USING RESEARCH AND DEVELOPMENT TO GROW STATE ECONOMIES

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Since their initial meeting in 1908 to discuss interstate water problems, the Governors have worked through the National Governors' Association to deal collectively with issues of public policy and governance. The association's ongoing mission is to support the work of the Governors by providing a bipartisan forum to help shape and implement national policy and to solve state problems.

The members of the National Governors' Association (NGA) are the Governors of the fifty states, the territories of American Samoa, Guam, and the Virgin Islands, and the commonwealths of the Northern Mariana Islands and Puerto Rico. The association has a nine-member Executive Committee and three standing committees—on Economic Development and Commerce, Human Resources, and Natural Resources. Through NGA's committees, the Governors examine and develop policy and address key state and national issues. Special task forces often are created to focus gubernatorial attention on federal legislation or on state-level issues.

The association works closely with the administration and Congress on state-federal policy issues through its offices in the Hall of the States in Washington, D.C. The association serves as a vehicle for sharing knowledge of innovative programs among the states and provides technical assistance and consultant services to Governors on a wide range of management and policy issues.

The Center for Best Practices is a vehicle for sharing knowledge about innovative state activities, exploring the impact of federal initiatives on state government, and providing technical assistance to states. The center works in a number of policy fields, including agriculture and rural development, economic development, education, energy and environment, health, social services, technology, trade, transportation, and workforce development.

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SUMMARY

The U.S. economy is undergoing a dramatic transformation as the nation moves to an economy driven by technology industries and the application of technology in traditional industries. To compete in this "new economy," states must have an economic base of firms that constantly innovate and maximize the use of technology in the workplace. Also critical is a strong research and development (R&D) base that can provide these technology-intensive companies with access to state-of-the art research, researchers, and research facilities.

ELEMENTS OF A TECHNOLOGY-BASED ECONOMY

A technology-based economy requires:

- a strong intellectual infrastructure, such as universities and public or private research laboratories that generate new knowledge and discoveries;
- efficient mechanisms through which knowledge is transferred from one person to another or from one company to another;
- excellent physical infrastructure, including high-quality telecommunications systems and affordable, high-speed Internet connections;
- a highly skilled technical workforce; and
- good sources of capital.

Each element has a direct impact on a state's R&D base and, therefore, on its ability to support a technology-based economy. Many states are building their R&D base through initiatives that address these elements.

Intellectual Infrastructure. The university system is an important component of a state's intellectual infrastructure. A recent report by the Milken Institute found that of the top thirty high-technology metropolitan areas, twenty-nine were home to, or within close proximity of, a major research university.[1] States can improve the intellectual infrastructure by strengthening the R&D capacity of their higher education system, investing in higher education in areas of industrial relevance, and encouraging greater university-industry interaction.

Spillovers of Knowledge. Much of the success of Silicon Valley can be attributed to its accomplishments in transferring knowledge and technology from universities to the private sector and among companies. States can encourage spillovers of knowledge by identifying and removing barriers to the commercialization of university-developed technology, encouraging access to federal laboratories, and providing seed funding to industry associations and technology councils that promote communication among companies.

Physical Infrastructure. The competitiveness of a state's economy increasingly depends on its enabling infrastructure. In the past, this meant roads, bridges, and rail and telephone systems. Today, it also includes proximity to airports, fiber optic networks, and high-speed Internet access. States can examine the quality of their physical infrastructure and take steps to improve it through public and private action.

Technically Skilled Workforce. Perhaps the most significant issue facing technology-intensive companies today is access to an adequate number of highly skilled technical workers. More than 300,000 information technology jobs were unfilled in 1998, according to a report by the Information Technology Association of America.[2] The U.S. Bureau of Labor Statistics projects that an additional 2 million workers will be needed during the next ten years.[3] States can help ensure the availability of a technically skilled workforce by encouraging more students to enter science and engineering fields, developing internship programs for students in science and engineering, and providing training for workers in technology-based companies.

Capital. The availability of capital to support start-up and emerging companies—the type of companies on which the new economy depends—is essential if a region is to build its R&D base. Although the supply of venture capital in the United States has increased dramatically in recent years, venture capital investments are geographically concentrated. Consequently, venture capital is not available in all regions. In addition, as the size of venture funds have grown, fewer investments are being made at the preseed or seed stage. State options to address the need for venture capital include investing state funds in technology companies, using state funds to leverage private funds to invest in technology companies, helping companies access private and public funding sources, and offering R&D tax incentives.

Implications for a State's Research and Development Base

Technology industries are driving the new economy. States that position themselves to take advantage of this changing economic environment will realize its benefits; those that do not will see a widening income gap and declining revenue base. Growing state economies in this new century will require building a strong R&D base to support the burgeoning technology industries. To participate fully in the new economy, states should take several actions.

- **Develop a plan for building the R&D base.** The first step is to develop a clear plan for building the R&D base. The plan should reflect the vision for the state's future, be based on a thorough understanding of the state's economy and R&D assets, and benefit all areas of the state.

- **Recognize that building the R&D base means a long-term, sustained, and significant investment.** There is no quick route to acquire a thriving R&D base. Silicon Valley in California, Route 128 in Massachusetts, and Research Triangle Park in North Carolina are the results of decades of public and private investment. For example, North Carolina invested hundreds of millions of dollars during more than twenty-five years to support its universities and the research park's development. Most policy options to build an R&D base require a long-term, sustained, and significant investment.

- **Hold initiatives accountable.** State policymakers should determine in advance what policies and programs aim to accomplish and how results will be measured. Given the long-term nature of R&D investments, both interim and long-term performance measures should be developed and implemented.

The Changing Economic Environment

In 2050 Americans will look back with an understanding that the U.S. economy was transformed in the last decade of the twentieth century. The nineteenth century's transition from an agrarian-based economy to a manufacturing-based economy is paralleled in today's transition from a manufacturing-based economy to a technology-based economy. Unquestionably, agriculture and manufacturing will continue to be important economic sectors, but the new economy will be driven by technology industries and their influence on traditional economic sectors. The changing economy has been dubbed the new economy, the digital economy, the knowledge-based economy, and the technology-based economy. All are accurate descriptions of an economy that is becoming less dependent on making and growing things and more dependent on promoting ideas and innovations. The new economy also is less reliant on natural resources and more dependent on human resources.

The Importance of Technology and Technology Firms

Technical innovations have spawned new products and industries, including personal computers and cellular phones and electronic commerce (e-commerce) and biopharmaceuticals. They can improve the quality of people's lives by providing medical advances, a cleaner environment, enhanced communication, and more entertainment options. The technology-based economy holds great promise for simplifying lives by providing easy access to information and improving health care through telemedicine. Yet the challenges posed by this economy are as profound as its benefits. Income disparity among regions and people may widen considerably as some participate fully while others are left behind.

The economic importance of high-technology firms in today's economy can hardly be overstated. Employees in high-technology industries make significantly more than those in other industries. In 1996 the average pay per employee in high-technology industries was 67 percent higher than the average pay per employee for all other industries, $44,041 compared with $26,363.[4] Information technology, a component of high-technology, is credited with one-third of U.S. economic growth between 1995 and 1998, according to the U.S. Department of Commerce.[5]

Perhaps even more significant than the current economic impact of high-technology firms is the actual and projected growth of the industries. The Internet and e-commerce alone will fundamentally change every industry in the coming decades. E-commerce among businesses began roughly in 1995; by 2002 it is expected to account for about $300 billion worth of transactions.[6] As high-speed Internet access becomes commonplace, businesses and people will purchase products and services directly from the supply source, removing or reducing the role of various parts of the supply chain. For example, online travel sales are expected to grow twenty times during a four-year period.[7] Although people will be able to make travel arrangements at their own convenience, it will result in the closure of thousands of travel agencies across the nation. Similar scenarios can be forecast for the insurance, banking, and real estate industries, automobile dealerships, and video rental stores. Small businesses that survive in this environment will likely be focused in niche geographic or market areas.

Investment in Research and Development

For more than forty years, states have been taking advantage of their R&D assets to improve their economic future. North Carolina's Research Triangle Park (RTP) was one of the earliest efforts. Created in 1959 through a public-private partnership involving business, academia, and state government, RTP seeks to build on and encourage greater cooperation among Duke University, North Carolina State University-Raleigh, and the University of North Carolina-Chapel Hill. Its efforts to attract companies to locate R&D facilities within the park have resulted in more than 100 R&D facilities. These facilities employ more than 37,000 people with combined annual salaries of more than $1.2 billion.[8]

However, in today's global economy, state policymakers must be aware not only of the actions of other states, but also of other countries. Recognizing that a strong R&D base is critical in the technology-based economy, nations worldwide are increasing their investments in their R&D base. Although many European countries have invested heavily in programs designed to promote economic growth through the application of science and technology, countries in Asia and the Americas are also making significant investments. Approaches include funding R&D, offering tax and other incentives to attract and grow technology-based companies, and providing financial and technical assistance to entrepreneurs and new start-up technology companies. As in the United

States, foreign governments are encouraging government-industry and university-industry partnerships, and subnational levels of government have begun to offer incentives and support for technology-based companies.

In recent years, Singapore, South Korea, and Taiwan have made tremendous strides in building a technology-based economy. South Korea and Taiwan, both major suppliers of computer equipment to the United States, dramatically increased their patent activity in the late 1980s, and they continue to aggressively pursue technology commercialization. Singapore is making substantial investments to promote a climate for innovation. Through its National Innovation Framework, Singapore's National Science and Technology and Economic Development Boards have committed $2 billion during the next five years to support the development of industry-driven R&D. These funds will be used to build infrastructure, support university-industry collaboration, recruit and develop R&D-trained personnel, and commercialize technology.[9] Taiwan's Industrial Technology and Research Institute, a government-funded, nonprofit intermediary organization, seeks to bridge the gap between university research and industry needs by coordinating research, analyzing industrial trends, conducting market assessments, and gathering global competitive intelligence.[10]

While Singapore and Taiwan are positioning themselves to participate fully in the technology-based economy, other countries, including Ireland and Israel, have clearly established themselves as key competitors. Ireland, which has succeeded in attracting a large number of multinational information technology and electronics corporations, is now seeking to grow its base of technology companies, with an emphasis on software development. A key strategy is building a strong R&D base in its universities and businesses. Its National Research Support Funding Board administers grant programs that fund basic research and joint industry-university projects. Ireland also has made a commitment to encourage Irish industry to invest in R&D. The Research Technology and Innovation Initiative, launched in late 1997, provides grants to Irish companies meeting certain criteria to cover between 35 percent and 50 percent of the costs incurred for a research project, depending on its size.[11]

Israel has built on its strong base of defense-related technologies and capitalized on its highly skilled, technical workforce. The country has one of the highest per-capita ratios of scientists and engineers in the world. Like Ireland, Israel has succeeded in attracting corporate investment by providing financial and tax incentives to build the country's industrial base. Israel also provides incentives for R&D investments.

Clearly, policymakers around the world are developing strategies to take advantage of the technology-based economy. Areas that thrive will boast a strong and vibrant research and development base. For state policymakers to develop that base, they must understand what sectors comprise the U.S. R&D base and what elements are needed for a technology-based economy.

COMPOSITION OF THE U.S. RESEARCH AND DEVELOPMENT BASE

Four sectors comprise the largest part of the U.S. R&D base: the private sector, colleges and universities, the federal government, and state government. State action can influence each sector's effect on the technology-based economy.

The private sector is by far the largest R&D performer in the United States, accounting for 70 percent of R&D spending in 1995. Most R&D performed by the private sector is focused on development; knowledge or understanding gained from research is directed to producing useful materials, devices, systems, or methods, including products and processes. Colleges and universities are the second largest R&D performer, accounting for about 12 percent of R&D spending. They focus primarily on basic research designed to gain greater knowledge or understanding, with limited attention to specific applications. The federal government, including federal laboratories, performs 9.4 percent of the nation's R&D, with some emphasis on development. Often overlooked, states spent more than $3 billion on R&D in fiscal 1995. Most of this spending was for basic research.[12]

ELEMENTS NEEDED FOR A TECHNOLOGY-BASED ECONOMY

Most states envy the economic triumphs of Silicon Valley, Route 128, and Research Triangle Park, and there is no simple formula to replicate the success of these technology-based meccas. However, research on technology clusters points to seven elements that are critical to building a technology-based economy.[13] These elements can be grouped into tangible elements—those that are definable and measurable—and intangible elements—those that can be defined only subjectively and are difficult to measure. There are five tangible elements.

- **Intellectual infrastructure**. In a technology-based economy, a key component for success is a thriving source of new ideas with people who advance their field. This source could be any one of the four sectors already performing R&D or ideally some combination of the four.
- **Spillovers of knowledge**. A technology-based economy also requires a free flow of ideas or spillover of knowledge. This movement can occur formally, for example, through invention licensing, or informally, for example, through the migration of employees.
- **Physical infrastructure**. Although a technology-based economy holds out the prospect that people can work wherever they like, an excellent physical infrastructure is still required. In addition to good highways and proximity to airports, physical infrastructure in today's economy also means high-quality telecommunications systems and affordable, high-speed Internet connections.
- **Technically skilled workforce**. In an economy that is based more on ideas than on manual labor, knowledgeable people with technical skills are fundamental to success. Companies are more likely to locate in areas where a supply of technically skilled workers exists than in areas where training to upgrade workforce skills is needed.
- **Capital**. For companies to grow, they must have capital. Regardless of the stage or source of capital, companies need financing to expand.

There are two intangible elements.

- **Entrepreneurial culture**. The intangibility of entrepreneurial culture makes it difficult to define. However, in an entrepreneurial culture, people view starting a company as a routine rather than an unusual occurrence, entrepreneurs are celebrated, individuals know many others who have started their own company, and people view company failure as a possible outcome of doing business rather than a cause for social disgrace.
- **Quality of life**. Quality of life is subjective and largely in the eye of the beholder, so it can translate into different things for different people. For example, some may view as important low taxes, varied cultural and recreational opportunities, a strong education system, and proximity to environmentally protected areas. In a technology-based economy, companies have more freedom to locate, and quality of life could play a more important role in their decision than it has in the past.

Each tangible element has a direct impact on the R&D base. An inadequate intellectual infrastructure strangles the technology-based economy of ideas and innovations, its lifeblood. Similarly, if spillovers of knowledge are not occurring, the R&D performers cannot build on others' research. A substandard physical infrastructure prevents the R&D performers from communicating with one another. Without an adequate supply of qualified workers, the research cannot be conducted. A lack of capital bars the R&D performers from paying for research and development. States can influence the tangible elements needed for a technology-based company. Difficulties in defining the intangible elements sometimes limit or preclude state action.

INTELLECTUAL INFRASTRUCTURE

For a state, the strength of its university system is probably the most critical element in the technology-based economy. Although the university R&D base can be measured in different ways, perhaps the most widely accepted is the classification of institutions of higher education developed by the Carnegie Foundation for the Advancement of Teaching.[14] The 1994 classification includes all colleges and universities in the United States that are degree-granting and accredited by an agency recognized by the U.S. Department of Education. The foundation classifies these institutions based on the number and type of degrees they award and the level of federal research support they receive.

The highest classifications are Research University I and Research University II.

- A Research University I awards fifty or more doctoral degrees each year and receives $40 million or more annually in federal support.
- A Research University II awards fifty or more doctoral degrees each year and receives between $15.5 million and $40 million annually in federal support.

For the 1994 classification, which is the most recent, 126 universities in forty-three states fit the criteria. Alaska, Maine, Montana, Nevada, New Hampshire, North Dakota, and South Dakota lacked institutions meeting the criteria.

A recent report by the Milken Institute identifying the top fifty high-technology metropolitan areas suggests the significance of universities in the technology-based economy. Of the top thirty high-technology metropolitan areas, twenty-nine are either home to, or within close proximity of, a Research University I or II.[15]

To improve the intellectual infrastructure, states can:

- strengthen the R&D capacity of the state's higher education system;
- invest in higher education in areas of industrial relevance; and
- encourage greater university-industry interaction.

STRENGTHEN THE R&D CAPACITY OF THE STATE'S HIGHER EDUCATION SYSTEM

Recognizing the importance of a strong university system to the state's economic future, Nebraska created the Nebraska Research Initiative (NRI) to strengthen the research capabilities of the University of Nebraska. NRI aims to enhance the state's basic and applied research capacity, develop the state's national and international competitiveness, diversify the state's economy and bring job opportunities to the state, improve Nebraska's workforce, and improve the state's competitiveness in attracting research funds. In 1988 the state planned to increase the university's base budget for research by $4 million per year for five years, so that by 1993, NRI's annual budget would be $20 million per year; however, the spending was capped at $12 million per year. NRI has used the additional funding to support research centers focused on biotechnology, engineering, materials, telecommunications, and water sciences. As a result, Nebraska has seen its rank in the amount of funding it receives from the National Science Foundation climb from forty-sixth in 1990 to thirty-seventh in 1997. The rank for most states remained static during this period.[16]

INVEST IN HIGHER EDUCATION IN AREAS OF INDUSTRIAL RELEVANCE

States can also bolster the intellectual infrastructure by targeting state funds to research areas of particular strength. Typically, the areas are selected based on university capabilities and the existing industrial base. Investing in research when there is no corresponding private-sector base is less likely to result in positive economic development impacts for the state.

Georgia is targeting research through the Georgia Research Alliance (GRA), which it founded in 1990 as a partnership involving the state's research universities, industry, and state government.[17] GRA fosters economic development within Georgia by developing and leveraging the research capabilities of the state's research universities. It also develops and assists scientific and technology-based industry, commerce, and business.

Advanced communications, biotechnology, and environmental technologies are strategic areas for research. Centers formed around each area promote cross-disciplinary and cross-institutional research and facilitate the transfer of technology to applications relevant to industry. GRA is leveraging the research capabilities by constructing new facilities, installing state-of-the-art equipment, and recruiting eminent scholars.

Public and private funds support GRA programs. Through fiscal 1998, the state had invested $200 million in R&D programs at the universities, an amount matched by $50 million in private funds. This funding has helped attract more than $500 million in additional sponsored research. GRA also cites as an example of its success Lucent Technologies' decision to choose Atlanta for its new wireless laboratory. The decision resulted from the company's close working partnership with researchers at a GRA-funded center and GRA's commitment to establish an eminent scholar chair and develop a laboratory in wireless systems at Georgia Tech.

More recently, Michigan has announced a strategy to build its universities' capabilities in life sciences.[18] The state is planning to spend $1 billion of tobacco settlement funds during the next twenty years for life sciences research, development, and commercialization. The intent is to create a "life sciences corridor," making four research institutions—the University of Michigan, Michigan State University, Wayne State University, and the Van Andel Institute—national leaders in biotechnology applications.

The annual allotment will be divided among three program areas:

- forty percent will support a basic research fund that will be distributed to projects from the four institutions on a competitive basis;
- fifty percent will go to a collaborative R&D fund, with an emphasis on testing or developing emerging discoveries in partnership with biotechnology firms; and
- ten percent will go to a commercialization development fund to invest in start-up biotechnology companies.

ENCOURAGE GREATER UNIVERSITY-INDUSTRY INTERACTION

State matching grants for research partnerships encourage greater university-industry interaction and improve the intellectual infrastructure for the private sector. More than thirteen states have an ongoing program to fund university-industry partnerships. These programs tap the significant investments that states make in their higher education system and help bridge the gap between university and industry cultures.

Born out of the depths of Ohio's worst economic downturn since the Great Depression, the Edison Program is one of the nation's largest university-industry partnership programs.[19] The bulk of the program funding is invested in seven technology centers. These university-industry consortia were selected through a competitive process, and they are located throughout the state. They focus on Ohio's traditional and emerging strengths in advanced manufacturing, polymers, materials, welding and joining, and biotechnology.

The technology centers must provide at least a 1:1 match of state funds with industry membership fees, research contracts, federal grants, and donated equipment. Each center is unique in its organization and management, but all of the centers are independent, 501(c)(3) nonprofit organizations. A majority of each center's board of trustees must come from the private sector to ensure that industry is driving the center's agenda.

Some centers have in-house research staff who are supported by university professors, while others have a small administrative staff who coordinate and oversee research at member universities, federal laboratories, and companies. Each center provides technical services, research, and networking opportunities for its members. Membership fees are based on company size and range from $100 for a small business to more than $100,000 for a Fortune 100 company. At some of the centers, members can earmark a portion of their membership fees for specific services such as proprietary research.

SPILLOVERS OF KNOWLEDGE

States have experimented with ways to encourage spillovers of knowledge among companies and from universities to the private sector. Much of Silicon Valley's success is attributable not only to the world-class research conducted at Stanford University, but also to the university's policy of encouraging its faculty and students to commercialize their research. In addition to liberal-leave policies, Stanford sometimes provides investment capital for the start-up companies. Due, in part, to state and university policies, few universities are as proactive as Stanford was in the 1950s and 1960s. Some state statutes impede the transfer of technology from academic institutions to industry. Moreover, a university culture that rewards publications rather than interactions with industry is a significant barrier to faculty members who are interested in working with the private sector.

To encourage spillovers of knowledge, states can:

- identify and remove barriers to the commercialization of university-developed technology;
- encourage access to federal laboratories; and
- provide seed funding to industry associations and technology councils.

IDENTIFY AND REMOVE THE BARRIERS TO COMMERCIALIZATION OF UNIVERSITY-DEVELOPED TECHNOLOGY

As a result of the Bayh-Dole Act, which provided universities with the rights to intellectual property resulting from federally funded research projects, universities began setting up technology transfer offices in the 1980s. These offices review invention disclosures, identify technologies with commercial potential, manage the patent process, and license technologies. In 1997 universities responding to the annual survey of the Association of University Technology Managers (AUTM) reported almost $700 million in gross income from licenses.[20]

Despite the growth in licensing, increasing the flow of university technology into the commercial market remains a challenge. State policymakers should review barriers to commercialization, which may result from state law, university policy, or external factors, and develop plans to remove them. Common obstacles include restrictions on the use of university-owned equipment to benefit private companies, requirements on how faculty must spend their time, understaffed and underfunded technology transfer offices, and criteria for tenure that focus on publication rather than commercialization.

Removing the barriers to commercialization must be balanced with other public policy concerns. For example, commercialization can be encouraged by rewarding faculty who spend more time working with companies, but this focus could result in faculty spending less time in the classroom. Moreover, encouraging universities to license more technologies may not necessarily result in those technologies being commercialized in-state, though incentives could be crafted to encourage universities to work with companies located in the state.

Technology transfer "best practice" universities provide incentives for faculty members to support and participate in technology transfer activities. The promise of additional resources to continue their research is one of the best motivators for faculty to pursue commercialization. Several universities, including the University of California, Pennsylvania State University, the University of North Carolina, the University of Virginia, and the University of Wisconsin-Madison, changed their policy on the distribution of patent revenues to provide an additional incentive for faculty members to patent and license their inventions. In addition to changing the distribution of patent revenues, the University of California is reviewing its academic review process to find ways to recognize and reward faculty for receiving patents and licenses.[21]

Another approach to commercialize university research, and one that is receiving more attention, is to form start-up companies. Some universities provide business planning and marketing assistance to faculty wanting to start a company. Others play a more active role by helping identify strategic partners and, in some cases, providing seed capital. In 1997, 101 academic institutions responding to the AUTM survey reported forming 333 new companies.[22] It is becoming increasingly common for universities to take equity positions in companies in addition to receiving royalties and licensing fees.

Centennial Venture Partners is designed to leverage the R&D base of North Carolina State University. A limited liability company, it invests in companies that commercialize technologies developed at the university or that are affiliated with the university.[23]

In November 1998, Oklahoma took steps to reduce the barriers to commercializing university-developed technology. Voters statewide approved two initiatives to promote the commercialization of university research and support university innovation. Under Oklahoma law, public property could only be used for public purposes. One ballot initiative authorized the use of public property for certain projects that involve the research and development of a technology. A state college or university can now let a business use college or university property to work on technology projects, especially those linked to the institution. As a result of the second ballot initiative, state colleges and universities, as well as their employees, may own technology and equity in private businesses. The companies have to make a product or invent a process or other idea with help from the institutions or their employees. No appropriated tax dollars may be used to invest in the business venture.[24]

Encourage Access to Federal Laboratories

Federal laboratories are a critical part of the R&D base, employing one-sixth of the nation's scientists and engineers. The more than 700 facilities located across the nation undertake cutting-edge research in numerous fields. In addition to having a significant economic impact on the communities in which they are located and providing the area labor pool with highly skilled workers, federal laboratories can assist companies in resolving technical problems.

The Wright Technology Network (WTN) was created in 1989 by Ohio and the U.S. Air Force to serve as a bridge between the private sector and Air Force laboratories. WTN facilitates technology transfer by linking federal laboratories, academia, and industry. It specializes in providing access to federal laboratory technology to solve business technical problems. WTN identifies needed expertise, locates sources of improved technology, and makes the link. It also brings potential products to a company's attention and minimizes the red tape involved in dealing with federal laboratories. The depth of research available through federal laboratories is evident in the list of fields in which WTN works, including medicine, automotives, general aviation, environment, construction, education, and law enforcement.[25]

Provide Seed Funding to Industry Associations and Technology Councils

States can encourage spillovers of knowledge among firms by providing start-up funding for industry associations and technology councils. States such as Maryland, Virginia, and Washington have provided start-up funding for industry associations or regional technology councils that provide formal and informal means of networking. These groups offer opportunities for companies to develop business alliances and learn from others' experiences in raising capital, recruiting and retaining employees, and developing new markets. They can also become a potent political force, serving as a voice for the state's technology community and lobbying for actions beneficial to the technology community.

Physical Infrastructure

With advanced telecommunications, companies and people have more flexibility in deciding where to locate. This prospect brings hope to geographically isolated regions that have lagged economically. However, for this potential to be realized, the physical infrastructure, in particular high-speed Internet access, must be in place. States can examine the quality of their physical infrastructure and take steps to improve it through public and private action.

During the past fifteen years, Iowa has invested more than $300 million to create the Iowa Communications Network (ICN), a statewide, state-administered, fiber-optic network.[26] ICN provides full-motion interactive video services, high-speed Internet access, and competitive long-distance telephone rates to the state's educational institutions, hospitals, medical facilities, and government agencies. Today, ICN includes more than 3,000 miles of fiber-optic cable reaching every county in the state. Every citizen resides within fifteen miles of a video site.

The impetus for creating the network was to ensure that all urban and rural regions of the state had equal access to educational resources. This was to be accomplished by providing the highest quality and technologically advanced telecommunications services. Today, ICN is used to provide distance learning, enhance educational opportunities for Iowa students, and deliver telemedicine services to rural residents. State agencies use ICN to conduct public hearings and train workers. The Venture Network of Iowa uses ICN to link entrepreneurs with potential investors.

At least three states—Iowa, Texas, and Virginia—have considered providing excess bandwidth to the private sector. States are able to buy large amounts of service from Internet service providers (ISPs), so they can secure volume discounts and pass them on to state agencies and universities. The three states have considered making those discounts available to the private sector to offer lower cost Internet access, but ISPs have raised objections to the states competing against the private sector.

Communities in Indiana, Iowa, Kentucky, Oregon, and Washington have taken action to develop municipally owned communications systems that offer high-speed Internet access and phone and cable television service. The communities, primarily in rural areas, believe the improved telecommunications system will have a positive economic development impact in retaining and attracting companies while improving the quality of life for their residents. The telephone companies in some of these states assert that such action results in unfair competition with the private sector. The communities counter that they are concerned about the lack of investment the companies are making in rural areas.[27]

TECHNICALLY SKILLED WORKFORCE

One of the most significant problems the private sector faces today is access to an adequate number of technically skilled workers. Recent studies and company anecdotes clearly suggest a significant shortage of workers in key economic sectors, particularly information technology.

More than 300,000 information technology jobs were unfilled in 1998, according to a report by the Information Technology Association of America.[28] The information technology industry is particularly concerned because of the projected growth of the industry and increased demand for jobs. The U.S. Bureau of Labor Statistics projects that an additional 2 million workers will be needed during the next ten years.[29] In addition, the American Electronics Association reports that the number of high-technology degrees awarded by colleges and universities declined 5 percent between 1990 and 1996.

Compounding the difficulty for states in ensuring a technically skilled workforce is the global economy and improved telecommunications system. With worldwide Internet access, work can be farmed out to other countries with qualified workers. For example, automotive companies in Detroit hope to reduce product cycles for new cars to twenty-four months. One way to accomplish this is employing teams of engineers to work on the design in the United States and India. Engineers in Detroit can assign a problem to their team in India. With the time zone difference, the engineers in the Far East can work on the problem and get an answer back to their counterparts in Detroit by the next business day.[30]

A shortage of workers is a new dilemma for most state policymakers, who typically have had to focus on creating jobs rather than filling jobs. Although states have a track record in leveraging their R&D base, they are newcomers to workforce development for that base. However, some states are taking action to address the need for technology workers.

To help ensure a technically skilled workforce, states can:

- encourage more students to enter science and engineering fields;
- develop internship programs for students in science and engineering; and
- provide training for workers in technology-based companies.

Encourage More Students to Enter Science and Engineering Fields

More than fifteen Governors spoke about creating or expanding scholarship programs for college students in their 1999 state-of-the-state addresses.[31] Some of the scholarship programs are specifically directed to ensuring an adequate labor force for the state's R&D base.

Arkansas has a program to encourage more technically trained graduates of its colleges and universities and colleges to remain in the state. The state will forgive up to $2,500 of student loan debt annually for a maximum of four years and $10,000. The graduate must be employed full time in a high-demand technical position in Arkansas to receive the credit. For the current academic year, the fields of advanced manufacturing, computer and information technology, and biomedical and biotechnology are included in the program.[32]

Pennsylvania is using a two-pronged approach. When fully implemented, the state's incentives will provide assistance to approximately 23,000 Pennsylvania students and workers annually at a cost of $49.6 million per year. A SciTech Scholars program provides scholarships of up to $3,000 per year for a maximum of three years to full-time students earning a bachelor's degree in select science and technology fields. Scholarships are available for the second, third, and fourth years of a student's academic program. To qualify for a SciTech scholarship, students must maintain a 3.0 grade point average, complete an internship with a technology-intensive Pennsylvania company, and work in Pennsylvania for one year for each year of scholarship assistance. If the requirements are not met, the scholarship converts to a loan.

A second initiative, tagged a "GI Bill for the New Economy," provides up to $1,000 a year in scholarships for full-time students and current workers pursuing an associate's degree in select science and technology fields at community colleges or two-year private technical institutes. Workers attending school part time are eligible for a scholarship of up to 20 percent of their tuition and fees. Participants must maintain a 3.0 grade point average and complete their associate's degree, or the scholarship converts to a loan.[33]

Develop Internship Programs for Students in Science and Engineering

Increasing the supply of potential workers is one step to address the need for a technically skilled workforce. In Virginia the Governor's Commission on Information Technology points out that even if all the workers could be produced immediately, the worker shortage would not end because employers want experienced workers. "Herein lies the dilemma: the only way to produce a sufficient number of experienced workers is to first hire less experienced workers and have them gain the experience they need on the job. Instead, we heard a whole host of reasons why companies cannot or will not hire newly trained candidates, and the gaps grow larger each day."[34]

To respond to that dilemma, Governor James S. Gilmore III has challenged Virginia's technology companies to hire 5,000 advanced high school and college students through a proposed Virginia Technology Internship Program. The three-year program would include tax incentives to students and businesses in the first two years and to students in the final year.[35]

Provide Training for Workers in Technology-Based Companies

States can also target worker training funds to technology-based companies. Maryland's Partnership for Workforce Quality provides matching funds for companies to upgrade their employees' skills. The program provides grants to reimburse companies for up to half the cost of training for new technologies and processes.

Grants are provided to companies with fewer than 500 employees.[36]

CAPITAL

Capital to support start-up and emerging companies—the types of companies on which the new economy depends—is critical if a region is to build its R&D base. The good news is that the supply of private venture capital in the United States has increased greatly in the 1990s. In 1998 more than $14 billion of venture capital was invested in more than 2,800 companies. The bad news is that venture capital investments are geographically concentrated, with Silicon Valley alone receiving one-third of the investments, so venture capital is not always available in all regions.[37]

In addition, most areas face a shortage of seed capital—typically less than $1 million to $2 million of investments provided in increments of $250,000 to $500,000—and preseed capital—typically investments of $50,000 to $250,000. Traditional institutional venture capitalists are not providing preseed or seed capital. At one time the amount of traditional venture capital invested at the seed stage was tracked; however, several years ago, when the share became less than 2 percent, this category was no longer reported separately.

To encourage greater access to capital sources to invest in the private-sector R&D base, states can:

- use state funds to invest in technology companies;
- use state funds to leverage private funds to invest in technology companies;
- help companies access private and public financing sources; and
- offer R&D tax incentives.

USE STATE FUNDS TO INVEST IN TECHNOLOGY COMPANIES

One of the oldest programs that provides financing to technology companies is the Massachusetts Technology Development Corporation (MTDC).[38] Created in 1978, MTDC, a state-sponsored venture capital company, has a longer track record than many state initiatives. MTDC is a source of early-stage risk capital. Since 1988, it has been entirely self-supporting. The corporation was created to address the capital gap for start-up companies and encourage the growth of early-stage technology firms. Throughout its existence, MTDC has pursued four basic objectives:

- help create jobs in technology-based industries in Massachusetts;
- attract and leverage private investment in Massachusetts companies;
- foster the application of technological innovations where Massachusetts companies are, or can be, leaders; and
- nurture entrepreneurship among Massachusetts citizens.

Initial funding for MTDC came from a $2-million grant awarded by the U.S. Department of Commerce's Economic Development Administration (EDA) in 1979. These funds were used to establish a revolving loan fund for Massachusetts companies with operations that involved a significant amount of technology and were located in an EDA-eligible area. In 1981 EDA awarded an additional $1 million for a second revolving loan fund to help develop small, innovative, high-technology companies in Massachusetts. The commonwealth provided $1 million in matching funds. Each year from 1982 to 1988, Massachusetts appropriated additional funds totaling $4.2 million.

MTDC seeks to make all of its investments on a co-venture basis with private-sector investors, including venture capital firms, banks, limited partnerships, and individual and corporate investors. Investments can range up to $500,000, but typically MTDC provides between $100,000 and $300,000 of an investment of $1 million to $1.5 million. The balance is provided by private co-investors. Investments are made as debt, equity, or a combination of debt and equity. MTDC's staff negotiate the exact terms of the investment with each company.

MTDC focuses on companies seeking small amounts of venture capital in the range of $1 million to $2 million. The size of the total fund of private venture capital firms typically ranges between $200 million and $800 million, so they are not usually interested in making such small investments. MTDC also differs from private venture capital firms because it is more willing to invest in an entrepreneur who has yet to establish a track record.

From 1980 until June 1999, MTDC invested $35 million in eighty-seven companies. Of its original investments, MTDC has exited or begun to exit sixty companies. As of December 1997, the companies in which MTDC had invested reported that they employed more than 8,600 people with an annual average salary of $49,900, generated an annual payroll of more than $431 million, and provided state tax revenue of more than $19.6 million. In addition, MTDC's investments have helped leverage additional private capital. As of June 1998, MTDC's investment of $35 million had leveraged $173.7 million. The firms in which MTDC initially invested raised an additional $265.8 million in subsequent rounds of investment in which MTDC did not participate.

USE STATE FUNDS TO LEVERAGE PRIVATE FUNDS TO INVEST IN TECHNOLOGY COMPANIES

In 1990 the Maryland general assembly passed legislation authorizing the Venture Capital Trust to increase the availability of seed and early-stage venture capital in the state.[39] The program created a state-sponsored but privately managed venture trust that was designed to become a "fund of funds," investing state and city pension funds in diverse venture capital partnerships managed by different venture capital firms.

The trust spent two and one-half years obtaining $19.1 million in commitments from state and city pension systems. In addition to the $2-million initial commitment from the state, the Maryland State Retirement and Pension System invested $15 million. The Employees' Retirement System of the City of Baltimore invested $840,000, and the Fire and Police Employees' Retirement System of the City of Baltimore invested $1.26 million.

The accomplishments of the Maryland Venture Capital Trust can be measured in terms of the economic benefits to the state and financial performance of the funds. By December 1996, the trust had invested $15.8 million in eight partnerships. Public stock offerings and private sales of several companies in four of the partnership portfolios have already returned $3.7 million to the trust, reflecting the trust's partnership interests in those companies. However, the trust's annual report notes that the eight venture capital partnerships have an operating life of eight to ten years, a period during which their investment cycles should be complete and their rate of returns realized. The overall financial performance of the trust can only be measured during a similar number of years.

The trust has succeeded in leveraging its resources. Total investment in the eight venture capital partnerships is $327 million. By the end of 1996, the eight partnerships reported that they had invested approximately $50 million in twenty-nine Maryland companies, more than two and one-half times the trust's initial investment of $19.1 million. Six of the firms have met or exceeded the minimum goal for investing in Maryland companies; the two that have not met their goal are still in the early stages of finding investments. The twenty-nine Maryland companies in which investments have already been made have combined annual sales of more than $600 million and employ more than 2,400 people.

HELP COMPANIES ACCESS PRIVATE AND PUBLIC FINANCING SOURCES

States can use other means to provide access to financing sources in addition to providing funding for direct and indirect investment in the private-sector R&D base.

ACE-*Net*. The Access to Capital Electronic Network (ACE-*Net*) is a national securities offering listing service that enables venture capitalists and accredited institutional and individual investors to find small, growing companies through a secure Internet database. The day-to-day operations are managed by regional network operators that are nonprofit, university- or state-based entrepreneurial development centers.[40]

Venture Capital Conferences. Typically sponsored by states, chambers of commerce, or nonprofit organizations, venture capital conferences or fairs provide entrepreneurs with an opportunity to present their business plans to accredited investors. Investors and entrepreneurs then negotiate investment conditions on a case-by-case basis. The conferences vary from focusing on a community, a state, or multiple states, depending on the level of potential deals available.

Federal R&D Programs. Federal programs such as the Small Business Innovation Research (SBIR) program and the Advanced Technology Program (ATP) are other sources of capital for technology companies. The two programs provide more than $1.2 billion in research funding each year. Forty-eight states have some structured SBIR promotion or assistance effort under way. In fiscal 1998, states spent more than $8 million to promote participation in the federal SBIR program. They held more than 100 workshops, conferences, and seminars reaching thousands of businesses. State service providers estimate that 8,400 individuals and companies received information or assistance in 1998.[41]

OFFER R&D TAX INCENTIVES

Tax incentives are another way to encourage development of the private-sector R&D base. The most recent comprehensive report on state R&D tax incentives found that thirty-five states have some type of tax incentive. Many of these states offer an income tax credit modeled after the federal research and experimentation tax credit. Other types of incentives include sales and use tax credits and property tax credits. Only sixteen of the thirty-five states can provide information on the impact of their tax incentives in terms of the number of companies using the incentives and the resultant tax expenditures.[42] This lack of tracking to assess the impact of R&D tax incentives should concern state policymakers. Moreover, no studies have been done to evaluate the impact of state R&D tax incentives on the private-sector R&D base.

OUTLOOK FOR STATE POLICYMAKERS

Technology industries and the application of technology in traditional industries are changing the fundamental economic structure of the nation. Areas that are prepared to participate in the new technology-based economy will benefit; those that are not will see a widening income gap and declining revenue base. Five elements are critical in this economy: intellectual infrastructure, spillovers of knowledge, physical infrastructure, a technically skilled workforce, and capital.

Some states are taking steps to ensure the availability of these key elements. States that have not yet begun to respond to the changing economic environment should act now to do so. States can use research and development to grow their economies. A strong R&D base attracts and supports technology-intensive companies by providing access to state-of-the-art research, researchers, and research facilities. Using research and development to grow state economies will require states to develop a plan for building the R&D base; recognize that building the R&D base means a long-term, sustained, and significant investment; and hold initiatives accountable.

Develop a Plan for Building the R&D Base

The first step is to develop a clear plan for building the R&D base. The plan should reflect the vision for the state's future, be based on a thorough understanding of the state's economy and R&D assets, and benefit all areas of the state. Developing this plan should be a joint public-private effort designed to obtain a wide range of viewpoints.

Recognize that Building the R&D Base Means a Long-Term, Sustained, and Significant Investment

Silicon Valley, Route 128, and Research Triangle Park are the results of decades of investments, so policymakers should recognize up front that they are charting a course for future generations. Although there will be successes in the short term, there will also be failures. Research and development do not bear fruit overnight, and R&D investment is inherently risky.

Most of the policy options to build the R&D base will require a long-term, sustained, and significant investment by the state. The size of the investment signals to private businesses and universities the state's level of commitment. Some R&D initiatives have failed, in part, because the state, the private sector, or the universities were unwilling to make the necessary commitment.

Hold Initiatives accountable

State policymakers should determine in advance what programs and policies aim to accomplish and how results will be measured. The payoff of research and development is rarely immediate, so ongoing accountability is key. Given the long-term nature of these investments, both interim and long-term performance measures should be developed and implemented.

ENDNOTES

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[4] A consensus definition of "high technology" does not exist. The information is based on a definition offered by the Bureau of Labor Statistics in a June 1999 *Monthly Labor Review* article. Average payroll per employee was calculated through data presented in *County Business Patterns*.
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[13] See, in particular, *Regional Advantage* by Annalee Saxenian, which compares and contrasts Silicon Valley and Route 128; and *America's Clusters: Building Industry Clusters* by DRI/McGraw-Hill, which identifies technology clusters around the nation.
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