AN OVERVIEW OF TECHNOLOGY DIFFUSION POLICIES AND PROGRAMS TO ENHANCE THE TECHNOLOGICAL ABSORPTIVE Capabilities OF SMALL AND MEDIUM ENTERPRISES

by

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1. Introduction

Throughout the developed industrial economies (and increasingly in developing industrial countries), there has been a great increase in recent years in policy and programmatic initiatives to promote the diffusion of technology. The effective deployment of technology has been associated with industrial competitiveness, productivity and efficiency, economic development, business growth, business flexibility, quality, the maintenance of high-wage jobs, and the support of further rounds of innovation. Attention has been paid not only to specific policy measures that might accelerate technology diffusion and tighten links between technology developers and users, but also to the creation and nurturing of supportive systems and infrastructures for technology diffusion.

In following sections, the paper considers the meaning of technology diffusion and how technology diffusion measures can be classified. This is followed by a discussion of specific policies which aim to increase the technological absorptive capacities of firms, especially small and mid-sized enterprises. A review of technology diffusion approaches in selected OECD countries is then presented, again with an emphasis on measures for small and mid-sized firms.

2. General Typology of Technology Diffusion Programs

Technology diffusion involves the dissemination of technical information and know-how and the subsequent adoption of new technologies and techniques by users.1 In this context, technology includes “hard” technologies (such as computer-controlled machine tools) and “soft” technologies (for example, improved manufacturing, quality, or training methods). Diffused technologies can be embodied in
products and processes. Although classic models of technological development suggest a straightforward linear path from basic research and development to technology commercialization and adoption, in practice technology diffusion is more often a complex and iterative process. Technology can diffuse in multiple ways and with significant variations, depending on the particular technology, across time, over space, and between different industries and enterprise types. Moreover, the effective use of diffused technologies by firms frequently requires organizational, workforce, and follow-on technical changes.

Technology diffusion can be contrasted with technological innovation, which emphasizes the development of new knowledge, products, or processes, and government-oriented technology transfer, which frequently seeks to shift advanced technology out of laboratories into commercial use. In many cases, diffused technologies are neither new nor necessarily advanced (although they are often new to the user), and they may be acquired from a variety of sources, including private vendors, customers, consultants, and peer firms, as well as public technology centers, government laboratories, and universities. Technology also diffuses through the internal “catch-up” efforts of firms, the transfer and mobility of skilled labor, the activities of professional societies and the trade and scientific press, varied forms of informal knowledge trading, and such practices as reverse engineering.

An active governmental role in support of fundamental research has long been justified on one or more of these three grounds: market failure (that is to say, the problem of purely private basic research in appropriating its benefits, thereby leading to under-investment from the view of potential social returns); public good (for example, in the medical and environmental fields – arguably, a subset of market failure, in that purely private efforts are judged unable to maximize social well-being); or strategic interest (in support of national missions such as defense and energy security, or the advancement of industrial competitiveness and economic development). It was often assumed that, once innovations were developed, private mechanisms, aided by existing public institutions, could adequately disseminate available technologies. In many instances, this assumption has held true. However, it is increasingly recognized that market failures and strategic interests also exist in the process of technology diffusion. Potential users face uncertainty, information and learning costs, and other externalities which may result in under-investment in available technologies; similarly, potential suppliers of information and assistance also face learning costs, may lack expertise, or face other structurally barriers in promoting the diffusion of rewarding tech-
nologies. System-level factors, such as the lack of standardization, regulatory impediments, weaknesses in financial mechanisms, and poorly organized inter-firm relationships, may also constrain the pace of technology diffusion. In the context of rapid international flows of information and capital and increased global competition, it has also been argued that strategic national and regional efforts to maintain industrial competitiveness depend not only on innovativeness, per se, but more than ever on the diffusion, effective application, and further incremental improvement of known technologies.

To address these concerns, a wide variety of policy measures have been pursued to promote or accelerate the diffusion of technology. Numerous typologies have been put forward to categorize these efforts. Frequently, these classifications demarcate policy measures by “functional type” – by what problems they address and by they aim to do. Here, lines are drawn between measures according to whether they seek to change the broader economic and regulatory environment for technology diffusion, provide specific inputs such as information and training, or influence linkages between different infrastructural elements of the technology diffusion process (for instance, the relationships between technology vendors and users). In addition, some typologies emphasize the “operational focus” of policy measures, distinguishing between “supply-side” instruments (which seek to augment factors such as sources of information and assistance) and “demand-side” instruments (which aim to increase the internal willingness to take-up technology through mechanisms like challenge grants, peer learning, or public procurement). A third approach is represented by typologies which organize measures by their “policy targets,” for example, those which are aimed at particular technologies and practices, specific industrial sectors, small firms, large firms, the overall industrial competitiveness of a national system, regional technology development, or international technology transfer.

While there are different classifications schemes, the technology diffusion measures which form the subject matter of these definitional efforts broadly include the following:

- **Awareness-building and technology demonstration.** These measures seek to make potential users more knowledgeable about available technologies, their possible applications, and their benefits and costs. Demonstration services are offered by the Center for Manufacturing Information Technology, a program sponsored by the Georgia Institute of Technology and Georgia Power (USA), where computers, manufacturing control systems, and software are available for potential users to see and try. Similarly,
Japan’s prefectural and municipal technology centers (Kohsetsushi) demonstrate new technologies to firms, often extending to hands-on training and pilot production. A method of awareness-building attracting increasing interest is benchmarking. In the United States, the Industrial Technology Institute (Michigan) offers a Performance Benchmarking Service which allows companies to compare their use of technology with that of comparable and best practice firms. The TOPS programs now found in the United Kingdom, Germany, and Spain identify “good practice” firms and structure opportunities for other companies to visit these models and learn how they operate. Media and new communications technologies can assist in awareness-building. For example, the National Technological University and other organizations offer remote users throughout the United States video and satellite broadcasts on new technology and manufacturing topics. The European Union Community Research and Development Information Service (CORDIS) provides electronically accessible information about technology development program opportunities to service providers as well as potential users.

- **Information search and referral services.** These efforts aim to reduce the information search costs associated with technology diffusion. Information services often add further value by qualifying information requests and matching user needs with appropriate resources. Examples of programs in this category include the Pennsylvania Technical Assistance Program (USA), operated by the Pennsylvania State University, with partial funding from the Pennsylvania Department of Commerce, to businesses access technical information; and Denmark’s Technological Information Centers, which are established in all counties of the country and offer information and other technical services to firms. For-profit companies, such as TelTech, Inc., of Minnesota, also offer specialized technology information services, in this case (for a subscription fee) matching corporate technology needs with appropriate sources of expertise. In several countries, new initiatives are underway to use the internet as a medium to service technical information needs.

- **Technical assistance and consultancy.** This encompasses a wide band of measures which support experts to assess business problems, identify opportunities to upgrade technologies and industrial practices, and assist in implementation. These measures seek to address limitations of expertise among both users and suppliers of technology and to stimulate and assist firms to take action (or, in some cases, not to act on an undesirable investment). Technical assistance services are located in many applied technology centers, for example, in the Valencia Institute of Small and Medium Enterprise (Spain), a network of trained staff offers technological advice, conducts assessments,
and offers recommendations to firms in local industries. In some cases, private consultants are engaged, through cost-sharing schemes, to assist particular firms—a number of U.S. Manufacturing Extension Partnership centers employ this approach, including centers in Oklahoma, Kansas, and Ohio.

• **Training.** The effective deployment of technology and improved operational techniques invariably involves changes in human capital requirements. A very common technology diffusion measure is thus training, conducted in many different forms, including on-the-job training, classroom training, management seminars, team-building workshops, and distance learning. These measures address the tendency of technology users to under-invest in human capital development, which often not only hinders the initial decision to deploy a technology but can also lead to subsequent inefficiencies once in use. Additionally, special measures to promote training for technology diffusion may also address deficiencies among existing institutions and vendors (who may be unable to effectively mount courses in new technologies without additional support). For example, training programs focused on industry needs in specific technological areas are offered by Australia’s more than 60 Cooperative Research Centers. In the U.K., local Training and Enterprise Councils (known as Local Enterprise Councils in Scotland) aim to identify industry training needs, including those in areas of new technology, and support appropriate training initiatives, drawing on public and private resources.

• **Collaborative research and technology projects.** To address the gaps between technology development and deployment, a range of collaborative public-private research mechanisms have been established. These measures also seek to shorten the time taken to commercialize new technological innovations and, through industry involvement, focus research on key needs and opportunities. Often, collaborative research efforts are embodied in the numerous applied technology centers now found throughout the OECD (and other) economies. In Baden-Wurttemburg, Germany, the quasi-public Steinbeis Foundation sponsors a system of about 130 technology transfer centers, often associated with polytechnic institutes, each of which conducts collaborative industry-focused research. Japan’s prefectural public technology institutes and new third-sector projects conduct applied research and technology projects with individual firms and groups of firms.

• **Personnel exchange and the support of R&D personnel.** Potential users of technology, especially if small or mid-sized enterprises, may lack the internal expertise to absorb new technologies or they may lack resources to apply their existing personnel to new research and technology projects. Measures have been developed to support the secondment of personnel to technical
centers or other firms where new technologies are developed or in use. In Japan, local public technology centers accept staff from smaller firms for periods of time to receive training in new technologies and participate in cooperative research. Increasingly, international exchanges are encouraged: in the United States, the National Science Foundation and the U.S. Department of Commerce sponsor schemes to place engineers in Japanese companies and research institutions. In Germany, ministries have sponsored programs to subside research personnel in small and mid-size firms to help them absorb and develop new technologies.\textsuperscript{15}

- **Standardization.** Uncertainty about the compatibility of a technology can present barriers to diffusion investments by users. The diffusion of technology can be accelerated by common agreement between technology developers and users about standards and technological compatibility. The area of electronic commerce is currently one of those areas where efforts to forge standards is underway. In the United States, the National Information Initiative, although federally-sponsored, has promoted an industry-driven process of standards development. In a different context, the development of standard measures to document quality, through ISO 9000 and subsequent reference marks, has also facilitated the diffusion of quality measurement techniques and the avoidance of duplicative marks.

- **Financial support.** These measures are indented to reduce financial constraints among users associated with the initial or ongoing costs of adopting new technologies. Measures can include direct financial support or subsidies to enterprises, through grants, loans, or interest write-downs. Other mechanisms are loan guaranties (often associated with third-party lending institutions), equity or near-equity investments, and various kinds of royalty agreements. In many cases, public financial policies to promote technology diffusion operate through intermediary institutions, including banks and quasi-governmental corporations. Requirements may be set as to the user’s own cost-share or match. Examples of policies range from the preliminary cost-sharing of private consultant assistance sponsored by the Minnesota Manufacturing Technology Center (USA) to grants through Italy’s Act 696 to assist small companies in purchasing high technology equipment. The diffusion of product and process technology through the promotion of new start-up and existing small technology-based firms often involves a financial element. The Small Business Innovation Research program in the United States allocates a share of federal R&D budgets to support the development of technology-based small firms. In Britain, the Support for Products Under Research and the Small Firms Merit Award for Research and Technology programs also support technol-
ogy development in smaller firms.

- **Procurement.** Purchasing and specification policies by public institutions and large private firms can have a role in promoting (or constraining) the diffusion of technologies. In the United States, defense procurement policies have favored small technology firms (through small business offsets) and the diffusion of new process technologies. In some cases, the public support of large firm investments is associated with conditions for local procurement, which then may require supplier upgrading programs. A variation - the joint-production or offset agreements typically found in military, aerospace, or large transportation projects. Procurement policies may generate concerns related to free trade.

- **Inter-firm cooperation.** A series of new programs have sponsored different forms of inter-firm collaboration to promote technology diffusion. The efforts seek to resolve common problems and share information and learning, achieve scale economies in service provision and technology deployment, and strengthen ongoing business and technology development relationships. Collaborative efforts may be “horizontal” (for example, groups of small firms), “vertical” (suppliers and customers), “sectoral” (firms in the same industry) or “lateral” (firms in different industries but with shared interests in a technology). In Finland, applied technology and implementation programs have sponsored the formation of more than 200 collaborative groups, involving both large and small firms. In Germany, the Aachen Gesellschaft fur Innovation und Technologietransfer helps groups of five or more companies identify common problems or needs and develop collaborative R&D projects. Japan has launched a technology fusion program where groups of about 30 small companies work with local brokers and technology centers to commercial new product technologies. The New England Supplier Institute (Boston, USA) brings together small and large firms within specific industries to address share problems and pursue best practice manufacturing and quality initiatives. SPRINT and other more recent European Union projects have supported cross-country (EU) inter-firm collaboration.

- **Facilities for technology transfer.** A large number of applied technology centers and other facilities to promote technology transfer have been established. These centers often extend the capabilities of existing research facilities, for example when associated with universities, or they may be industry-driven initiatives. Centers give a visible physical presence to technology diffusion policies and house many of the activities already described, such as information provision, technology demonstration, and access to new equipment, computers, and software. Many countries have invested in physical infrastructure
efforts to establish technology incubators and technology parks. These aim to improve links between technology developers and users through physical proximity, allowing shared access to facilities and equipment, expertise, and skilled employees. The Advanced Technology Development Center at Georgia Institute of Technology encourages faculty to spin-off technologies through new start-up companies and provides space and services to new firms located adjacent to the campus. Numerous new technology incubator facilities have been sponsored in Japan, including the Kanagawa Science Park, a complex which accommodates and assists new start-up technology firms. Local governments in Japan have also established new buildings for information exchange and diffusion for area small firms, comprising of meeting, training, and exhibition facilities.

- **Regional or sectoral cluster measures.** In addition to building physical facilities, governments have recognized the need to strengthen organizational capabilities and linkages within particular regions and industrial sectors. Levels of communication and dialogue between technology developers and users and among users, institutional credibility and leadership, and other aspects of “social capital” have been shown to be extremely important in the diffusion of technology.\(^\text{16}\) Regional or sector cluster measures can involve strengthening industrial associations, promoting forums of stakeholders, building collaborative technology consortia, labor-management collaboration, developing leadership strategies and shared visions, and strengthening links between users, service providers, and complementary public and private assets (such as banks or training institutions). For example, in Germany, a Baden-Wurttemburg Future Commission has promoted a “dialogue-oriented” approach to policy, involving all the main actors in the process of industrial and technological change.

- **Macro-policy measures.** The overall economic and social environment has important impacts on technology diffusion. This includes factors such as business cycle stability, the cost of capital, intellectual property protection, environmental regulation, labor market policy, and tax policy. A typical technology promotion measure is the offering of tax incentives or favorable depreciation schedules to enterprises that invest in new technology, new facilities, or in research and development. Measures to ease regulatory burdens are also common, although in some cases tighter regulation (for example, in the environmental sphere) can promote introduction of new environmental technologies.

3. **Measures to increase technological absorptive capabilities of SMEs**
Many recent technology diffusion measures have been particularly focused towards small and medium-sized enterprises (SMEs). Definitions differ by country as to what comprises an SME, but generally the cut-off point is those enterprises with fewer than 500 employees. The role of SMEs varies considerably among the OECD economies. For example, in Japan, almost 90 percent of all employment and about two-thirds of manufacturing employment is in SMEs. The SME employment share, on both counts, is comparably high in Italy. However, in the United States, SMEs comprise about 60 percent of all employment and just over one-third of manufacturing jobs—a rather lower share. Nonetheless, given the ongoing restructuring of large firms and bolstered by observations about flexible production methods which promise, if not return, new advantages to networks of smaller firms, increased attention is now being paid to promoting SMEs, including greater efforts to enhance their technological capabilities.

Within the overall category of SMEs, there are differences in capabilities and motivations to absorb and deploy new technologies. A small proportion of SMEs have strong internal technological development capabilities, highly-skilled managers and employees, and may, indeed, be at the leading-edge in their industries and markets; most SMEs follow technology (using it, rather than developing it), with a mixed range of internal skills; while other SMEs, particularly in craft or labor-intensive (sometimes “sweated”) industries, are relatively indifferent to technology. Most technology diffusion measures focus on the first two groups of enterprises, although in the third group there can be an important role for “soft” techniques—such as improved management, production, and workforce practices—that can upgrade these firms at relatively low cost (and help ameliorate the intense downward cost pressures such firms frequently face from lower wage developing economies).

Overall, however, and even among some technologically-advanced SMEs, there are often considerable barriers which slow down, if not hinder, the absorption of new technologies and techniques, especially when compared with larger enterprises. At the firm-level, managers of smaller firms face problems of time, cost, and technical expertise in accessing information on available technologies and on possible solutions, whether involving hardware, software, process control, management methods, or training. While external information sources may be present, firms do not always know where to go, who can help, whom to trust. Some managers have insufficient information about their own manufacturing processes or be unaware of best technologies and practices applied elsewhere. In other situations, firms may lack receptivity to new ideas and to the idea of change.
itself. Even when SMES have good traditional skills, processes or product, these may be rapidly obsoleted by advances in technology (for example, in shifts from electro-mechanical to electronic technologies). Finding the financial resources for new technology investments can also be an issue.

The business infrastructure, involving the organization of industry, inter-firm relationships, and associations in which small firms find themselves, presents another group of important factors affecting technology diffusion. Included here are the nature and intensity of industry competition and cooperation, the closeness of links with customers, suppliers, vendors, and subcontractors, and the role of trade organizations and other industry and regional associations. The character of these relationships varies between (and even within) countries. In the United States and the United Kingdom, supplier-customer links have typically been of a shorter-term than in Japan and some other European countries, increasing uncertainty and the risk associated with new technology investment. However, across all countries, there are weaknesses in private industry infrastructures that could support and stimulate technology diffusion in SMEs, whether found in vendor support for small firms, the affordability of private consulting services, or the general reluctance of many small firms to share technical, training, and other business information and resources with neighboring small firms in their industry or region.

The social infrastructure for technology diffusion to SMEs, including education and training systems, technology transfer programs, and other public services, is also an area of concern. At the local and regional level, where the workings of this infrastructure are most relevant for small firms, many problems are apparent. Small firms usually provide much less formal training than in larger firms, but area educational institutions may not always be responsive to SME needs. Universities stress research and teaching, or seek alliances with larger firms able to absorb advanced technologies and who can provide reciprocal financial support. Government laboratories may also lack commercial motivations to diffuse technologies to small firms. Equally, local economic and business development programs may not offer appropriate technological expertise. Finally, there is a dimension to the problem involving overall policies and attitudes. Macro issues such as the cost and availability of capital, tax and trade policies, regulation and intellectual property rights, labor market policies, attitudes towards risk-taking and innovation, overall research and development policies, and the stability, depth, and strategic coordination of policy measures all have a bearing on the processes and outcomes of technology diffusion.
Efforts to enhance the technological absorptive capabilities of SMEs thus involve a complex series of issues of information, management, training, and financing, and raise questions of structures, relationships, attitudes, policies, and practices at multiple levels. Addressing gaps and opportunities at the “micro” level of the firm is critical; but the problem also involves “macro” economic, technological, and social policies, as well as “meso” issues of business relationships and practices, institutional linkages and inter-firm networks, and public-private cooperation. It is also evident that a diverse set of infrastructures, institutions and mechanisms already exist at most of these levels in the developed economies of the OECD. The challenge for technology diffusion policy is mostly not to create entirely new structures, but to improve the diffusion-promoting performance of current elements and make them work together more effectively. The specific measures that governments pursue to increase the absorptive capabilities of SMEs reflect the need to work at multiple levels and with existing infrastructures and include the following:

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<th>MEASURES</th>
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<td>Firm-level</td>
<td>Benchmarking Increase awareness of best technology use and exposure of SMEs to these practices, through benchmarking services, facility visits, or technology demonstrations.</td>
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<td>Assessment Assist firms in diagnosing technology needs and identifying technology opportunities.</td>
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<td>Strategy Development Aiding firms to develop longer-term technology upgrade paths, in the context of broader business plans.</td>
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<td>Information Provision Enriching the information resources available to firms, including information about technology trends and opportunities and responses to specific information needs.</td>
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<td>Brokering Helping firms identify other resources that can help them in deploying technologies, such as private consultants, public service providers, and other firms.</td>
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<td>Implementation Assisting SMEs to implement new technologies, through in-plant technical assistance and problem solving.</td>
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<td>Cost-sharing and justification Reducing financial barriers to the technology implementation, through cost-sharing, grants, loans, and other financial mechanisms. Also includes helping SMEs cost-justify investments in new technologies.</td>
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<td>Training Increasing human capital and exper-</td>
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tise to understand, absorb, operate, and improve technology within SMEs.

- **Teaming** Assisting the managers and workers of SMEs to work together, to find joint solutions to operational, business, and technological problems.
- **Marketing** Aiding SMEs to commercialize new technologies, particularly new product technologies, through assistance with pilot production, marketing, and procurement.
- **Learning and exchange** Providing opportunities for SMEs to continuously learn about new technology developments and opportunities. May include promoting membership in learning groups and associations, as well as traditional exhibitions or seminars. Can also include personnel exchanges.

**Business-infrastructure**

- **Qualification** Upgrading the capabilities of complementary private service providers to assist SMEs.
- **Best practices** Identifying, promoting and disseminating best practices among customers, vendors, private support services to support SME technology diffusion.
- **Association** Collaboration with/strengthening trade and industry associations and increasing their involvement in technology diffusion.
- **Dialogue and information flow** Promotion of forums and mechanisms to strengthen relationships and information flows within industries and regions, such as customer-supplier forums or industry consortia.
- **Networking and collaboration** Seeding industrial networks and other collaborative projects, to encourage SMEs to be involved in shared efforts to understand, apply, and commercialize new technologies.

**Social infrastructure**

- **Facilities** Improving facilities, physical infrastructure, and the availability of new technology equipment, software, and other technical resources.
- **Cost sharing** Financial support or match to support program development.
- **Technical assistance** Technical assistance for program development and operations.
- **Training** Training of service personnel to work effectively with SMEs.
- **Linkages and industry feedback** Promotion of closer linkages between technology developers and SME users, and incorporation of SME feedback into the process of new technology development.
- **Partnership** Promotion of partnership among
different service providers to coordinate assistance to SMEs. Also promoting inter-regional and inter-national partnerships and information flows beneficial to SMEs.

- **Innovation** Seeding innovative new approaches, pilot projects, model programs.
- **Best practices** Development and sharing of program best practices to increase the technological absorptive capabilities of SMEs.
- **Tools** Development and sharing of analytical tools, such as performance benchmarking instruments and methods, which can help diagnose SME needs and be shared among service providers.
- **Information** Availability of timely technical information sources for service providers and creation of opportunities for information development, exchange, and dissemination.
- **Participation and governance** SME representation and involvement in program design and operations, through advisory mechanisms, program governance, focus groups, etc. Also, SME membership and financial commitment, including cost-sharing of services.
- **Evaluation and review** Ongoing evaluation and review of program performance, using internal and external evaluation methods, aimed at program improvement.

**Policy and attitude**

- **Leadership** Policy leadership in raising attention to SMEs and their technology needs and in focusing public and private resources.
- **Policy dialogue** Promoting forums and other exchange opportunities where SME needs and opportunities can be represented.
- **Analysis and monitoring** Problem research and analysis about the technological needs and opportunities facing SMEs.
- **Coordination** Developing coordinated policy frameworks to guide program measures and service delivery.
- **Complementary macro measures** Ensuring that other policies, such as tax, regulatory, trade, or labor market policies, support SME technology diffusion and their own self-investment in their capabilities.

4. **Country comparisons**

This section of the paper considers how selected countries approach technology diffusion, focusing particularly initiatives to assist technology diffusion for SMEs. The countries examined are Germany,
the Netherlands, Denmark, Italy, Spain, and the United Kingdom, the United States, and Japan. These brief case studies cannot comprehensively describe all facets of the technology diffusion systems in each of these countries, but focus on particularly significant policy aspects and programs.

4.1 Germany

Germany employs a dense array of technology diffusion instruments. Most policy measures have been established, and are supported to varying degrees, by the länder (state). Programs in two of the more heavily industrialized länder, Baden-Württemberg and North Rhine-Westphalia (NRW), will be used to illustrate the German technology diffusion infrastructure. Baden-Württemberg is a region of 9 million population situated in the southern part of a nation of 80 million. It is home to a number of large multi-national corporations (including Daimler-Benz, Porsche, Robert Bosch, and Audi) yet half its production comes from small- and mid-sized enterprises (SMEs). NRW is a region with a population of 7 million and which had been dependent on older, traditional steel and coal-based industries but now is looking to technology for new manufacturing opportunities.

Although the German Ministry of Research and Technology supports research and technology transfer, technology diffusion policy is largely implemented by the länder. Baden-Württemberg, for example, has a Ministry of Economic Affairs and Technology. It sees its prime task as playing an active role in articulating the needs for cooperation and technology and providing organizational and expert support for companies concerned about approaching the various institutions.

The building blocks of Germany’s technology diffusion infrastructure are the Fraunhofer Gesellschaft (Society), or “FhG,” the Chambers of Commerce, state, regional, or institutional technology transfer programs, and research centers.²¹ These are undergirded by applied educational institutions – vocational schools, polytechnics and technical institutes. In addition, federal and state governments have various matching grant programs to stimulate private sector investment in R&D and technology acquisition. Programs typically are coordinated through interlocking directorates. For example, in Baden-Württemberg the president of the region’s largest technology transfer organization, the Steinbeis Foundation, serves as Government Commissioner for Technology Transfer and the board of the Steinbeis Foundation includes representatives from the chambers, polytechnics, research institutes, government, and major political parties.
The government and industry both invest heavily in applied research and technology transfer, but most of the industry funds come from large and mid-sized firms. SMEs are quite subsidized, particularly in the early, or technology assessment stages. Government grants allow SMEs to purchase services from regional programs and lower costs. The government also encourages firms to organize into self-help groups such as sector-based associations and to collaborate in order to take advantage of market of technological opportunities.

The FhG is a national system with 46 centers and 60 establishments (some are branches of centers) and an annual budget of $750 million. Established in 1949 to revitalize the German economy by promoting practical research, Baden-Württemberg is home to thirteen FhGs and NRW, to five. The FhG’s forms of assistance include joint pre-competitive research, bilateral applied research agreements with a single firms, subcontract manufacturing for local firms, testing and pre-production, and cooperative technology transfer arrangements with companies. Institutes generally are located on university campuses, although run as private-oriented, non-profit centers. The Institute for Production Technology (IPT) in Aachen, NRW, a typical FhG center, has 276 employees (62 scientists, 38 non-scientists, and 176 students who work 11-19 hours per week). Its budget, mostly funded by government, is allocated 47% for industrial research, 31% from government-sponsored research, and 22% for basic research. However, FhGs tend to pursue longer-term R&D for larger corporations and have often had a difficult time reaching and serving SMEs.

As a result, most regions also have established other institutions to enhance technology deployment to SMEs. The largest and best known agency, located in Baden-Württemberg, is the Steinbeis Foundation. Founded in 1971, it operates as a private foundation but is wholly owned by the state government. It exploits existing know-how in education and industry and helps SMEs, through cooperative projects, technical assistance, and training, to absorb expertise and new technology. It sponsors a range of technical services delivered mainly through semi-autonomous technology or sector-focused technology centers located primarily at fachhochschulen (polytechnics). In 1995, the Steinbeis Foundation operated 258 technology transfer centers – the vast majority in Baden-Württemberg – employing 3,726 people part (553 full-time), up from 2,524 in 1990. Its income in 1995 was roughly $95 million, 80 percent from fees for services, the rest mainly from other sources, interest, and rents. For example, in 1995, the Foundation gave 2,659 training courses, carried out 338 evaluations of new technology oriented businesses, 419 studies of uses of new technologies, and 27 technology develop-
In Aachen in NRW, the Aachen Gesellschaft fur Innovation und Technologietransfer (AGIT) performs similar functions. AGIT was established in 1984, originally as an incubator for hi-tech firms. It was created as a limited liability company under the state’s Ministry of Science. Its shareholders include the Chamber of Commerce, city of Aachen, the technical university, counties, and industry. Technology transfer to existing companies, with emphasis on SMEs, was added to the mission in 1986. By acting as a facilitator, AGIT helps firms access government and institutional R&D resources. As a rule, AGIT does not provide technology transfer services to a single firm; only when five or more companies can identify a common problem or need (the optimal number is considered ten companies). AGIT works with these companies to develop collaborative R&D projects. AGIT currently has 30 staff and supports some 400 projects. AGIT also develops technology plans for the region and promotes its technology resources and infrastructure.

The German chambers are quasi-governmental organizations that include sub-chambers of small industries and crafts for SMEs. Membership is mandatory for German firms, and they receive a variety of services, including technical information, consultancies and apprenticeship programs for their fees. Germany’s educational system also works closely with industry, providing apprentices with new skills, engineering students to work on industry projects, and faculty members who are rewarded for their work with industry. The state of NRW, for example, has about 25,000 scientists employed in 50 universities and polytechnics, three major national research centers, and many smaller research institutes and programs positioned to assist, such as the Aachen Demonstration Laboratory for Integrated Production Technology, to help SMEs learn about new technology. This is a non-profit teaching factory, located at the Technical University, that trains and retrains technical and other workers.

### 4.2 The Netherlands

In the Netherlands, R&D is highly privatized and concentrated, with two-thirds of the nation’s R&D taking place in five large multinational companies. The Ministry of Education and Science is responsible for planning and coordinating science policy, but in cooperation with Ministers of Economic Affairs, Defense, Physical Planning and the Environment and others. Total public expenditures on R&D and technology were about $2 billion in 1992, with about half going to stimulate industrial R&D. After nearly a decade of declining R&D investments by large corporations, in 1993 the Gov-
ernment created a stimulus package for private sector R&D, which included incentives for SMEs. The Netherlands also spends a relatively high proportion of its R&D on basic research. In 1994, $50 million was set aside for public-private programs to strengthen the knowledge infrastructure in targeted industries or technologies.

The Netherlands has a national applied research and technology diffusion mechanism, the Netherlands Organization for Applied Scientific Research, commonly referred to as the TNO. While other institutions and agencies conduct basic research, the TNO is mainly responsible for applied research, technology transfer, and working with industry—particularly the SMEs. The TNO was established as a decentralized (about 50 institutes), independent non-profit company in 1932 by an act of Parliament to “solve problems of third parties.” In 1982, the TNO was centralized into a single organization with seven divisions. It was more recently again reorganized, this time as a not-for-profit with a small number of institutes (presently 16) with the charge that it improve its links to businesses, become more market driven, and become more efficient.

The TNO has about 4,500 employees and is governed by a supervisory board, with all its members from industry and a management board, with five industry and two government members. The budget of the TNO in 1993 was 760 million Dutch Guilders (about $500 million). Of that, two-thirds was industry related. About 27 percent of the industry budget is core government support, down from 55 percent in 1988. About 58 percent domestic and foreign contracts with industry, and 15 percent contracts with the government. Not all industry funds are generated only by the private sector, however. The government offers incentives for industry-sponsored R&D. For example, if three or more firms sign a contract with TNO, the government pays 50 percent of the costs. Other funds come from the European Union (EU); the TNO was involved in 130 cooperative EU projects in 1993. Success is measured on economic terms—annual turnover. The TNO depends heavily on universities for research support, although it also competes with universities for some contracts. When compared themselves to Germany’s Fraunhofers, TNO officials point out that FhGs are more dependent on government dollars and more closely tied to Germany’s technical universities, the TNO is more self-sufficient and more independent.

Each of TNO’s individual institutes has a special focus (e.g., metal research, plastics and rubber research, environmental and energy technology, nutrition and food, physics and electronics, product center, and policy studies. The TNO’s current plan identifies nine broad clusters as its target areas: media/graphics, harbor/transport, energy, chemistry, manufacturing (metals, plastics,
and textiles), building and construction, health care, commercial services, and agriculture/food. The items displayed at the TNO product development center, for example, are not on the cutting edge of advanced technology but each demonstrates a new or innovative application for consumers. All intellectual property remains with the TNO. Since they have government support, the customer’s research is partly subsidized and therefore not entitled to exclusivity.

TNO views itself as an intermediary between firms and universities. Yet even the TNO has disproportionately served larger companies, which were willing to purchase its services. To make it easier for SMEs to access information and technology, a new network of eighteen innovations centers was recently established. These Innovation Centers are governed and coordinated by a central board in the Hague. The annual budget for the centers is 40 million Dutch Guilders (about $30 million), with 2.5 million DG for the Amsterdam center. Each center has a special industry-specific expertise and must submit an annual three-year plan. The center in Amsterdam, for example, focuses on life sciences. It has a staff of 15, including 10 to 12 engineers. The staff of the centers, though engineers, are generalists (but often with some expertise in a particular area) and with technical industry experience. All information is confidential, and all advisors are sworn to secrecy. The centers have two types of activities. One is reactive, responding to requests from SMEs and acting as brokers. The other is pro-active, developing programs. They also encourage group or collective projects by making certain services available only to ten or more companies. Staff provide a certain amount of assistance to companies without charge, after which customers pay a commercial rate for services and advice. Ninety percent of the centers’ work is with existing technology, only ten percent is on new technologies.

One tactic the innovation centers use to generate demand is to organize firms by common process or technology (for example, machining, transportation, or environment) and ask them what they need. The Amsterdam center facilitates about 30 meetings per year with industry groups—learning networks, which build trust and the start of cooperation. From this beginning, they have developed a core group of companies that they consider “friends of the house.” The centers are developing a data base of services and experts that is based on customers’ experiences, not an inventory of resources, by asking companies themselves who helped them to solve their problems. They also intend to use this data base to help match companies with complementary core competencies or common problems.

Dutch trade associations are relatively weak. As in Germany, mem-
bership in Chambers of Commerce is mandatory but, unlike Germany, they provide fewer real technology services. However, in recent years, the government has begun to support network (inter-firm cooperation) programs to enhance the ability of SMEs to innovate and modernize. A new national suppliers-contractors program, for example, invites companies to apply for funding for technological collaboration projects with their suppliers.

4.3 Denmark

Denmark has only 50 companies with more than 500 employees, which has led it to pay particular attention to the business, information, and technology needs on its SMEs. These include more than 6,000 manufacturers, each with between 6 and 50 employees. Denmark, because of its small size, also believes that its firms must be particularly innovative to compete globally. Denmark has a well-endowed R&D infrastructure that includes: the Danish Technological Institute, Academies of Technical Sciences (23 in 1990, now consolidated into 10, including materials technology, electronics and optics, and manufacturing technologies) five research universities, and several national research centers.

The government’s science and technology is governed by six research councils (natural sciences, agriculture, technical sciences, social sciences, humanities, and health sciences), all under the Danish Ministry of Research. There is also an Industry and Trade Development Council that reports to the Minister of Industry, which coordinates industrial R&D for Denmark. The various agencies that provide technical services to industry are called Approved Technological Service Institutes (ASTIs), approved by the Ministry of Industry, and managed by a board of directors appointed by the Danish Academy of Technical Sciences. Overseeing all is the Danish Council on Research Policy.

When the Danish government establishes programs to address emerging technology issues, these are often for a finite time period and with specific objectives. The research program on informatics, for example was a four-year program from 1991 to 1994; the manufacturing network program ran from 1989 to 1992; the environmental research programs, from 1992 to 1996. And a program to stimulate inter-firm cooperation ran for three years, from 1991-94.

The elements of the Danish technology diffusion system are the ASTI, which includes the Danish Technological Institute, ten advanced technology centers, and other centers; 14 technology information centers; private consultants; local technology centers; and the five universities – in particular, the Institute of Production
at the University of Aalborg and the business school at the University of Copenhagen. The largest and oldest component is the Danish Technological Institute (DTI), initially founded by industry leaders in 1906 to provide technical training. Its purpose is “to further the interests of the business community and society in general by the advancement and propagation of technological progress. By technological in this connection is meant technical and the associated discipline of the economics and process of management as well as its practical application.” [Translated from its Articles of Association] Objectives include “interdisciplinary problem-solving, developing and processing technological know-how, extending its market and information network.” DTI is governed by a Board of up to 32 members drawn (number of seats for each specified) from industry (associations), science, economic development, and labor.

DTI has about 1,000 employees, down from 1,350 a year ago. DTI’s budget is about $140 million, of which about 20% is core funding from the Ministry of Industry. The rest is earned from contracts—up to half from firms of 50 or fewer employees. The Institute focuses on the needs of small firms because it believes SMEs have fewer option than large firms, which can purchase their R&D anywhere. DTI has sold services to 12,000 Danish firms. The Institute is organized into eight divisions—five sector or technology specific (building and construction; wood, textile, plastics, and surface technology; metallurgy and materials technology; chemistry, biotechnology, and environment; and energy) plus production and distribution; management; and industrial development.

The current philosophy of DTI is that there are three sub-systems in a technology infrastructure: universities, which do basic research and serve society; government research labs, which do strategic research, create a knowledge base, and inform public policy; and technology services, which enhance innovation and technology transfer. DTI’s own technology development process is based on its assumption that it must help firms learn but that firms learn best from the following, in descending order of importance: their customers, their suppliers, their competitors, their neighbors, their acquaintances, and then DTI. Thus, DTI encourages collective services and inter-firm activity and learning.

Towards this end, DTI put considerable emphasis on organizing SMEs into “clubs” intended to build bridges to SMEs, trust, and ultimately demand for services. There are currently 89 such clubs with varying levels of activity. About one-third meet regularly and are active. Firms pay annual fees to DTI ranging from $1,000 to $6,000, which gets them information, newsletters, conferences, discounted services, and the opportunity to share experiences. For
example, 120 window manufacturers pay $5-7,000/year. Benefits include DTI setting quality standards and certifying product quality for EU markets, and market information. A small subset of these firms will soon announce a new energy efficient vacuum window that can provide the same insulation less thickness and weight. DTI also organizes learning groups or 10-15 companies. And it still supports a network program to help firms establish joint marketing, production, and product development arrangements.

There are also other institutions in Denmark to promote technology diffusion. In the late 1980s, more than two dozen applied research centers were established to help industry with its technological problems. Each was either technology or industry-specific. Started with government funds, they were supposed to become market-driven and mostly self-sufficient, and those that could not meet this goal were closed or consolidated with others. Today, the remaining ten centers are focused on key Danish industries or technological strengths. They include electronics and acoustics, toxics, hydraulics, biotechnology, fisheries and aquaculture, ship technology, and metals and welding.

Earlier, in the mid-1980s, Denmark created county-based and subsidized offices to diffuse and help SMEs access information about technologies, techniques, and markets. These offices, each staffed by 3-6 experienced industry people, were expected to help firms clarify their needs, define tasks, and suggest solutions. They conducted training courses for SMEs, helped find and broker needed services, and generally provided information to local firms. Their measures of success are the number of requests for information and companies served. Direct problem solving is limited and usually requires other Danish institutions.

Since the early 1980s, Denmark, in some cases with European Union funds, has also supported about 70 local centers, designed locally to meet local technology needs and managed locally. One, for example, was a state-of-the-art furniture production facility at Fars, which local firms could use to try new equipment and training workers, and another was a center with telecommunications and computer technologies available as a new business incubator or for training. Most of these have not met the test of self-sufficiency and many have closed. One notable success is TekNord, a program in northern Jutland in which experienced industry technology managers are shared among 5-10 SMEs. These managers contract with SMEs to spend 10-20 percent of their time for at least two years not to work on daily production problems but to help the firms plan for the future and adopt new techniques and technologies.
4.4 Italy

Italy, compared with some other European countries and the United States, is a nation of small firms. About 84% of the manufacturing work force are employed by SMEs (less than 500 employees), and more than half work in firms of fewer than 20 employees. In general, R&D activity is lower in Italy than in other industrialized countries. Italian universities produce fewer scientists and engineers per capita and industry links to the universities are weak. This is partly due to the nation's industrial composition, with more employment in traditional industries that conduct less R&D and large proportions of small artisan firms, often organized in dense, industrial districts. But there are significant variations within the country, and there are many technology diffusion activities not included in R&D budgets.

In 1989, the federal government established a Ministry for Universities and Scientific and Technological Research and charged it with coordinating public scientific research. The main funding body for basic and applied science (with increasing emphasis on applied) is the National Research Council, which has a network of 300 institutes, study centers, and research groups. The main national agency engaged in technology transfer and diffusion is the Agency for New Technologies, Energy, and the Environment (ENEA). Originally established as a nuclear energy agency, in 1991 it was renamed, given its new mission and its 4,500 person staff took on new roles, the most recent of which is technology transfer. ENEA operates nine major research centers and a series of other smaller centers.

National policies in Italy have supported the belief that technology is demand driven and that incentives for technology adoption ought to go to private sector. For example, since 1965, the Sabatini Act has provided loans to firms to purchase or sell machinery and tools. Similarly, since 1983, Act 696 has given SMEs grants to purchase high tech machinery. A current initiative is the Diffusion of Technological Innovation (DIT) project, which provides technical assistance, information, and training to SMEs in Southern Italy (the least developed half of the country). DIT is operated through 30 chambers of commerce, under the guidance of the Ministry for Universities and Scientific and Technological Research. Each chamber has a dedicated office (DIT SPOT), with trained staff. The project focuses on assisting private firms in agro-food, furniture, clothing and textile, mechanical and tourism sectors. Services are tailored in response to company needs. Efforts are also made to improve other existing service providers, to help them be more responsive to companies. Over two recent years,
DIT dealt with 4,500 information requests, offered 7 training programs, and assisted 600 entrepreneurs. Program managers note, however, that there are challenges in increasing the take-up of training programs and matching them with the style of business operations found in Southern Italy, expanding the network of qualified service providers, and sharing experiences and information among different DIT offices.23

Although these and other national technology diffusion policies do exist, the greater part of Italy’s technology deployment infrastructure, like Germany’s, is strongly influenced by regional governments, regional industry, and regional policy. Italy is organized into 20 separate regions, with regional governments given considerable authority for economic development and regional technology policies. One of the locations where regional approaches are most highly developed is the northern industrial region of Emilia-Romagna. This region of 3.9 million people has about 305,000 SMEs. Only 1.2% of these firms have more than 50 employees. Emilia-Romagna is home to a number of industrial districts, including packaging equipment (Bologna), shoes, wood products (Rimini), biotech (Modena), machine tools (Piacenza), farm machinery, and food processing (Parma).

The major structures for technology diffusion in Emilia-Romagna are the Regional Board for Economic Development (ERVET), the National Confederation of Artisans (CNA), the regional government, and the technical institutes. The regional government provides core support for ERVET (revenues are 74.5% government, with the rest from chambers of commerce, banks, and trade associations) and has various grant programs available to businesses—often targeted to small businesses—with which SMEs can purchase services from whom they choose. A law was passed in 1985, for example, to promote technological innovation in small scale enterprises with grants for technological research, technical applications, acquisition of patents, or acquisition of services and technical assistance with introducing new technologies. A second law provides credit to SMEs to cover the leasing of new machinery or equipment. Another law provides capital to encourage technical services and technological and scientific research or experimentation, with a stated emphasis on working with consortia, not individual firms.

ERVET is responsible for translating industrial policy objectives into action and serving as an interface between business, research institutions, and government. It focuses on export certifications and technological innovation. ERVET has 120 employees and a budget of one billion lira ($840 million)/year. It also receives European Union (EU) Social Funds under objective two (sectoral dependence).
To serve the region’s leading industry clusters, ERVET is organized into seven sector-specific business centers and three horizontal service centers. The sector-specific are for metal-working (CERMET), farm machinery (CESMA), industrial automation (DEMCENTER), footwear (CERCAL), textiles and apparel (CITER), construction (QUASCO), and ceramics (CENTRO CERAMICO). The three horizontal centers are export promotion (SVEX), innovation financing (FIT), and technology development (ASTER). ERVET’s programs integrate technology with other related needs of SMEs. Each of the sector centers has a goal of technology diffusion but also helps firms meet new specifications and identify market opportunities. Although each receives some core government support, they all are expected to generate most of their revenues from memberships or fees for services. CITER, for example, receives 30% of its funding from ERVET but the rest from dues (400 member firms and associations) and fees. The only center with a strong link to a university is CENTRO CERAMICO which is located at the University of Bologna. Other regions in northern Italy operate similar sector centers. In Lombardia, 26 centers, also with support from government, business associations, and firms, serve regional industry sectors.

The horizontal center ASTER has a mission most directly targeted to technology diffusion. ASTER has about 50 employees plus consultants who conduct problem diagnoses with firms and assist in innovation and commercialization. It has a broad range of objectives, including technology transfer, R&D support, system innovation, promoting cooperation among companies and between companies and public and private bodies, helping companies relate to the EU, identifying new economic opportunities, and establishing training standards and monitoring training for new technologies. Many of its projects are in cooperation with EU programs. ASTER represents a merger of the expert centers and R&D. It is not as customer-driven as other services and has more difficulty finding revenue sources within the region, and increasingly they seek work outside of Italy. ASTER, for example, is a consultant to UN for programs in developing countries.

The other key element in technology diffusion in Emilia-Romana is CNA, a trade association serving SMEs (businesses with up to 40 employees). Although much of its support is for financial and management activities (bookkeeping, payroll, taxes, and financing), it also assists SMEs with technical problems and research, technical and vocational training and skill upgrading, and financing new technologies. The CNA in Emilia-Romagna has 62,700 member firms. Although the CNA is not directly responsible for technology diffusion, it provides an environment in which firms can learn from each other and facilitates firm cooperatives and networks that allow
them to more easily acquire new technology.

4.5 Spain

Spain has experienced considerable industrialization and modernization over the past two decades. From a relatively low level, the country has increased its support of R&D and technology development in recent years. A series of national R&D and technology action plans have been pursued, and national programs have been funded in such areas as R&D staff training and communications technologies. The Ministry of Education and Science and other ministries sponsor major research institutes and university research. For industrial technology, the Ministry of Industry and Energy (MINER) has established the Centro Dejarrollo Tecnologico (CDTI) to identify priority technologies and fund technology development and pre-competitive projects. CDTI also operates two other grant programs (Technological Promotion Projects and Technological Innovation Projects) which help firms commercialize technology internationally and diffuse existing or new technologies into their own operations. The Ministries of Industry and Education have jointly set up a network of Offices for the Transfer of Technological Results (OTRI), which is aimed at transferring research into industry and helping industry define the research that takes place in the universities. Grants to universities are used to link businesses with researchers. OTRI offices also provide advice on patents, training, and national and EU programs. For SMEs, which dominate much of Spanish industry, an Initiative for Industrial Design is working with regional authorities to expand the use of information services, provide industrial and financial assistance, and strengthen networks of financial and technical service providers. However, there are still significant gaps in the national technological infrastructure. For example, Spain has no comprehensive system of polytechnics or advanced vocational schools to produce sufficient numbers of engineers or offer technical assistance to industry.

Spain’s regions also operate their own industrial support and technology diffusion programs. In some of these regions, such as Mondragon, Catalonia or Valencia, an extensive set of technology centers and technology diffusion measures now operate. In the case of Valencia, a region of 4 million people where 96% of enterprises have fewer than 50 employees, the central organization for encouraging and supporting technology diffusion and innovation is the Institute of Small and Medium-Sized Enterprises of Valencia, or IMPIVA.24 This public institution was created in 1984 by the regional government’s Department of Industry, Commerce, and Tourism to develop policies to promote innovation and technology adoption by SMEs. Its structure was predicated on three criteria: that ser-
IMPIVA’s objectives include modernizing (making more competitive) existing firms, supporting innovation and technology diffusion, and developing new production activities. There is a network of eleven technology institutes, four enterprise and innovation centers, and a technology park for R&D businesses and research centers. Each of these initiatives was established by IMPIVA as an association—a network of business organizations, chambers of commerce, and trade unions, local governments, universities, and other stakeholders. IMPIVA itself is governed by a chairman (the Regional Minister of Industry, Commerce and Tourism), two vice-chairmen, and an advisory council composed of representatives of IMPIVA’s centers, unions, chambers of commerce, universities, and business associations.

Each center has a special focus related to the needs of local industry concentrations. Examples of technology institute specialties are for ceramics, optics, textiles, toys, biomechanics, and plastics. Centers are each responsible for technology assessments and quality standards, design technologies, information, technical training, R&D (including demonstration sites and experimental plants for new technologies), and facilitating cooperation among firms. Staff size ranges from 10 in the newest center (plastics, established in 1990) to 76 in the ceramics center (founded in 1984). One center, the footwear institute, predates IMPIVA. Centers are typically governed by a Supervisory Board of 10 to 13 business owners and one to two IMPIVA representatives. In the early 1990s, the combined centers annually trained about 3,850 individuals, made 860 technological recommendations, prepared 10,000 information reports, and conducted 1,000 technology assessment. Overall, 3,500 businesses used these services.

A critical part of the Valencian scheme is to improve the collective capabilities of area SMEs, by encouraging cooperation between firms, among institutions, and with international bodies and associations. The program of inter-firm cooperation was formalized and in 1991–92, industry people were trained (with assistance from Denmark) to become network brokers. IMPIVA provided grants to cover part of the costs of developing networks. IMPIVA also supports ACTIA, a business intelligence service for SMEs’ technical and economic problems. It includes ACTIA Flash, an on-the-spot problem solving service, ACTIA Sintesis, which are in-depth syntheses of information for strategic technology planning, ACTIA Vigilancia Prospectiva, a technology monitoring service that scans information
to meet firm needs, and ACTIA Transfer, a service to detect technology opportunities and industrial partners.

4.6 United Kingdom

In the United Kingdom (U.K.), there have long been well-developed institutions, mechanisms, and traditions for the promotion of scientific research and advanced technology development. Ministries, national research bodies, national laboratories, universities, non-profit organizations and private companies are among the key elements in scientific and technology development. In recent decades, there has been an increased focus on technology diffusion. It is hoped that improved technology diffusion measures will increase the commercialized outputs of the U.K. science base, as well as enhance industrial competitiveness and regional. At the national level, the government has set up diffusion programs to encourage industry to partner with organizations in the scientific and technology community. Current diffusion initiatives include programs in biotechnology, environmental technology, and information technology. Efforts have also been established to promote technology development and use in SMEs (in the U.K., 97% of manufacturing establishments employing 39% of the manufacturing work force comprise firms with fewer than 200 employees).

Beginning in the 1970s, the U.K. has tried a number of successive schemes for supporting the technological modernization of its SMEs. The central government had a Small Firms Service combining counseling with information. Local authorities built incubators. Local Enterprise Agencies were created as public private partnerships to transfer expertise and know-how to SMEs. And, more recently, technology was diffused through local Training and Enterprise Councils, or TECs (in Scotland, Local Enterprises Councils or LECs), which were first established with resources originally centralized in the Manpower Services Commission and targeted to training.

The TECs, a major vehicle for SME competitiveness and technology diffusion programs, were formed in 1990 primarily to help employers diagnose training needs and invest to meet them. In 1993-94, the government spent 32.3 million pounds on the following generic business support activities: (1) information and advice, 4.2 million; (2) business counseling and consulting, 10.0 million; (3) skills training, 8.8 million; (4) diagnostics and innovative products and services, 9.0 million. The LECs – the Scottish version of the councils – are similar but have a stronger local development mission. These centers are governed by local business and community leaders. SMEs are expected to pay part (but rarely more than half) of the costs of all but the information services.
Because these centers have established relationships with SMEs, they are also assuming broader sets of responsibilities and providing a home base for new technology diffusion programs. One of these has been Business Net Limited, a program to encourage and support collaboration among SMEs wishing to enter new markets or develop new technologies or products. Network Centers were created at the TECs and individuals were trained and licensed to become network brokers. These centers also are attempting to establish partnerships with innovation centers. The Avon TEC, for example, is working with the Centre for Innovation and Industry at the University of West England.

In 1988, U.K. launched the Enterprise Initiative to provide comprehensive advice and guidance to SMEs. The elements included consultancies, research and technology assistance, an enterprise and education assistance. The consultancies, supported by Enterprise Support Ltd., provided technological and management skills to SMEs and was the most popular. Firms were eligible to receive a subsidy of half the cost of the consultancy for between 5 and 15 days. Its budget for 1991-92 was 59 million pounds. About two-thirds of the SMEs taking advantage had fewer than 25 employees, and the most popular objective was quality improvements. About 85 percent felt “certain” they would implement the consultants’ recommendations.

In 1994 the government created Business Links, to rationalize the often confusing services to SMEs and, additionally, to provide a system of Innovation and Technology Counselors. By mid-1995, more than 100 Business Links were operating, bringing together partnerships of TECs, Chambers of Commerce, Enterprise Agencies, local authorities, and other local organizations to offer coordinated services to SMEs (including, but not limited to, assistance with technology). The Business Links Innovation and Technology Counselors are backed by an on-line data base of specialized technology expertise residing in universities, trade associations, businesses, and consultants. A Supernet system matches SMEs with technical centers for assistance with product or process technology problems. Another network of International Technology Promoters offers information to SMEs about technology developments and possibilities in other countries. Each Business Link can also apply for funding for a Design Counselor.

Business Links are intended to achieve economies of scale and accelerate technology diffusion by empowering SMEs to learn from other firms. Trained brokers work through Business Links to encourage joint ventures and strategic alliances such as sharing the
costs of new equipment. Further, Business Links favors sector strategies and looks for clusters of firms in regions to assist. Another Department of Trade and Industry program called Business Bridges establishes a framework for larger companies helping SMEs develop managerial skills and new technologies.

The U.K. has a number of other local centers to expose SMEs to new technologies that receive some government funds. In Wales, for example, these include the EDI Awareness Centre, the Welsh Garment Centre, and the Innovation Wales. Finally, the U.K. also has a system of Further Education Institutes, some of which work closely with industry to provide information and skills for technology adoption. There are 37 of these institutes in Wales alone.

The government’s Department of Trade and Industry recently completed a national study called Technology Foresight, which is an analysis of 15 sectors of the economy with promising market opportunities and the technologies and skills necessary to exploit them. The government has committed 6 million pounds this year to support its new Business Link programs with business and science for areas targeted by Foresight. Another 40 million over three years will be available for matching grants for collaborative R&D to enhance competitiveness in the 15 sectors, with special attention to information technologies.

4.7 Japan

With more than 800,000 manufacturing enterprises employing 300 or fewer workers, Japan’s small firm sector occupies more than three-quarters of the country’s 14 million manufacturing workers. There is much variety by segment of industry, scale and scope, independence, level of technology, and capability for research and development. About one half of Japan’s SME’s are micro-workshops with three or fewer workers, while the rest – still a huge segment of some 432,000 enterprises – each employ between 4 and 299 people.

Many Japanese SMEs have become proficient in using new technologies, with diffusion rates for computer-controlled machine tools, robotics, and other shop-floor technologies at the forefront of all nations. But diffusion rates for off-the-floor information and communications technologies are weaker, while just under 10 percent of Japanese small firms reported that they conducted research (compared with almost two-thirds of larger firms with 300 or more employees). SMEs typically find it difficult to attract good scientists and engineers, who generally prefer to work in the more stable and better resourced environment of large Japanese companies.
Up to now, most Japanese SMEs have compensated for the limitations of their own R&D efforts by absorbing technology from larger customers and other external sources (many SMEs then make subsequent incremental improvements in acquired technologies). Long-term relationships between smaller and bigger firms have given the smaller units the confidence to invest in new equipment, workforce training, and ongoing product and process improvement. Larger firms may also provide technical assistance to their smaller suppliers or second personnel. However, these relationships have come under pressure as larger firms have become more internationalized and cut back in many industries on traditional domestic sources of supply. SMEs have responded to these changes with intensified efforts to simultaneously lower costs in existing lines and to develop enhanced and new products to enter higher value-added markets. Other Japanese SMEs are seeking to reduce traditional vertical dependencies on a few large firms by building stronger horizontal and lateral ties with a wider variety of other enterprises and with research centers to secure business survival and greater technological autonomy. To support this direction, new regional research and technology initiatives focused on SMEs are being added to Japan’s long-established programs for small firm technological modernization.

Traditionally, separate technological institutions have been established to serve SMEs (for example, until very recently, there was not much involvement from universities in collaborating with SMEs in R&D). The cornerstone of this system is the network of local public technology and testing centers (kohsetsushi). These centers—many of which trace their origins back to the 1920s and 1930s—provide technological assistance and conduct research aimed at assisting local SMEs. New manufacturing equipment and computer facilities are made available to SMEs for evaluation, training, and trial production. Kohsetsushi centers supplement these facilities with seminars, cooperative research projects, industrial exhibitions, and individual technical assistance to area companies. The centers also organize technology exchange and fusion groups, consisting of collaboratives of small and medium companies who meet to exchange technical information and cooperatively develop new products and technologies. All told, there are over 180 public research and testing institutes, employing over 7,100 staff (including 5,400 engineers and researchers). National guidance and coordination is provided through the Ministry of International Trade and Industry (MITI), by its Small and Medium Enterprise Agency (SMEA) and the Agency of Industrial Science and Technology (which oversees Japan’s national laboratories). In FY 1994, Japan’s overall spending for all the kohsetsushi centers was ¥98.2 billion ($1.1 bil-
lion) - an average of ¥551 million ($6.1 million) per center. Most of this funding is provided by prefectural or city governments.

Local governments in Japan also sponsor trade centers and other local small enterprise assistance centers. These centers may provide facilities for equipment testing and prototyping and organize trade exhibitions where new products and process technologies can be viewed. This is the case for the Ota-ku Trade Center, in Tokyo’s Ota ward, which serves several thousand clustered small metalworking, machinery, and electrical industry clustered. In addition, under national guidance, a wide range of public financial incentives, loans, and tax concessions are made available to SMEs to help them in the process of technological upgrading and absorption. Three national public financial institutions target fund to SME; there are systems to support equipment leasing; and prefectural and local governments offer subsidized loans and matching project funds for SME technology projects.27

The kohsetsushi system and similar local government centers are currently undergoing a phase of restructuring and review. Concerns have grown about the technological skill level of researchers and institutional capabilities to foster advanced product development in SMEs (in addition to process improvement). In a number of locations, kohsetsushi centers have been reorganized and provided with new facilities and advanced equipment to raise the level of their research.

While the kohsetsushi centers still have an important role, increased interest in new forms of technological development and in addressing regional problems of industrial restructuring and the distribution of technology-intensive firms in Japan have led to the emergence of additional programs and centers. New public and “third-sector” (public-private) technology centers have been established in Japan to promote software development, new materials, biotechnology, and other emerging technologies. Most (but not all) of these projects are located outside of Japan’s congested Tokyo-Nagoya-Osaka central core as part of government policies to promote the technological upgrading of existing industries and the diffusion of technological capabilities to peripheral regions.

Perhaps the most well-known of these initiatives is the Technopolis program which, in the 1980s, designated 26 areas in outlying regions to serve as nodes for high technology growth. Technopolis aimed to create new environments for high technology research, venture business development, and “creative” living, supported by investments in infrastructure and research facilities and various incentives and subsidies. However, few Technopolises have gener-
ated significant growth in new indigenous technology enterprises. This has led policymakers to promote more intensive efforts to upgrade regional research and technology support for existing industries in local areas, as well as to promote new venture development. For example, a Research Core program has been established to build special facilities for promoting small firm technology transfer, business incubation, and training. Sponsored by MITI, although funded mainly by local government and the private sector, about a dozen Research Core locations have been chosen to date. A research core is a grouping of four facilities: an open research and technological development facility, an education/training facility, a technological information exchange facility, and a venture business incubator. Other regional technology projects championed by MITI and other ministries include the Key Facilities Concept (promoting facilities for information services and research in peripheral areas) and the New Media Community (developing new information systems in part for local firm networking). 28

In almost every local industrial area in Japan, there industrial organizations, chambers of commerce, and trade associations which often receive some prefectural and local government support. These organizations performed critical roles in the demonstration and diffusion of technology in the early modernization of Japan and they continue to serve as part of the social fabric for the exchange of information about new technology and the sponsorship of new technology projects and study groups. 29 Over the last few decades, local associations have worked with governmental agencies to cluster related industries together with the aim of promoting and sharing modern facilities.

Many local governments have built new facilities ("TechnoPlazas") and promoted organizations ("Business Exchange" groups) to help SMEs meet one another, exchange ideas, learn about new R&D and technology trends, and develop new business opportunities. Additionally, a growing number of technology exchange and technology fusion groups have been formed under the aegis of a 1988 Technology Fusion Law. This was enacted to encourage small firms to work together for knowledge exchange, business diversification, and joint product development and marketing. The fusion program is overseen by the MITI’s SMEA but implemented by local organizations. Only a few million dollars of central funds are allocated for business exchange, fusion group subsidies, and commissioned research. However, this is matched by prefectural resources. Fusion activities also draw on various "off-budget" SME loan programs and incentives, public banks and credit associations, and other support institutions. In 1994, more than 2,500 fusion groups were registered in Japan involving more than 80,000 SMEs. Most of the groups are
still at the stage of initial association and research, but some have moved to commercialize jointly-developed new products.

4.8 United States

The United States has a very extensive science and technology base. It combines federal level research funding and performing institutions, federal laboratories, universities, non-profit research organizations, and private laboratories and companies. The system is decentralized, with multiple organizations at national, state, and sector levels involved in policy-making, research, and development. While there have been numerous ways in which technology is diffused through this system and into industry, concerns during the last decade about the links between the U.S technology development base and industrial performance have resulted in new policy measures to promote technology diffusion. American policymakers have been particularly worried about the slowness of the country’s 400,000 SMEs in adopting and fully using new manufacturing technologies and techniques and the resulting adverse effects on industrial competitiveness, domestic supply chains, regional economies, and the stability of high-wage manufacturing jobs.

To assist U.S. SMEs, a series of technological infrastructural initiatives and programs have been put into place by federal and state governments, academic and industry organizations, and other groups. These efforts include legislation and policies to promote industrial technology transfer, the expansion of industry assistance centers, the stimulation of industrial networking, and support for the conversion of defense suppliers to civilian technologies and markets. Manufacturers, of course, obtain information and guidance about new technologies from a variety of sources, including private ones such as customers, vendors, trade associations, and other firms and business associates. In general, private sources are more significant to SMEs than public ones, although the role of the public sector is increasing with the expansion of federal and state manufacturing modernization and extension measures. In many instances, diffusion policies are implemented through non-governmental or private agencies (for example, through private consultants and “third-sector” technology centers).

From a public policy perspective, three major approaches to technology diffusion in the United States can usefully be identified. The first is an extension of the federal government’s own investment in science and technology. Since the end of World War II, the government has sponsored research and technology development through mission-driven agencies in such areas as defense, space, energy, agriculture, and health and through the support of fundamental science, particularly in universities. In numerous cases, public sup-
port has allowed federal laboratories, universities, and private industry to develop, test and refine new technologies, build prototypes, and define new applications. A series of key technologies have been developed through this system and subsequently commercialized. But, in recent years, this “technology pipeline” and “technology spin-off” model has been subject to review on grounds of cost-effectiveness, timeliness, and linkage to commercialization. This has led to new initiatives to improve collaboration between federal research and industry and promote the development and diffusion of dual-use technologies (with the latter seeking the simultaneous – rather than linear – combination of mission-specific and commercial technologies). The mechanisms to do this are numerous and include the promotion of public-private consortia, the development of industry-focused technology centers (such as the National Science Foundation’s Engineering Research Centers), and the establishment of technology transfer offices and cooperative research and development agreements.

State and local governments are also active in the promotion of technology development and the diffusion of its results into their local economies and businesses. These measures include university-industry technology centers, university-industry research partnerships, equipment and facility access and demonstration programs, technology financing to projects and companies, start-up assistance for technology-based spin-off firms, information services and interactive databases, network promotion, and help in forming strategic technology alliances. The number and scope of these measures has increased significantly over the past decade, and there is a considerable degree of experimentation and mutual learning among these initiatives.

A second approach involves the diffusion of new process technologies, including equipment and software. Again, there has been an important defense sector role, with defense services and logistics agencies supporting manufacturing technology programs to assist defense suppliers in using new or specialized production technologies. These “ManTech” programs have supported the demonstration and deployment of numerical machine tools, automated manufacturing, shop-floor management software, rapid replacement part production, and other technologies. Some ManTech programs have had a specific focus on smaller suppliers. Such efforts have contributed to higher adoption rates of advanced manufacturing technologies among defense suppliers (who generally also supply civilian products) than non-defense firms in the U.S. Among civilian agencies of the federal government, the National Institute of Standards and Technology (NIST) has operated an Advanced Manufacturing Research Facility to develop and demonstrate new integrated manufacturing technology and
software, as well as a NIST “Shop of the ’90s” focused to smaller-firms interested in up-to-date but lower cost technologies. Over the last decade, the federal government has also supported consortia of companies in specific industrial sectors to develop, test, and disseminate new technologies. Examples include the National Center for Manufacturing Sciences in the machine tool industry and Sematech in the semiconductor industry.

At the state and local level, there has been a considerable growth of centers whose activities include the diffusion of new process technologies. Many technical and vocational colleges have established facilities to demonstrate new technologies in computing and automated manufacturing and to enhance workforce training in these technologies. In several area, these colleges have themselves formed consortia to share information and experience. For instance, in the U.S. Southeast, a multi-state Consortium for Manufacturing Competitiveness is comprised of two-year colleges seeking ways to improve their activities in technology deployment. A further elaboration is the establishment of shared manufacturing facilities (also known as teaching factories) where machinery, computers and software are made available for demonstration, company evaluation, and training. Of the more than two-dozen teaching factories that have been set up or are in planning, many are associated with community colleges or area universities. Equipment is often donated by vendors.

Another major development is the expansion of manufacturing technology and extension centers and programs sponsored by states and localities with matching federal funds through NIST’s Manufacturing Extension Partnership (MEP) program as well as industry support. Over 60 MEP centers have now been established, with additional ones planned. Some of these centers were established by state governments before the MEP33; others have developed as a result of the MEP. While each center operates its own particular mix of services, the activities of MEP centers typically include information provision, assessments, demonstrations, brokering, field agent services, qualified referrals, group projects, and training. Improvements are often also sought in inter-firm and industry relationships and in public technology, training, and business assistance infrastructures. Most MEP services are focused towards SMEs. Non-profit organizations, colleges and universities, state agencies, industrial associations, and private consultants are most frequently engaged in providing industrial modernization services. In a number of centers, core staff conduct initial assessments and then involve outside experts or consultants to provide follow-up assistance. Companies frequently pay at least some of the costs involved. In other centers, full-time professional staff provide the bulk of service. This is the case for the Georgia Manufacturing Extension Alliance,
led by the Georgia Institute of Technology, where industrial engineers in 17 field offices around the state provide direct technology assistance services to firms.

The typical MEP center has about 35 professional and technical staff and, each quarter, uses an additional ten consultants. The average number of targeted manufacturers in an MEP’s service area is around 6,200. But the spread is wide, with smaller MEPs (usually serving dispersed rural areas) targeting 1,300 to 1,500 enterprises and a few larger centers (in urbanized locations) targeting more than 15,000 firms. While there are again variations by center size, on average each MEP center assists about 300 firms a quarter through individual engagements and projects. More than two-thirds of the firms served have fewer than 100 employees. Most frequently, assistance is provided in areas of business systems and management, quality, market development, process improvement, and human resources through a combination of initial visits, engagements, assessments, and technical assistance projects. The leading categories of MEP service thus mostly emphasize “soft” technologies and techniques, followed by assistance with process, environmental and product technology. There is a lower level of service in “hard” areas of factory automation.

In a comparatively recent development, several states, regional organizations and MEP centers have started to promote industrial networks or groupings of manufacturing companies to promote shared approaches to business development, including technological upgrading. Networking seeks to aid groups of firms, usually within a proximate geographical area, through information sharing, solving common problems (such as training), and cooperation in design, production and marketing. A pilot 11-state consortium called USNet has received federal and state support to share best practices for networking and provide training, information, and evaluation services to support inter-firm collaboration.

The third area of publicly-supported technology diffusion aims to promote improved “soft” practices in manufacturing, management, and training. At the national level, the federal government sponsors (through NIST) the Malcolm Baldrige National Quality Award. This aims to encourage firms to improve quality. While a national contest annually highlights exemplary companies, more subtle impacts have been identified through the dissemination (more than a million copies to date) of the award’s guidelines and the use of these guidelines by many firms to upgrade quality, employee involvement, and customer satisfaction. Another national example is the U.S. Department of Labor’s pilot demonstration project to promote “high-performance” work environments. Federal funds have been provided to
groups of firms and local institutions to help them demonstrate improved ways of organizing work and improving productivity. State and local manufacturing technology and extension centers, colleges, and other programs in many locations are also sponsoring various continuous improvement groups, learning networks, and industry consortia to demonstrate and disseminate best manufacturing and workforce practices.

Note
This paper was prepared as a background paper for the Organization for Economic Cooperation and Development (OECD), Directorate for Science, Technology and Industry, Paris. The views expressed in this paper are those of the authors and should not be attributed to OECD.


5. There have, of course, been traditional variations in the emphasis on diffusion. The technology policies of the U.S., Britain, and France have been highlighted as more “mission-oriented,” while those of Germany, Switzerland, and Sweden have been characterized as more “diffusion-oriented” (H. Ergas, Does technology policy matter? in B. Guile and H. Brooks (editors), Technology and Global Industry: Companies and Nations in the World Economy, Washington, DC: National Academy Press, 1987). But, in recent years, all advanced economies, including the mission-oriented ones, have paid much more attention to technology diffusion.


8. Supply-push v. demand-pull and top-down v. bottom-up are other (perhaps more value-laden) variations on this definitional framework. It has also been sug-

9 See, for example, R. Rothwell and W. Zegveld, Industrial Innovation and Public Policy, Westport, CT: Greenwood Press, 1981.

10 See Center for Manufacturing and Information Technology world wide web site: http://cmit.edi.gatech.edu/

11 Details of the Performance Benchmarking Service can be accessed through the world wide web site: http://www.iti.org/pbs/. See also D. Luria and E. Wiarda, Performance benchmarking and measuring program impacts on customers: Lessons from the Midwest Manufacturing Technology Center, Research Policy, 1996, 25, 233-246.

12 See the Community Research and Development Information Service world wide web site: http://www.cordis.lu/.

13 This program, and numerous other U.S. federal-state technology programs are described in C. Coburn (editor), Partnerships: A Compendium of State and Federal Cooperative Technology Programs, Columbus, OH: Battelle, 1995.

14 For more details, see F. Pyke, Small Firms, Technical Services, and Inter-firm Cooperation, Geneva: International Institute for Labour Studies, 1994.


17 Enterprises with less than 300 employees.


21 Fraunhofer Gessellschaft, Profile of the Fraunhofer Gessellschaft: Its Pur-


24 Pyke, op. cit. (Chapter 2).


27 Note should also be made of Japan’s broadly favorable macro-level regime for the identification, deployment, and improvement of technology including relatively high levels of workforce education and training, a strong commitment to internal self-development within firms, and supportive economic, and trade policies.


29 See, for example, the discussion on the role of local industrial groups and initiatives in T. Morris-Suzuki, The Technological Transformation of Japan, Cambridge: Cambridge University Press, 1994.


31 C. Coburn (editor), Partnerships, op. cit.


33 For example, in the US South, industrial extension programs were started by North Carolina in 1955 and Georgia in 1960.