to and case studies made of 15 programs in Georgia, Ohio, Indiana, Maryland, Michigan, New York, North Carolina, Pennsylvania, and Virginia in 1988 and 1989. Stephen Wahlstrom, Melissa Geiger, and Michael Doyle provided assistance for some of these cases.

17. One of the IRCs specializes in helping small biotechnology firms. Of the eight other IRCs, one is also involved in statewide/regional initiatives and IRC coordination.

18. Abegglen and Stalk (1985) note that Japanese firms usually try to get their existing operations to run as efficiently as possible with manual systems before introducing automation. Similarly, Port (1989), in setting out five crucial steps to factory automation, emphasizes the importance of simplifying and reorganizing the shop floor with no automation, or at least no new automation, to provide the basis for new technologies.

19. In the traditional agricultural extension model, the field agent not only transfers technology from the university and experiment station to the farmer but is also expected to provide feedback from the farmer to the researcher.

20. Personal interview with Shigehiro Okamura, Deputy Director, Technology Division, Guidance Department, Small and Medium Enterprise Agency, Ministry of International Trade and Industry, Tokyo, July 31, 1989, and subsequent correspondence.

21. The 35 programs in the state survey indicated federal support of $9.3 million. This includes two NIST-sponsored regional manufacturing technology centers. Excluding these, federal support totals $6.8 million. Given the high response rate, the coverage of state programs that primarily focus on manufacturing technology extension is quite good. Almost all the large programs (Michigan, New York, Pennsylvania, Georgia,

North Carolina, Ohio, and Virginia) are included. The high estimate of $12 million assumes a further 20 programs at comparable levels of federal funding (averaged) as the 33 programs (excluding NIST centers) identified in the survey. The National Governor's Association (NGA) survey (Clarke and Dobson, 1989) identifies more than 200 organizations providing business services and receiving federal funding of $161 million, but this includes small business centers, incubators, seed capital programs, technology research centers, and research parks, as well as technology assistance programs. Of the 200 organizations, NGA identifies only 13 as primary manufacturing technology assistance providers, receiving under $2 million of federal assistance.

22. National Income and Product Accounts, Table 6.1, data supplied on computer diskette by the U.S. Department of Commerce, Bureau of Economic Affairs.

23. In part, the Administration explained zeroing out NIST's state extension services budget by arguing that the states were already providing extension services. However, as discussed earlier, many of the programs which say they provide technology assistance only do so as a secondary function. Most states do not have well-developed substantive extension programs. Moreover, zeroing out the program eliminated the only source of funds the federal government has to *directly* assist extension program development in smaller/rural states unlikely to win a regional manufacturing technology transfer center, to leverage resources from states to expand existing programs, and to support other necessary extension program support and coordination activities.

24. Many issues are associated with this extension block grant concept. For example, would a match requirement be biased against smaller/rural states with fewer resources to match federal support? Not entirely, since smaller/rural states presumably would not need as large a program. However, the match requirement could be adjusted to compensate for such factors as the number of small and midsized manufacturing firms and the extent to which industry is geographically dispersed. Should federal matching funding be permanent or just enough to leverage the start-up of new extension programs? Federal funding probably could decrease after helping states overcome the initial costs of starting/expanding industrial extension programs, but, as with agricultural extension, a continued level of

federal support (which might need to run at levels of 25-40 percent of total system costs) is desirable to give the system essential stability. How much flexibility should states have to design their programs and identify providers of services? In general, states should be allowed great flexibility since they know best their local conditions and they will be putting up their own matching funds. Federal support of ongoing independent research and evaluation will help to ensure states are supporting effective programs. But the federal government might consider establishing selected guidelines on such aspects as program focus (e.g. technology assistance mainly for smaller manufacturers).

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