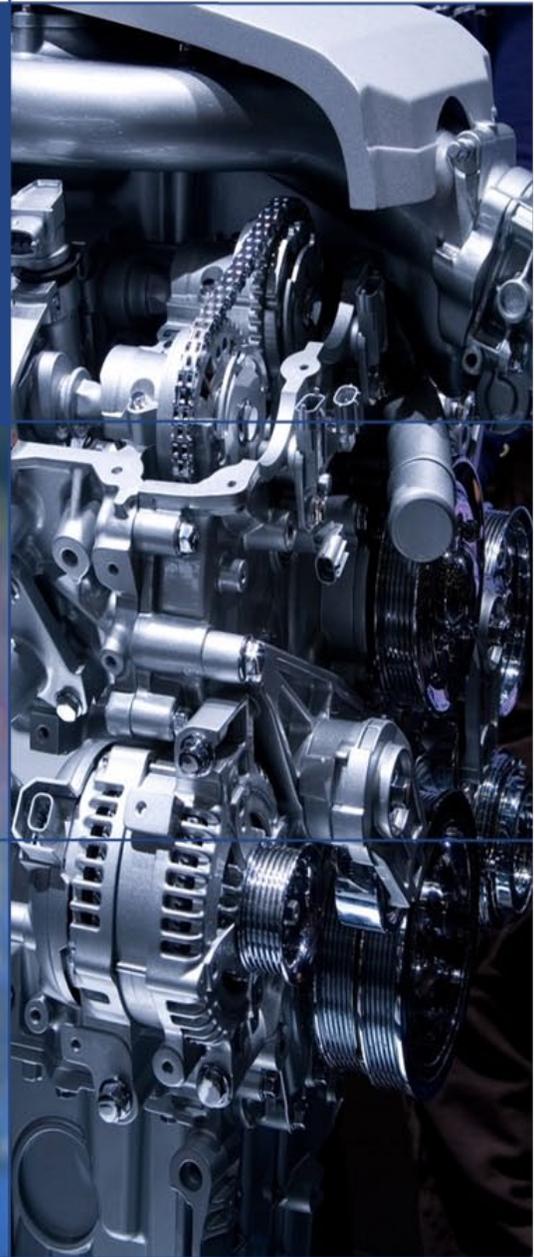


Making an Impact

Assessing the Benefits of Ohio's Investment in
Technology-Based Economic Development Programs:



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Making an Impact:

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

SRI International

September 2009

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Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
INTRODUCTION AND BACKGROUND	14
OBJECTIVE OF STUDY	14
EVOLUTION OF OHIO'S MAJOR TECHNOLOGY-BASED ECONOMIC DEVELOPMENT PROGRAMS	17
ASSESSING THE FOUNDATIONS FOR INNOVATION-BASED GROWTH IN OHIO'S ECONOMY	32
MAJOR STRUCTURAL CHANGES IN OHIO'S ECONOMY AND RECENT HIGH-TECH SECTOR GROWTH	32
ANALYSIS OF OHIO'S RESEARCH & DEVELOPMENT CAPACITY, 1980-2007	40
IMPACTS OF OHIO'S MAJOR TECHNOLOGY-BASED ECONOMIC DEVELOPMENT PROGRAMS	50
GENERATING A POSITIVE RETURN ON THE OHIO THIRD FRONTIER INVESTMENT	50
INCREASING THE AVAILABILITY OF EARLY-STAGE CAPITAL	56
IMPROVING THE ENVIRONMENT FOR TECHNOLOGY ENTREPRENEURS	64
INCREASING R&D CAPACITY AND IMPROVING RESEARCH COLLABORATION	70
CONTRIBUTING TO THE DIVERSIFICATION AND COMPETITIVENESS OF OHIO MANUFACTURERS	76
SUPPORTING THE EMERGENCE OF NEW HIGH-TECH INDUSTRY CLUSTERS	79
CHARTING A COURSE CONSISTENT WITH SUCCESSFUL TECH-BASED GROWTH IN OTHER REGIONS	84
RECRUITING NON-OHIO COMPANIES	89
SUMMARY AND CONCLUSIONS	94
SIGNIFICANT ECONOMIC IMPACTS OF OHIO'S TBED PROGRAMS	94
CREATING AN EFFECTIVE AND INTEGRATED INNOVATION SUPPORT SYSTEM	96
LOOKING TOWARD 2012: DEVELOPING OHIO'S THIRD FRONTIER	98

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

LIST OF FIGURES

FIGURE 1. OHIO TBED PROGRAMS ALONG THE TECHNOLOGY COMMERCIALIZATION CONTINUUM	3
FIGURE 2. OHIO'S INVESTMENT IN THE OHIO THIRD FRONTIER VERSUS A HYPOTHETICAL TAX REBATE: COMPARATIVE INVESTMENTS AND IMPACTS	4
FIGURE 3. OHIO'S EMERGING TECHNOLOGY CLUSTERS AND EMPLOYMENT GROWTH, 2004-2008	9
FIGURE 4. DETERMINANTS OF THE SUPPLY AND DEMAND FOR INNOVATION	12
FIGURE 5. OHIO'S MAJOR TBED PROGRAMS AND THE YEARS FOUNDED	14
FIGURE 6. HIGH-LEVEL LOGIC DIAGRAM FOR OHIO TBED PROGRAMS	15
FIGURE 7. TECHNOLOGY COMMERCIALIZATION FRAMEWORK	19
FIGURE 8. LOCATION OF UNDERLYING VENTURE CAPITAL FUNDS ATTRACTED THROUGH OCF/OVCA	29
FIGURE 9. LOCATION OF OHIO TBED PROGRAMS ALONG TECHNOLOGY COMMERCIALIZATION FRAMEWORK	30
FIGURE 10. SOURCES OF CAPITAL AT DIFFERENT STAGES OF NEW COMPANY DEVELOPMENT	58
FIGURE 11. DETERMINANTS OF THE SUPPLY AND DEMAND FOR INNOVATION	96

LIST OF CHARTS

CHART 1. GROWTH IN OHIO VENTURE CAPITAL INVESTMENT	5
CHART 2. OHIO HIGH-TECH AND NON HIGH-TECH EMPLOYMENT GROWTH	8
CHART 3. COMPARISON OF U.S. AND OHIO MANUFACTURING EMPLOYMENT AS PERCENTAGE OF LABOR FORCE	32
CHART 4. REAL AVERAGE ANNUAL GDP GROWTH IN OHIO AND SELECT STATES	33
CHART 5. COMPOUND ANNUAL GROWTH RATES (CAGR) OF INDUSTRIAL SECTOR EMPLOYMENT	35
CHART 6. OHIO HIGH-TECH AND NON HIGH-TECH EMPLOYMENT GROWTH	37
CHART 7. R&D PERFORMED AS A PERCENT OF GDP FOR OHIO AND BENCHMARK STATES	42
CHART 8. PERCENT OF WORKFORCE IN SCIENCE & ENGINEERING OCCUPATIONS	44
CHART 9. SCIENCE & ENGINEERING DOCTORATES AS A PERCENT OF THE WORKFORCE	44
CHART 10. OHIO'S PATENTING ACTIVITY AND SHARE OF U.S. PATENTING ACTIVITY	46
CHART 11. ANNUAL PRIVATE CAPITAL INVESTMENT-LEVERAGED BY THE OHIO TITC	60
CHART 12. CUMULATIVE PRIVATE CAPITAL INVESTMENT-LEVERAGED BY THE OHIO TITC	61
CHART 13. COMPARISON OF US AND OHIO VENTURE CAPITAL INVESTMENT TRENDS	62
CHART 14. ACADEMIC R&D EXPENDITURES RELATIVE TO SIZE OF ECONOMY IN OHIO AND THE US	71

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

LIST OF TABLES

TABLE 1. OHIO'S MAJOR TBED PROGRAMS _____	2
TABLE 2. OHIO THIRD FRONTIER PROGRAM INVESTMENTS, 2003-2008 _____	20
TABLE 3. GROWTH IN OHIO HIGH-TECH INDUSTRIES EMPLOYMENT, 2004-2008 _____	39
TABLE 4. SOURCE OF OHIO R&D FUNDING, 1999, 2002, 2005 _____	43
TABLE 5. TEN-YEAR CHANGE IN PATENTING ACTIVITY IN THREE TECHNOLOGY FIELDS _____	47
TABLE 6. TECH TRANSFER INDICATORS AT OHIO UNIVERSITIES _____	48
TABLE 7. ECONOMIC IMPACTS OF THE OHIO THIRD FRONTIER INVESTMENTS _____	52
TABLE 8. COMPARISON OF OHIO THIRD FRONTIER IMPACTS WITH HYPOTHETICAL TAX REBATE _____	53
TABLE 9. ECONOMIC IMPACTS OF RESEARCH ACTIVITIES _____	54
TABLE 10. ECONOMIC IMPACTS OF PRODUCT SALES _____	55
TABLE 11. ECONOMIC IMPACTS OF CONSTRUCTION _____	55
TABLE 12. OHIO THIRD FRONTIER ESP AND PRE-SEED FUND SUCCESS STORIES _____	68
TABLE 13. ECONOMIC INDICATORS FOR OHIO'S EMERGING TECHNOLOGY CLUSTERS _____	83
TABLE 14. SOME OF THE MOST WELL-KNOWN U.S. TECHNOLOGY CLUSTERS _____	87
TABLE 15. HOW THE OHIO THIRD FRONTIER AND RELATED INVESTMENTS MATCH UP TO THE ELEMENTS OF THE INNOVATION SYSTEM _____	97

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

EXECUTIVE SUMMARY

STUDY BACKGROUND

In 2002, the State of Ohio launched a \$1.6 billion, 10-year commitment to support technology-based economic development through the creation of the Ohio Third Frontier. Three-quarters of the way through its first 10 years, program data, regional economic data, and anecdotal evidence point to the Ohio Third Frontier's positive short-term impacts and indicate that longer-term structural changes are taking root. In light of the challenging economic environment and difficult fiscal choices ahead, the Ohio Department of Development (ODOD) sought a rigorous, objective, and credible assessment of the impacts of key technology-based economic development (TBED) programs on Ohio's current economy, as well as indicators of future impact. ODOD engaged SRI International and its partner, the Georgia Institute of Technology's Enterprise Innovation Institute, with the guidance of the Ohio Third Frontier Advisory Board and Commission, to address a series of questions:

- What are the tangible economic impacts of the Ohio Third Frontier and related programs on Ohio companies, institutions, and universities?
- Does the return on these programs support their levels of investment?
- Do these programs place Ohio's high-tech industries on a path consistent with successful cluster development and move Ohio toward a higher growth trajectory?

AN OVERVIEW OF TECHNOLOGY-BASED ECONOMIC DEVELOPMENT PROGRAMS IN OHIO

Ohio's thinking about issues related to technology-based economic development and how the state could play a catalytic role in this development dates back to the early 1980s. The state invested in the Thomas Edison Program in 1984, creating the Edison Technology Centers and Edison Incubators. The state's second major endeavor, nearly 20 years later, was to put in place a comprehensive set of programs to support world-class research in industry-aligned platforms, to encourage collaborative research and commercialization activities, and to spur new technology company formation. This ten-year, \$1.6 billion set of programs is known as the Ohio Third Frontier. In addition, the State introduced two programs to increase the availability of early-stage risk capital in Ohio. The first, in 1996, was the Technology Investment Tax Credit program, which provides tax-based incentives for risk capital investments in technology startups. The second, in 2003, was the Ohio Capital Fund overseen by the Ohio Venture Capital Authority. This program was designed to bring more venture capital firms to Ohio and to encourage more venture capital investments in Ohio companies. (See Table 1)

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Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Table 1. Ohio's Major TBED Programs	
OHIO THIRD FRONTIER (2002)	TOTAL AWARDS THRU 2008
Research and Commercialization Collaboration	
Ohio Research Scholars Program creates 26 endowed chairs at Ohio Universities	\$146.5M
Wright Centers of Innovation Program supports university-based Centers of Excellence in target technology platforms ¹	\$295M
Research Commercialization Program provides funds for applied research	\$190.1M
Wright Projects provides grants for capital equipment purchases	\$52.2M
Entrepreneurial Support	
Entrepreneurial Signature Program pairs high-growth-potential technology startups with experienced entrepreneurs, risk capital, network in six regions	\$84.8M
Pre-seed and Seed Funds award grants to pre-seed funds that invest in startups	\$34.8M
Product Development Assistance	
Third Frontier Action Fund awarded grants to pre-seed funds and to companies for applied R&D leading to near-term commercialization	\$18M
Ohio Research Commercialization Grant Program (SBIR III) awards grants to improve viability of technologies developed through Federal R&D projects	\$11.2M
Fuel Cell Program supports applied R&D to help commercialize fuel cell components produced in Ohio	\$39.9M
Advanced Energy Program supports applied R&D to commercialize advanced energy system components produced in Ohio	\$19.9M
Cluster Development	
Ohio Innovation Loan Fund provides subsidized debt financing to established companies to develop next-generation products and services	\$54M committed over program life
Targeted Industry Attraction Grants attract out-of-state companies in target industry sectors to locate new facilities in Ohio	\$3.4M
Workforce Development	
Third Frontier Internship Program places highly-trained students (up to the doctoral level) with Ohio tech-based industries	\$1.5M
Thomas Edison Program (1984)	
Edison Technology Centers (7) support the industrial competitiveness of Ohio companies in key industry verticals by providing access to technology and business expertise	Varies year-to-year; currently \$13M-\$13.5M/year
Edison Technology Incubators (13) assist technology-oriented startups during concept definition and development stages, allowing entrepreneurs to concentrate on development of their core product/service	Varies year-to-year; currently \$4M-\$4.5M/year
The Ohio Capital Fund/Ohio Venture Capital Authority (2003)	
Ohio Capital Fund "Fund of funds" mechanism increases venture capital available for early-stage investment in Ohio companies	\$98.5M (of total \$150M)
Ohio Technology Investment Tax Credit (1996)	
Technology Investment Tax Credit provides tax credit to taxpayers who invest in small, Ohio-based technology companies	\$28.5M (of total \$45M set aside)

Note: ¹The five technology platforms targeted by OTF are: Biosciences; Advanced Materials; Advanced Energy; Instruments, Controls & Electronics (ICE); and Power & Propulsion.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

In conceptualizing the Ohio Third Frontier, the State adopted the following technology commercialization framework to guide its program initiatives and review of related investments (see Figure 1). The framework employs five phases of commercialization characterized by the following forms of “proof” (in parentheses): 1) Imagining (commercial concept), 2) Incubating (business plan), 3) Demonstrating (commercial product and market entry plan), 4) Market Entry (product sales, growth plan), and 5) Growth & Sustainability (profitability). At the transition between each phase and the next is the need to mobilize resources.¹ Collectively, Ohio's four TBED programs support the advancement of entrepreneurs and companies across this technology commercialization continuum.

Figure 1. Ohio TBED Programs Along the Technology Commercialization Continuum



Innovation is important to Ohio's long-term economic growth because new products, services, and production processes provide Ohio companies with opportunities to enter new markets and to gain greater market share. Innovation affords Ohio's economy the opportunity to diversify into higher growth, higher value-added economic activities that can move Ohio to a better growth trajectory. Ultimately, this will generate higher quality jobs and higher incomes for current and future generations of Ohio citizens.

LEVEL OF INVESTMENT AND RETURN ON OHIO'S THIRD FRONTIER

What has been the return on the State's investment in Ohio's Third Frontier? The SRI study found that **the State's expenditures of \$681 million generated \$6.6 billion of economic activity, 41,300 jobs, and \$2.4 billion in employee wages and benefits as a result of the Ohio Third Frontier.** This represents a nearly \$10 return on every dollar of the State's investment.

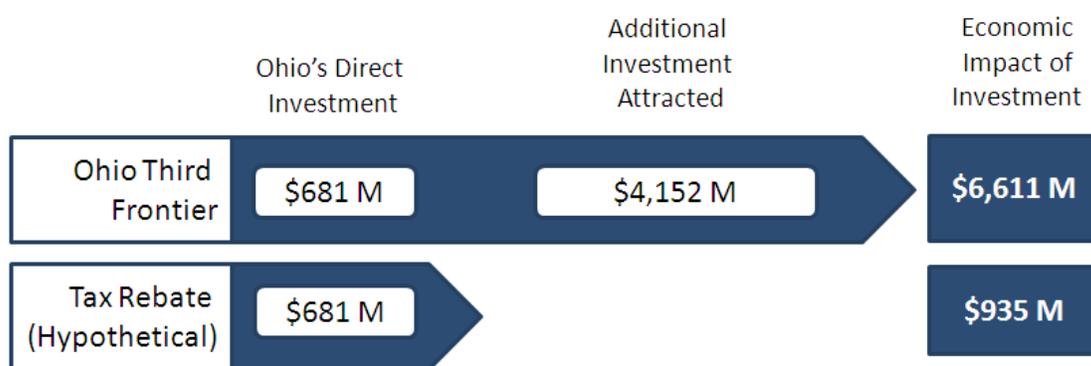
¹ BizLogx (2006). Technology Commercialization Framework. Columbus, OH.
<http://www.as.ysu.edu/~adhunter/RFPs/CommercializationFramework.2006.03.25m.pdf>

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

For comparison, SRI also modeled a hypothetical scenario in which the State of Ohio returned this \$681 million to taxpayers. The estimated impact associated with this tax rebate is significant, \$934.6 million of economic activity, 6,400 jobs, and \$214.2 million in employee wages and benefits. However, the Ohio Third Frontier investments resulted in follow-on Federal and private sector investments and increased R&D activity, products sales, and construction, generating more than seven times the level of economic activity, more than six times the employment growth, and 11 times the wage growth for Ohio's economy compared to that of a hypothetical tax refund.

Figure 2. Ohio's Investment in the Ohio Third Frontier Versus a Hypothetical Tax Rebate: Comparative Investments and Impacts



Source: SRI International

It is important to note that this estimated impact reflects only State expenditures from 2003-2008. Ohio Third Frontier investments in future years are likely to generate much larger impacts for several reasons:

1. A majority of the Ohio Third Frontier funds remain to be spent. Some Ohio Third Frontier funds have not yet been awarded, and some funds awarded have not yet been spent in their entirety. The economic impact of the program is expected to increase significantly over the next five to ten years.
2. The Ohio Third Frontier and related initiatives are generating successful outcomes in spite of the longest U.S. recession in the post-World War II era.² It is likely that new products and processes being commercialized by Ohio companies and new industries which are emerging will be in a position of strength during the next global expansion.
3. Many intermediate impacts of the Ohio Third Frontier, such as new products and services resulting from university research and better linkages among research institutions, industry, and

² According to the National Bureau of Economic Research (NBER), the average post-World War II recession in the United States is 10 months.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

financial institutions, are long term in nature. Although many of these impacts have not had large economic effects yet, they are likely to have much more significant impacts in the long run.

MAJOR ACCOMPLISHMENTS OF OHIO'S TBED PROGRAMS

DRAMATICALLY INCREASING THE AVAILABILITY OF EARLY-STAGE CAPITAL

The Ohio Third Frontier's Pre-Seed Funds and Entrepreneurial Support Program, the Ohio Technology Investment Tax Credit, and the Ohio Capital Fund/Ohio Venture Capital Authority have contributed to a marked expansion in seed and early-stage capital from 2004-2008. This is important, since the availability of early-stage capital is critical to new company formation. According to a study by the Center for Entrepreneurship at Ohio State University, total seed and early-stage venture capital investment in Ohio expanded by 18.5 percent per year between 2004 and 2008 (from \$127.9 million to \$298.3 million). (See Chart 1)

According to the same study, between 2004 and 2008, total venture capital investment in Ohio grew by 13.2 percent per year (from \$243 million to \$445.6 million)—**more than double the annual growth rate of U.S. total venture capital investment** during the same five-year period (5.1 percent per year).

Chart 1. Growth in Ohio Venture Capital Investment, 2003-2008



Source: Fisher College of Business Center for Entrepreneurship, The Ohio State University

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

IMPROVING THE ENVIRONMENT FOR TECHNOLOGY ENTREPRENEURS

Entrepreneurship is a driving force of innovation and economic growth, yet entrepreneurs face significant challenges in transforming commercial opportunity into a viable business. In Ohio, the Ohio Third Frontier's six regional Entrepreneurial Signature Program (ESP) lead organizations and 13 Edison Technology Incubators are key resources for helping translate innovative ideas into investment-worthy companies through business assistance and pre-seed investments in startup companies. These programs report the following results:

- From 2007 to 2008, Ohio's six regional ESP organizations invested \$36 million in direct business assistance and pre-seed capital funding to 81 companies which then resulted in product sales, follow-on investment, and funding totaling \$145 million. Moreover, some ESP regions report significant excess deal flow (e.g., 150 total deals in which they would have liked to have invested if more investment capital had been available).
- For the fiscal year ending 2008, Ohio's 13 Edison Technology Incubators supported 270 startup companies which reported \$262.2 million in product sales, research grant awards (e.g., SBIR, STTR, etc.), and other revenue, and \$120.8 million in equity investments by private investors, venture capital funds, and others.

The number of technology startups supported by quality entrepreneurial assistance programs is important to the state's bottom line. Recent research by the U.S. Small Business Administration indicates that raising the number of small-business startups by 5 percent tended to boost gross state product (GSP) by 0.465 percent, increase a state's employment growth by 0.435 percent, and raise personal income by 0.405 percent. Similarly, small-business deaths detract significantly from state economic growth, employment, and personal income. A 5 percent increase in

CleveX ExiClip Device Poised to Seek FDA Approval

CleveX, Inc., a Columbus-based dermatological medical device company, was able to leverage Ohio's Technology Investment Tax Credit (TITC) to raise a \$1.65 million first round of financing led by the Ohio TechAngels Fund. This pre-seed fund was capitalized with support from the Ohio Third Frontier. The early-stage investment enabled CleveX to complete design and testing, and to seek FDA approval for its ExiClip device. A follow-on \$1.4 million investment enabled CleveX to begin high-volume manufacturing. This investment round was led by Reservoir Venture Partners, a Columbus-based venture capital fund leveraging the Ohio Capital Fund.



Image (above): ExiClip
Photo credit: CleveX

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

startups is equal to roughly 445 new small businesses in Ohio.³ **Therefore, if the Ohio Third Frontier ESP and Edison Incubator programs achieve a net increase of 450-500 technology startups over the next 10 years, they will have contributed one-half of one percent to Ohio's GSP growth.** Ohio's economy grew 1.9 percent from 2007-2008.⁴

IMPROVING R&D COLLABORATION

A key factor in successful technology-based economic development is getting industry, universities, and other research institutions to be aligned in their interests and to collaborate in their actions. A central aspect of the Ohio Third Frontier has been to support university research in areas that are aligned with Ohio's existing and emerging industrial and technological strengths. The Wright Centers, Wright Projects, Research Commercialization Program, and Ohio Research Scholars Program all support university work that is aligned with industry needs.

In addition, the Ohio Third Frontier and Edison Program have supported a variety of "bridging" organizations that build effective collaborations between companies, universities, Federal laboratories, and other research institutions. Such organizations are widely recognized to be critical in economic development. For example, the Edison Center, BioOhio, has brought together bioscience assets in the state to work together effectively. Similarly, the Institute for the Development and Commercialization of Advanced Sensor Technology (IDCAST), an Ohio Third Frontier Wright Center, has helped to connect Ohio sensor technology companies with Ohio universities and laboratories, especially the Air Force Research Laboratory (AFRL), to enable both research collaboration and market development. Other Ohio Third Frontier and Edison supported organizations are doing similar functions in different technologies and regions.

Interviews with stakeholders clearly indicated that the Ohio Third Frontier is improving both the research infrastructure and research collaboration in the state. Universities centers, such as the Liquid Crystal Institute at Kent State University, that in the past licensed their technology to overseas companies, are now collaborating with Ohio companies. Indicators of universities' connection to industry, such as industry funding of university research, university licensing revenues, and the number of university-based startup companies, are all showing positive trends. Although there remains work to be done to improve these linkages, Ohio Third Frontier has significantly strengthened linkages among universities, industry, and research laboratories, especially in the targeted technology areas.

³ Bruce, D., et al (2007). "Small Business and State Growth: An Econometric Investigation." U.S. Small Business Administration Office of Advocacy.

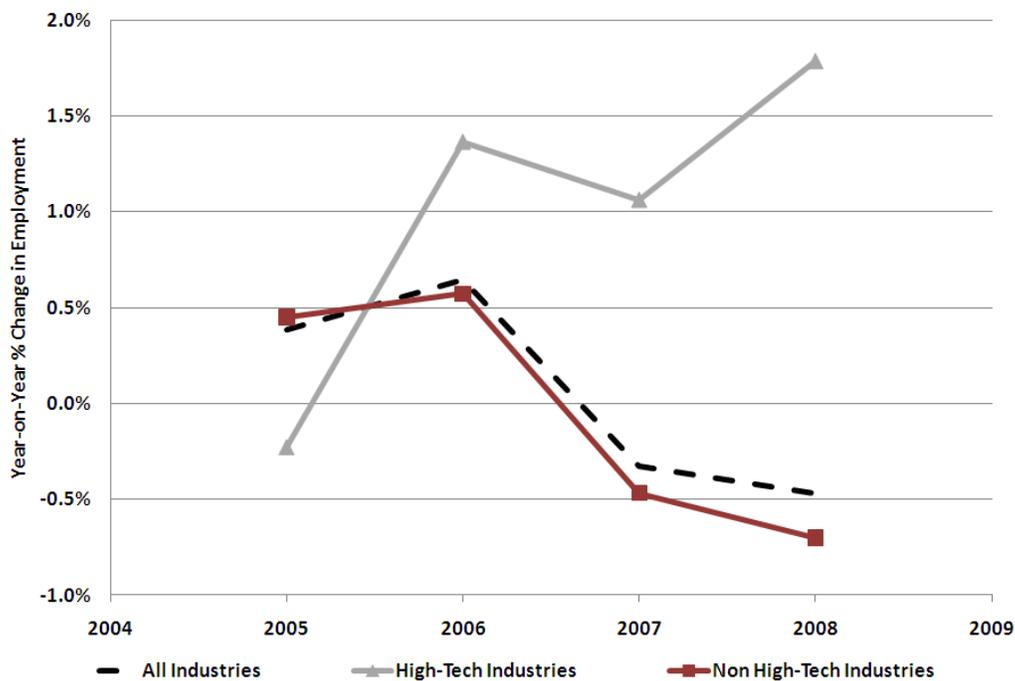
⁴ U.S. Bureau of Economic Analysis. Ohio gross state product (GSP) growth is in current dollars.

Making an Impact

DRIVING EMPLOYMENT GROWTH IN OHIO'S TECHNOLOGY SECTOR

Employment in Ohio's technology sector is growing. A recent study commissioned by NorTech and conducted by the Center for Economic Development at Cleveland State University found that between 2004 and 2008, total employment in Ohio's high-tech industries grew 4.0 percent, adding 19,198 jobs, in spite of the current recession which began in 2007. By contrast, all other industry sectors in Ohio declined by a total 7,247 jobs. In 2008, Ohio's technology sector employed approximately 495,000 people, accounting for 9.5 percent of total employment in Ohio, and mirroring the high tech sector's representation nationally. (See Chart 2)

Chart 2. Ohio High-Tech and Non High-Tech Employment Growth, 2004-2008



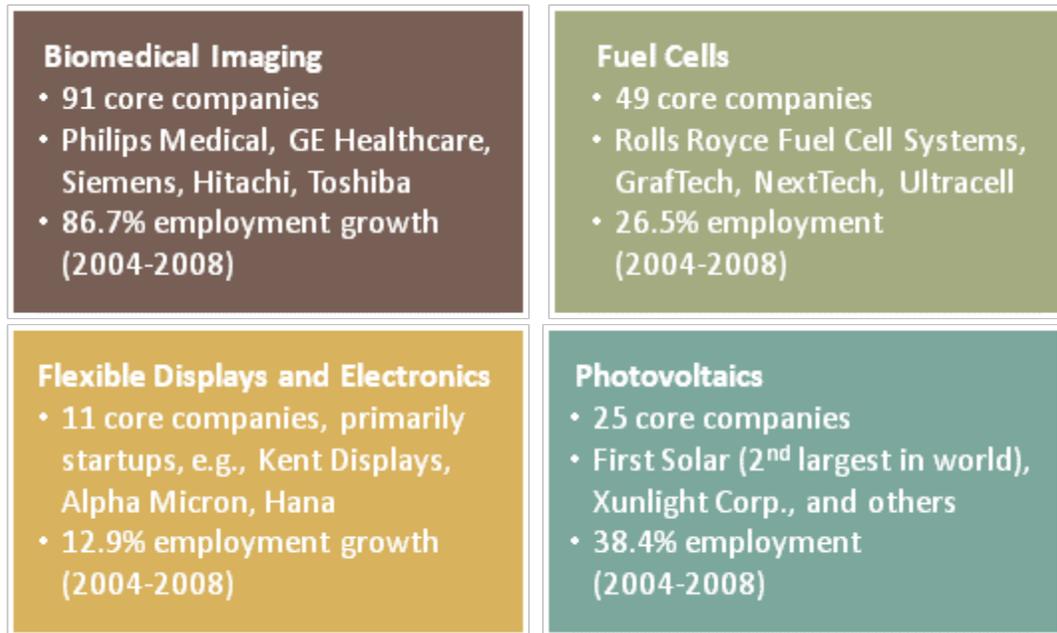
Source: NorTech and the Center for Economic Development at Cleveland State University's Maxine Goodman Levin College of Urban Affairs.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Within Ohio's technology sector, Ohio Third Frontier and related investments are catalyzing the emergence of new technology clusters, fueled by recent and on-going commercialization of new technologies. These emerging clusters include such areas as: Biomedical Imaging and Medical Devices more broadly, Liquid Crystals/Flexible Displays, Fuel Cells, and Photovoltaics. All of these clusters strongly leverage Ohio's existing advanced manufacturing supply chain.

Figure 3. Ohio's Emerging Technology Clusters and Employment Growth, 2004-2008



CONTRIBUTING TO THE DIVERSIFICATION AND COMPETITIVENESS OF OHIO MANUFACTURERS

The Ohio Third Frontier is making direct investments in Ohio companies which are using R&D to retool to stay competitive, as can clearly be seen in the stories of traditional manufacturers like Pilkington, American Trim, and Owens Corning. American Trim, a metal forming and coating company, has won Ohio Third Frontier R&D awards to develop an environmentally-friendly "chrome-like" coating for bumpers and a novel metal forming technology for the manufacture of fuel cell plates. This has enabled American Trim to enter new markets and to compete internationally. Pilkington is using Ohio Third Frontier-supported R&D to shift from the traditional production of glass and glass fibers to new cutting-edge materials for the photovoltaics and wind turbine markets. Pilkington has been a recipient of Ohio Third Frontier investments in Ohio's photovoltaics industry through direct company awards and the services of the Photovoltaics Innovation Center (PVIC) at the University of Toledo, an Ohio Third Frontier Wright Center. Owens Corning was a partner and recipient of an Ohio Third Frontier grant in 2007, along with the Center for Multifunctional Polymer Nanomaterials and Devices (CMPND) at OSU, another Ohio Third Frontier Wright Center, to develop longer, stronger windmill blades using nanotechnology.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The OTF directly funds technology research and commercialization through a competitive proposal process. On a broader scale, Ohio's seven Edison Technology Centers assist a variety of Ohio manufacturers by providing technical assistance, as well as serving as conduits to expertise in Ohio technology companies, universities, and research institutions.

RECRUITING NON-OHIO COMPANIES

There is substantial evidence that Ohio's TBED programs have improved the attractiveness of Ohio as a site for technology-based companies. While many factors are weighed in corporate site selection processes, the presence of strong university-industry research centers, supportive state programs, and emerging technology industry clusters all "shift the needle" toward Ohio in site selection decisions. Interviews with several companies spanning the fuel cell, advanced materials, photovoltaic, and medical imaging industries confirmed that Ohio TBED programs were important factors in their corporate decisions to locate in Ohio.

In 2006, 2007 and 2008, *Site Selection* magazine awarded Ohio the prestigious Governor's Cup for the most new facility locations and expansions. In 2008, Ohio beat out Texas, North Carolina, Illinois and Tennessee to take the top spot, with 503 new projects. Ohio's cities also received recognition. Cincinnati, Columbus and Cleveland ranked in the Top 10 for large metropolitan areas; and Dayton, Akron, Toledo and Youngstown-Warren ranked in the Top 10 for metropolitan areas with populations between 200,000 and 1 million.

CHARTING A COURSE CONSISTENT WITH SUCCESSFUL TECH-BASED GROWTH IN OTHER REGIONS

Stakeholder interviews and case studies indicate that the focus and implementation of the OTF is highly consistent with the best practices adopted in other technology-based clusters. Regions that excel in technology-based clusters today—Silicon Valley in California; Boston/Route 128 area in Massachusetts; the Research Triangle area in North Carolina; and the greater Austin metro area in Texas—share a number of common historical and present-day attributes, including:

Ohio's Advanced Manufacturing Base: Bringing New Products to Market

A few years ago, Texas-based Zyvex Performance Materials (ZPM) lacked the capability to manufacture the nano-enhanced composite materials it had developed. PolymerOhio, an Edison Technology Center, connected the company with an Akron-based manufacturer that could manufacture the products that ZPM developed. "This example demonstrates why we moved here: there is already a strong advanced materials infrastructure in place, and almost our entire supply chain is in Ohio," commented ZPM President Lance Criscuolo. Today, ZPM is headquartered in Columbus, Ohio.



Image: Aldila golf shaft incorporating Zyvex composite materials and used by PGA Tour players.

Photo credit: Zyvex Performance Materials

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

- Pioneering, research-intensive companies and top research universities that produce world-class research outputs, as well as a highly skilled workforce;
- The visionary leadership of regional leaders who aggressively sought State and Federal investments in strategic research, including Federal defense technology research investments in Silicon Valley and Boston; State investments in greenfield research parks and biotechnology in the Research Triangle; and private industry investments to create endowed chairs at the University of Texas;⁵
- Strong networks between the research, finance, and business communities; and
- Strong infrastructure for entrepreneurship in the technology sectors including ample early-stage capital and programs to support technology transfer and startup companies.

Ohio's Third Frontier and related programs represent a comprehensive approach to developing all of these attributes in Ohio.

LOOKING FORWARD TO 2012: DEVELOPING OHIO'S THIRD FRONTIER

Although the economic impacts to date are substantial, the more important effect of the Ohio Third Frontier is likely to be its long-term effects on Ohio's system of supporting innovation. The Ohio Third Frontier and related initiatives have created an effective, integrated system for supporting innovation at all levels and by all actors, including companies, entrepreneurs, universities, research institutions, and Federal labs.

It is now well understood that a region's capacity for innovation depends on an effective system that involves many elements, including R&D, skilled people, financing, market pull, a supportive policy environment, and other elements.⁶ Figure 4 presents one depiction of the elements of an effective innovation system.⁷ The lack of any element can cripple the overall functioning of the system.

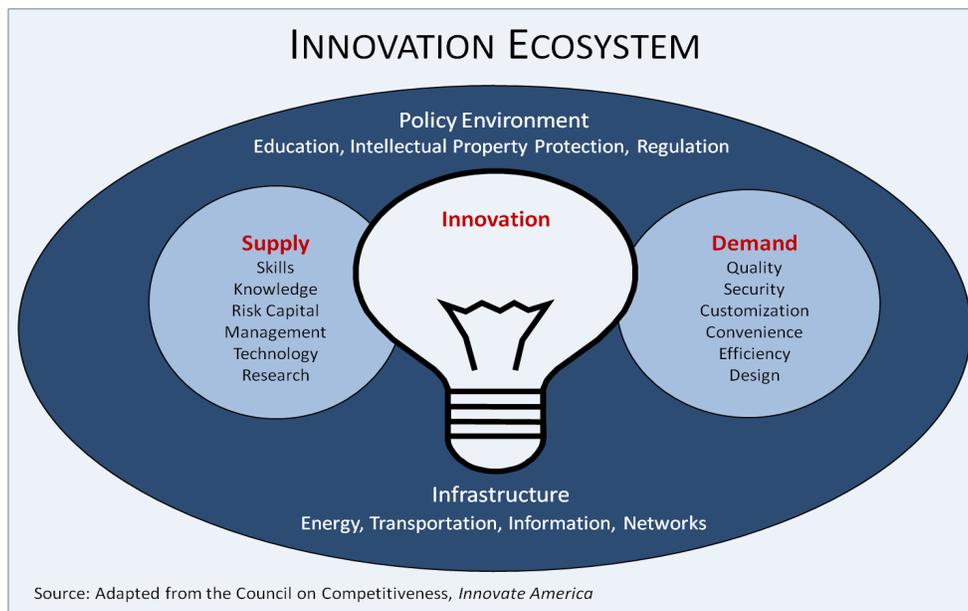
⁵ Since 1984, more than forty \$1 million-endowed chairs have been created at The University of Texas to recruit distinguished faculty and facilitate research in engineering and the natural sciences, with an emphasis on microelectronics, material sciences, physics and computer sciences. This initiative was a significant contributor to the ability of Austin to attract the Microelectronic and Computer Technology Corporation (MCC) and SEMATECH, and it spurred rapid semiconductor and IT-related growth in the regional economy.

⁶ Nelson, Richard R. *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press. 1993.

⁷ Council on Competitiveness. *Innovate America*. National Innovation Initiative Report. Washington. 2004.

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Figure 4. Determinants of the Supply and Demand for Innovation



How have Ohio's investments in the Ohio Third Frontier and related initiatives improved Ohio's innovation support system? The Ohio Third Frontier looked strategically at the key factors which determine innovation capacity and made investments on a scale that could make a difference. Historically, Ohio has had significant research assets and skill sets in its industrial sectors, manufacturing supply chains, universities, Federal labs, and other research institutions. The Ohio Third Frontier has successfully filled in the missing elements of risk capital and entrepreneurial skills, and catalyzed the connections between the various elements in the technology commercialization continuum ensuring that the whole is greater than the sum of its individual parts. The result is a comprehensive system to support the development and commercialization of new technologies that can change Ohio's growth trajectory in the coming decades.

The evidence presented in this report suggests that the Ohio Third Frontier is off to a good start and has a substantial record of accomplishment. As it goes forward, there is a need for both continuity and change. Continuity and consistent effort will be required to grow the businesses and clusters that have been started. The experience of other states and clusters, such as Silicon Valley, Research Triangle Park, or Austin, is that it takes 20 to 30 years for regions to achieve the critical mass that becomes self sustaining. We believe that the Ohio Third Frontier can be enhanced with greater communication efforts, both about the initiative and about Ohio's unique strengths. The Ohio Third Frontier can also be made more cohesive across the different institutions and regions of the state, and may consider expanding its scope to include more creative industries, such as consumer products. With regard to program balance, university programs, entrepreneurial support programs, and company relocation programs are all part of an effective system. SRI believes the university programs should be maintained,

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

but there should be a modest readjustment to place greater emphasis on entrepreneurial support programs and efforts to attract new growing technology companies, especially in Ohio's expanding technology clusters.

As is the case with geographic frontiers, the economic benefits of new technological frontiers come not from the initial exploration but from the subsequent development. This is the case with the Ohio Third Frontier. The initial stages have developed research capacity and partnerships, ideas and intellectual property, and fledgling technology-based companies and industries. Most of the economic benefit, however, will come from the subsequent development and growth of these companies, along with supporting industries. Based on the findings of the analysis laid out in this report, SRI believes that the Ohio Third Frontier has been an effective program. If Ohio's goal is to continue to support the growth and emergence of technology-based industries in the state, SRI believes the continuation of the Ohio Third Frontier is an effective strategy and is well warranted.

Making an Impact

INTRODUCTION AND BACKGROUND

OBJECTIVE OF STUDY

In 2002, the State of Ohio launched a \$1.6 billion, 10-year commitment to supporting technology-based economic development through the creation of the Ohio Third Frontier (OTF). The OTF builds on the state's pioneering predecessor, the Thomas Edison Program, which created the Edison Technology Centers and Edison Technology Incubators. Since the founding of the Edison Program in 1984, Ohio has gone on to establish complementary initiatives for increasing the availability of early-stage financing: a Technology Investment Tax Credit (TITC) in 1996 and a "fund of funds" Ohio Capital Fund/Ohio Venture Capital Authority (OCF/OVCA) in 2003. These are the state's four cornerstone technology-based economic development (TBED) programs.

The OTF is a little over three-quarters through its first 10 years. Program data, regional economic data, and anecdotal evidence point to the OTF's positive short-term impacts and indicate that longer-term structural changes are beginning to take root. Yet, given the challenging economic environment and the difficult fiscal choices ahead, the Ohio Department of Development (ODOD) sought a rigorous, objective, and credible assessment of the impacts of its key TBED programs on Ohio's current economy, as well as indicators of future impact. ODOD engaged SRI International, with the guidance of the Ohio Third Frontier Advisory Board and Commission, to address a series of questions. What tangible economic impacts are the OTF and related programs having on Ohio companies, institutions, and universities? Is the return on these programs supporting their levels of investment? Are these programs placing Ohio's high-tech industries on a path consistent with successful cluster development and best practices in other states?

Figure 5. Ohio's Major TBED Programs and the Years Founded

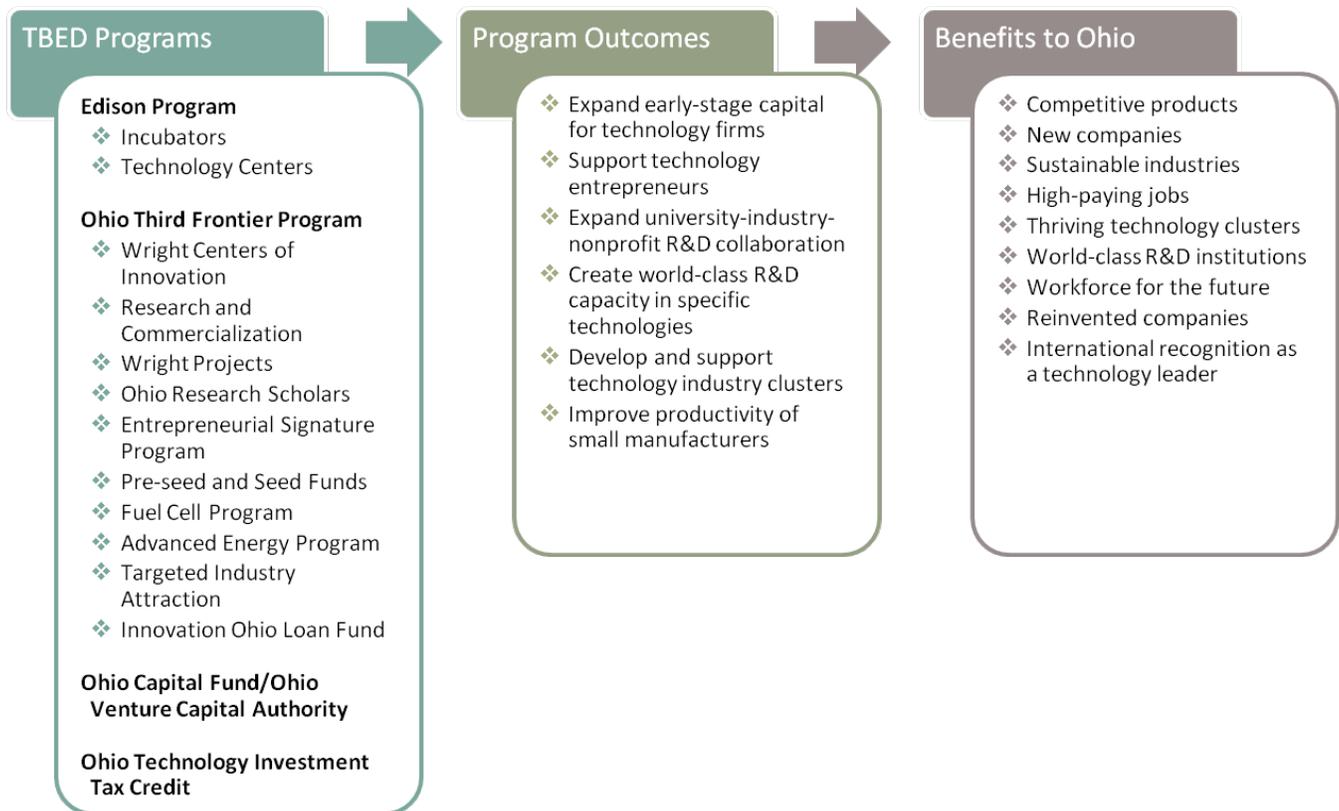


Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

SRI International and its partner, Georgia Tech, brought to bear a variety of evaluation methods, as well as knowledge and experience with state and regional science and technology (S&T) programs throughout the United States and the world. Our overall analytic approach is illustrated in a high-level logic model (see Figure 6) depicting the connections between the programs and their intended outcomes and benefits to Ohio.

Figure 6. High-Level Logic Diagram for Ohio TBED Programs



The SRI team determined what methods and data could be used to measure the program outputs, outcomes, and benefits, and what evidence supports the causal linkages between them. We utilized data from a wide variety of sources, including Ohio TBED program databases, state and national economic and employment data, R&D funding databases, publication and patent databases, and venture capital databases, and also interviewed a large number of program participants, stakeholders, and observers. The impact assessment focuses on the effect of the total set of TBED programs rather than the outputs of each program.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

To focus the analysis on the impact of the total set of TBED programs, the SRI team developed a set of hypotheses to test. These hypotheses are:

1. The OTF has resulted in a positive return on investment for the State of Ohio.
2. Ohio's TBED programs have led to a dramatic increase in early-stage capital for Ohio technology companies.
3. The programs have led to an increased number of technology startups and entrepreneurial activity.
4. The programs have contributed to increased university-industry-Federal-nonprofit R&D collaboration and have enhanced the commercial relevance of this R&D activity.
5. The programs have contributed to the competitiveness of Ohio's traditional manufacturers by supporting product innovation.
6. The programs have catalyzed the emergence of new technology clusters.
7. Ohio's technology clusters are on a path consistent with successful cluster development in other states.
8. The programs have resulted in the recruitment of non-Ohio companies.

We tested each of these hypotheses using the most rigorous evaluation approaches feasible for the circumstances of the TBED programs. In many cases, multiple approaches were used, combining both quantitative and qualitative measures. This combination of methods was important in order to develop not only strong quantitative evidence of investment outcomes, but also qualitative data that allows us to uncover "why" outcomes occur and the factors affecting the production of these outcomes. The SRI team conducted in-depth case studies to examine the impact of programs on emerging technology industry clusters, such as the photovoltaics and biomedical imaging industries in Ohio, as well as the impact of the state's entrepreneurial support programs. In addition, 20 company case studies examine the role programs have played in company successes from across the OTF's six regions and across industrial sectors.

The rest of the report is structured as follows. The subsequent two chapters in Section II present background information about Ohio's four cornerstone TBED programs—their stated objectives, levels of funding, and programmatic changes which have been made over time. We then describe ODOD's move to improve the alignment of these programs to avoid duplication of services and clients, and to avoid gaps in support for entrepreneurs and companies along the innovation continuum.

Section III places these programs in the context of long-term economic and R&D trends in the State of Ohio. We examine Ohio's economic growth and employment trends, and the performance of its high-tech sector in comparison to national trends and trends in peer states. In the second chapter, we analyze trends in Ohio's R&D expenditures, patenting and workforce development.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Section IV presents the evidence resulting from our testing of these hypotheses. Each chapter in Section IV is focused around a particular hypothesis. The data and analytical approaches used are discussed, followed by a presentation of the analysis and key findings. Relevant Ohio examples are pulled in from the industry and company case studies.

Section V discusses SRI's findings of the qualitative and quantitative economic impacts of these TBED programs. We examine the extent to which these programs are creating an effective and integrated innovation support system in the state, and the extent to which the programs are positioning Ohio's target technology clusters for development and growth.

EVOLUTION OF OHIO'S MAJOR TECHNOLOGY-BASED ECONOMIC DEVELOPMENT PROGRAMS

Ohio's thinking about issues related to technology-based economic development and how the state could play a catalytic role in this development dates back to the early 1980s. The state invested in the Thomas Edison Program in 1984, creating the Edison Technology Centers and Edison Incubators. The state's second major endeavor, nearly 20 years later, was to put in place a comprehensive set of programs for supporting research excellence, collaborative R&D, technology commercialization, and new technology startups. This ten-year, \$1.6 billion set of programs is known as the OTF. In addition, the State introduced two programs to increase the availability of early-stage risk capital in Ohio. The first, in 1996, was the Technology Investment Tax Credit program, which provides tax-based incentives for risk capital investments in technology startups. The second, in 2003, was the Ohio Capital Fund overseen by the Ohio Venture Capital Authority. This program was designed to bring more venture capital firms to Ohio and to encourage more venture capital investments in Ohio companies.

This chapter lays out the overall objectives, levels of funding, and evolution of these programs to date. A greater emphasis is placed on describing The OTF for the following reasons: (1) it represents the state's largest TBED program and most significant investment to date—\$160 million per year (on average) compared to the current \$17 million per year for the Edison Programs; (2) it reflects best practices learned over 20 years of tech-based economic development experience; and (3) it is influencing the future direction of the Edison Program and other state TBED programs.

OHIO THIRD FRONTIER

The OTF was launched in 2002 with the goal of expanding Ohio's technology-based research capabilities and promoting innovation and new company formation to create and retain high-wage jobs for future generations. It is the state's largest-ever investment in a technology-based economic development program.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The OTF has the following core principles, which are reflected in program award criteria:

- **Competitive advantage:** The state should fund projects in competitive niches which build upon Ohio's existing research and industrial strengths and which take advantage of global markets and opportunities.
- **Merit:** The merit of projects should be obvious to objective and knowledgeable third-parties. The National Academies and other third parties review proposals and make award recommendations based upon merit with respect to program criteria.⁸
- **Collaboration:** All programs require collaboration between the State and awardees as evidenced by mandatory cost sharing and matching by awardees. This is an attempt to ensure that the state only invests its own funds in projects in which a company or organization is also willing to be an equal investor. Further, all programs require collaborations between the grantee and other Ohio companies and universities that help build the supply chains and research capacity within Ohio.
- **Leverage for sustainability:** When the state plays a catalytic role in funding high-risk, but high-potential projects, it is expected that sustainability will be achieved through the accrual of additional financial resources to those projects. Along with Federal funding, leverage representing various private sources of support that provide market validation of projects is considered a critical success factor. Included in this latter category are industry sponsored research, license income, co- and follow-on equity investment, and sales.

In conceptualizing the program, the State of Ohio adopted the following technology commercialization framework to serve as a guide for its program initiatives and review of related investments (see Figure 7). The framework employs five phases of commercialization characterized by the following forms of "proof" (in parentheses): (1) Imagining (commercial concept), (2) Incubating (business plan), (3) Demonstrating (commercial product and market entry plan), (4) Market Entry (product sales, growth plan), and (5) Growth & Sustainability (profitability). At the transition between each phase and the next is the need to mobilize resources.⁹

⁸ Taratec, a technical consulting firm, has reviewed smaller technology proposals, and BixLogx has reviewed proposals related to high-risk capital and entrepreneurial services.

⁹ BizLogx (2006). Technology Commercialization Framework. Columbus, OH.
<http://www.as.ysu.edu/~adhunter/RFPs/CommercializationFramework.2006.03.25m.pdf>

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Figure 7. Technology Commercialization Framework¹⁰



The OTF is directed toward the “Imagining” through “Demonstrating” phases of technology commercialization. Accordingly, the full set of OTF programs is intended to support the following types of objectives:

- Improving research and commercialization collaboration across industry-university-nonprofits-Federal labs,
- Providing product commercialization assistance to new and existing firms, and
- Increasing entrepreneurial assistance and catalyzing early-stage, high-risk capital investments in technology companies.

The OTF’s current programs, their descriptions, and cumulative levels of funding from 2003 through 2008 are presented in Table 2 below. The programs are organized by the over-arching objectives specified above. Through December 2008, the OTF had made awards totaling \$897.7 million, or a little over half of the \$1.6 billion total project funding through 2012. Not included in this total are the \$54 million in funds committed through the Innovation Ohio Loan Fund which is financed through bond issues backed by liquor sale profits and loan repayments.

¹⁰ Adapted from Jolly, Vijay K. (1997). *Commercializing New Technologies: Getting from Mind to Market*. Harvard Business Press.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Table 2. Ohio Third Frontier Program Investments, 2003-2008

OBJECTIVE	PROGRAM	DESCRIPTION	TOTAL STATE AWARDS THRU 2008
Improving Research and Commercialization Collaboration	Wright Centers of Innovation and Wright MegaCenter	Creates university-based Centers of Excellence in target technology platforms ¹ with relevance to regional industry clusters	\$295.4M (\$147.3M in biomedical; \$148.1M in engineering and physical sciences)
	Research Commercialization Program	Funds applied research in scientific and technology platforms with excellent commercialization potential; commercialization requirement increasingly stringent over time	\$190.1M (\$128.4M in biomedical; \$61.7M in engineering and physical sciences)
	Ohio Research Scholars Program	Creation of 26 endowed chairs at Ohio universities aligned with target technology platforms	\$146.5M
	Wright Projects	Awards for capital equipment purchases to advance research in technologies with commercial relevance and build collaborations between Ohio firms and universities	\$52.2M
Entrepreneurial Support	Entrepreneurial Signature Program	Pairs high-growth-potential technology startups with experienced entrepreneurs, risk capital, network	\$84.8M
	Pre-seed Funds	Awards to pre-seed funds which in turn invest in technology startups	\$34.8M
Product Development Assistance	Fuel Cell Program	Supports applied R&D that addresses technical and cost barriers to fuel cell commercialization and adaptation of fuel cell components produced in Ohio	\$39.9M
	Advanced Energy Program	Supports applied R&D that addresses technical and cost barriers to commercialization and adaptation of advanced energy system components	\$19.9M

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Table 2. Ohio Third Frontier Program Investments, 2003-2008			
OBJECTIVE	PROGRAM	DESCRIPTION	TOTAL STATE AWARDS THRU 2008
		produced in Ohio	
	Ohio Third Frontier Action Fund (formerly Technology Action Fund)	An early program in the history of the OTF; supported pre-seed funds and applied R&D leading to near-term commercialization	\$18.0M
	Ohio Research Commercialization Grant Program (SBIR III)	Awards to improve the commercial viability of technologies developed through federal Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR) and Advanced Technology Program (ATP) R&D projects.	\$11.2M
Cluster Development	Targeted Industry Attraction Grant Program	Provides an incentive for out-of-state companies in target industry sectors to locate new technology facilities in Ohio consistent with Ohio Third Frontier technology platforms	\$3.4M
Loans for Next-Generation Product Development	Innovation Ohio Loan Fund	Provides subsidized debt financing to established companies for development of next-generation products and services in targeted industry sectors	\$54M
Workforce Development	Ohio Third Frontier Internship Program	Positions Ohio to develop and retain tech-based industries that require skilled workers by placing Ohio science, engineering, technology & mathematics (STEM) students (up to doctoral level) with Ohio companies.	\$1.5M

Note: ¹The OTF targets the following five technology platforms: (1) Advanced and Alternative Energy; (2) Biomedicine; (3) Advanced Materials; (4) Instruments, Controls & Electronics (ICE); and (5) Advanced Propulsion.

Of the total funds awarded from 2003-2008, over three-quarters (76.2 percent) went to improving university-industry-nonprofit research collaboration and creating world-class R&D capacity in target

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

technology platforms¹¹ relevant to Ohio industry. Approximately 13.3 percent of awarded funds went to supporting technology entrepreneurs through investments in formal support programs, as well as investments in pre-seed funds. Close to 10 percent of awarded funds went to product development assistance—providing support to new or existing companies trying to commercialize products based on new technologies. Less than one percent of award funds during this period went toward incentives to attract out-of-state companies in target industry sectors and toward supporting the placement of science, engineering, technology and mathematics (STEM) students with Ohio technology-based companies.

The high percentage of funds going to university-based research and commercialization programs reflects the original sources of OTF funding and the requirements associated with each type of funding. Indeed, the OTF has been driven by four key forces: (1) funding sources, (2) policy directives, (3) success in building the commercialization continuum pipeline, and (4) learning and integration of best practices.¹² Each of these forces and their impacts on the OTF are discussed below.

The OTF began as a \$1.1 billion program with original funding coming from:

- The Wright Capital Fund, which provided money for capital equipment and other research infrastructure (e.g., construction for new labs, buildings, etc.) and required that capital purchases be housed in educational institutions or at not-for-profit organizations that had joint-use agreements with educational institutions. No money for operating expenses was available from this fund.
- The Biomedical Research and Technology Transfer Trust Fund, which resulted from Ohio's tobacco settlement payments. It became the source of the majority of operating dollars and was restricted to use for biosciences projects.
- The Technology Action Fund, which represented general revenue funding, and could be used to support R&D activities of awardees.

With the passage of a \$500 million bond issue on the November 2005 ballot, the OTF was infused with a significant source of operating funds that had no programmatic restrictions on their use. The funds were used to balance the deployment of operating and capital dollars, balance support for engineering and the physical sciences with the biosciences, and increase support for entrepreneurs through formal assistance programs and pre-seed risk capital formation.

¹¹ The five technology platforms targeted by the TF are: (1) Biosciences, (2) Advanced Materials, (3) Advanced Energy, (4) Instruments, Controls & Electronics (ICE), and (5) Power & Propulsion.

¹² Norm Chagnon, "Evolution of the Third Frontier Strategic Direction," Presentation at the Third Frontier Commission and Advisory Board Joint Meeting, February 25, 2009.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

As mentioned earlier, the OTF's adoption of a Technology Commercialization Framework provided a conceptual framework for conveying the OTF's strategy, programs, and performance tracking. The strategy was driven by an understanding of critical gaps in the technology commercialization continuum which were stifling innovation and technology-based startup activity in Ohio. The design of programs and the evaluation of performance were defined by positioning within the framework. So, for example, success in the Incubating phase might be gauged by a company's ability to attract a \$1 million seed round of financing, while success in the Demonstrating phase might be evaluated by early market sales with key customers.

Early successes in supporting the creation of new technology companies and bringing technology-based products to market were the third influence on the evolution of the OTF. As new technology-based industry clusters developed and as existing Ohio companies moved to manufacture new tech-based products, the need arose to look further down the pipeline and to balance programming across the framework. The broader perspective generated by these early successes gave rise to The OTF Internship Program and the Targeted Industry Attraction Grant. It also highlighted a need to better integrate the OTF with other TBED initiatives.

A final influence was the learning-by-doing from OTF implementation and the integration of feedback and lessons learned into the programs. The OTF Commission, Advisory Board, and staff discussed a number of lessons learned at a February 2009 OTF meeting:

- The articulation of a viable commercialization plan and demonstration of industry collaboration are as important as the scientific and technical merit of proposals in generating desired economic development outcomes;
- In examining OTF project outcomes, the highly successful projects had some key attributes including:
 - Specific focus
 - Product orientation
 - Major commercial partner
 - World-class recognition
 - Leverage of Ohio supply chain
 - Sustainable competitive advantage
 - Strong leadership within lead organizations and collaborators
- New technology company formation and growth requires the support of both investment capital and business assistance services;
- The concentration of awards in technology sub-categories may suggest directions for greater investment focus and cluster development;

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

- Individual award decisions can be made stronger by considering the context of projects including past performance, fit with previous investments, and other relevant business intelligence; and
- Lastly, retaining program flexibility is critical on a year-to-year basis, and must be balanced with the need to maintain a strong long-term strategic vision. Examples of OTF programmatic changes include:
 - The scaling down of some programs to increase accessibility, e.g., the size of the OTF's average Research Commercialization Program grant changed from \$5-\$8 million to \$2-\$5 million to enable more companies to bid;
 - The scaling up of some programs, such as the Entrepreneurial Signature Program to address big challenges;
 - A pilot approach to test new program concepts, such as the OTF Product Development Program; and
 - The implementation of success funding to accelerate winners, e.g., the Success and Pre-Seed Fund Initiative

As the OTF approaches the end of its first 10-year period, the OTF Commission, the OTF Advisory Board and the ODOD are assessing possibilities for future strategic direction. Based on discussions at the OTF meetings held throughout 2008 and 2009, it is clear that the severity of the current recession, the need for better alignment of Ohio's many TBED programs and stakeholder feedback regarding the OTF's strengths and weaknesses are driving programming ideas for the next generation of the OTF.

EDISON PROGRAM

Ohio's first major foray into technology-based economic development was through the launch of the Thomas Edison Program. The Edison Program was conceived in response to a national economic recession (1981-82) and major manufacturing sector job losses, in part reflecting increased international competition in manufacturing, especially from Japan, South Korea, Taiwan and Singapore. Ohio's unemployment rate peaked at 13.8 percent in January 1983.

The State of Ohio created the Edison Program in 1984 to promote technological innovation within Ohio's existing industrial base through greater university-industry-Federal collaboration and to support new technology company formation through the creation of business incubators. The Edison Program's two major initiatives—the Edison Technology Centers and the Edison Technology Incubators—were the first of their kind in the United States, along with the Ben Franklin Partnership in Pennsylvania, New York's Centers for Advanced Technology program, and the programs coordinated by New Jersey's Commission on Science and Technology. The Ohio Edison Program became an early model for technology-based economic development.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Edison Technology Centers

The Edison Technology Centers support the industrial competitiveness of Ohio companies in key industry verticals (group of related industries in a value chain, e.g., the automotive supply chain) by providing access to critical technology expertise and networks. The seven centers, located throughout the state, provide a variety of product and process innovation services and commercialization services to Ohio companies. Each of the seven centers is focused on industrial strengths and needs, and offers specific technical capabilities and areas of expertise. The technology focus of the centers has changed over time with changing demand by Ohio industry.

In the first round of funding for the centers in the mid- to late-1980s, six centers were funded. Over time, there has been an ebb and flow of centers, as some centers were eliminated from the program, new centers were added, and existing ones have changed their names and focus. In the early 1990s, there were as many as nine centers, while today there are seven:

- BioOhio in Columbus (formerly known as the Edison BioTechnology Center, or EBTC)
- Center for Innovative Food Technology (CIFT) in Toledo (formerly known as the Edison Industrial Systems Center, or EISC)
- Edison Materials Technology Center (EMTEC) in Dayton
- Edison Welding Institute (EWI) in Columbus
- Manufacturing Advocacy and Growth Network (MAGNET) in Cleveland (formerly known as the Cleveland Advanced Manufacturing Program, or CAMP)
- PolymerOhio in Columbus
- TechSolve in Cincinnati (formerly known as the Institute of Advanced Manufacturing Sciences, or IAMS)

The Edison Technology Centers receive funding from the State of Ohio, Federal government agencies, and industry. Given the different missions of the centers, each receives varying degrees of funding from the state. State annual operating support for the Edison Program ranges from less than 10 percent to 50 percent of each Center's annual budgets. On average, each center receives just under \$1 million to \$1.75 million in Edison funding. In addition, the State of Ohio oversees the Ohio Manufacturing Extension Partnership (OHMEP) Program in partnership with the National Institute of Standards and Technology's Manufacturing Extension Partnership (NIST MEP) Program. As such, approximately \$5 million of Federal funding is provided to Edison Technology Centers to help expand Ohio's manufacturing economy. The OHMEP Program provides companies with services and access to public and private resources that help them identify opportunities for technology adoption, diversification, and growth.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

It is important to note that total state funding for the Edison Program has been in a long-term decline, down from \$30 million annually in the 1980s to under \$18 million annually in recent years.

Over the past 25 years, the Edison Technology Centers have changed and evolved in response to the needs of Ohio industry, changes in organizational leadership, and changes in state funding levels and new funding opportunities. The Ohio Department of Development is currently examining ways to improve the structure of the program to ensure it meets Ohio's economic development and competitiveness needs and strategy for the next ten years. More of this discussion follows in the "Alignment of TBED Programs" section at the end of this chapter.

Edison Technology Incubators

The Edison Technology Incubator Program was established in the mid-1980s, shortly after the Edison Technology Centers, to assist technology-oriented startup companies during their concept definition and business development stages. The incubators connect early-stage companies to business assistance, mentoring, investment capital and physical space.

The program started with four incubators and has since grown to 13 incubators and affiliates. Some of the later Edison Technology Incubators were founded by other organizations and received state support through the Edison Program upon recognition of their successful track records. For example, Cleveland-based BioEnterprise's founders and partners are The Cleveland Clinic, University Hospitals, Case Western Reserve University, Summa Health System and the BioInnovation Institute in Akron. Similarly, Ohio University founded The Innovation Center. The 13 incubators and affiliates comprising the Edison Technology Incubator Program today are:

- The Akron Global Business Accelerator in Akron (formerly the Akron Industrial Incubator)
- BioEnterprise in Cleveland
- BIOSTART LifeScience, Catalyst & Community in Cincinnati
- Braintree Center for Business Innovation in Mansfield
- The Entrepreneurs Center in Dayton
- Great Lakes Innovation and Development Enterprise (GLIDE) in Lorain
- Hamilton County Business Center (HCBC) in Cincinnati
- The Innovation Center, Ohio University's Business Incubator in Athens
- JumpStart in Cleveland
- MAGNET Innovation Center in Cleveland
- LAUNCH, the Regional Growth Partnership's Incubator in Toledo
- TechColumbus in Columbus (formerly the Business Technology Center)
- Youngstown Business Incubator in Youngstown

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

To a greater or lesser extent, the Edison Incubators have tailored their services to support clients emerging from regional technology and industrial strengths. For example, the Akron Global Business Accelerator works predominantly with manufacturing-oriented firms, while the Youngstown Business Incubator targets emerging information technology (IT) companies. All Edison Incubators assist technology-oriented startups during their concept definition and development stages, allowing entrepreneurs to concentrate their limited resources on the development of their core product/service. Client companies receive business assistance from the incubators' professional management teams, mentoring and access to capital and industry networks. Most incubators provide physical space, but two are "virtual," providing only business support services.¹³

Edison Technology Incubators look for companies with strong growth potential, but they do not require client companies to own intellectual property—the OTF's Entrepreneurial Signature Program (ESP) does require this of client companies. While each of the Edison Technology Incubators is differentiated by a standalone mission, all of the Edison Incubators are service collaborators within the OTF's regional ESP networks.

Funding for the Edison Technology Incubators comes from industry and the local, state, and Federal government. Annual operating support from the Edison Program for the incubators ranges from \$200,000 to \$500,000 per incubator for a total annual investment of \$4 million.

OHIO TECHNOLOGY INVESTMENT TAX CREDIT

The state created the Ohio Technology Investment Tax Credit (TITC) in 1996 to stimulate early-stage investments in Ohio technology-based startups by individuals and companies. The amount of the tax credit equals 25 percent (or 30 percent¹⁴ in some limited cases) of the amount invested by the taxpayer, with a maximum tax credit of \$62,500 per individual investor which translates into a maximum investment of \$250,000 in qualified companies by an individual investor. There is a limit of \$1.5 million on the amount that may be invested in a qualified company by multiple investors totaling \$375,000 in tax credits. Qualifying companies are small, Ohio-based research and development (R&D) and technology companies with annual revenues of less than \$2.5 million or a net book value of less than \$2.5 million in the last fiscal year. The State has authorized \$30 million of tax credits for the program. Tax credits may be claimed against personal income tax, corporate franchise tax, public utility excise tax, or the dealers in intangible taxes.

¹³ These two virtual incubators are—LAUNCH, a program of the Regional Growth Partnership in Toledo, and JumpStart in Cleveland.

¹⁴ Investors in Encouraging Diversity Growth and Equity (EDGE)-qualified companies and "distressed county"-qualified companies receive a 30 percent credit on their investment, up to \$90,000 for individuals making an investment of up to \$300,000.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The application procedure involves a three-step process. First, a new technology company must submit an application with a TITC Edison Center or Edison Incubator¹⁵. The application must be approved by the TITC Committee. After the initial year, companies may apply for requalification. Second, prospective investors also submit an application to a TITC Edison Center or Edison Incubator to qualify for the program. In the third step, the company and investor must submit a Tax Credit Certificate Request Form, along with the required investment documentation, to the ODOD in order to receive a tax credit certificate. The investor then submits the Ohio Tax Credit Certificate along with his/her/its Ohio tax return to utilize the credit. The tax credit must be used against current tax liabilities each year, but can be carried forward for up to 15 years.

The TITC is quickly approaching its ceiling. As of December 2008, \$28.5 million in tax credits had been approved, of which \$26.1 million in tax credits had been issued for eligible investments in small, Ohio technology companies. From the program inception in 1996 through 2008, private investors had invested approximately \$109.8 million in 422 qualified Ohio technology companies. More analysis of the impact of the TITC and other programs on the availability of early-stage risk capital for Ohio companies follows in Section IV of this report.

THE OHIO CAPITAL FUND/OHIO VENTURE CAPITAL AUTHORITY

Enacted by the Ohio legislature in 2003, the Ohio Capital Fund is a “fund of funds”¹⁶ established to increase the availability of venture capital for Ohio technology companies. The Fund invests in private venture capital funds which, in turn, look to invest in Ohio-based seed or early-stage technology companies. The Fund's activities are governed by an Investment Policy devised by the Ohio Venture Capital Authority (OVCA) and managed by Buckeye Venture Partners.¹⁷

According to the Fund's investment criteria, at least 75 percent of the Fund's commitments are required to be made in Ohio-based venture capital funds. At least 50 percent of the capital invested by the Fund in each underlying venture capital fund, Ohio-based or not, must be invested in one or more Ohio companies. The maximum amount the Fund can invest in a single underlying fund is \$10 million, and actual OCF/OVCA investments, through December 31, 2008, ranged from \$2 million to \$10 million per venture capital fund.

¹⁵ The TITC Edison Centers are BioOhio, the Center for Innovative Food Technology (CIFT), the Edison Materials Technology Center (EMTEC), the Manufacturing Advocacy & Growth Network (MAGNET), and TechSolve. The TITC Edison Incubators are the Akron Global Business Incubator, BioEnterprise, BIOSSTART, Braintree Center for Business Innovation, Hamilton County Business Center, Innovation Center at Ohio University, the Regional Growth Partnership, and the Youngstown Business Incubator.

¹⁶ A "fund of funds" (FoF) is an investment fund that uses an investment strategy of holding a portfolio of other investment funds rather than investing directly.

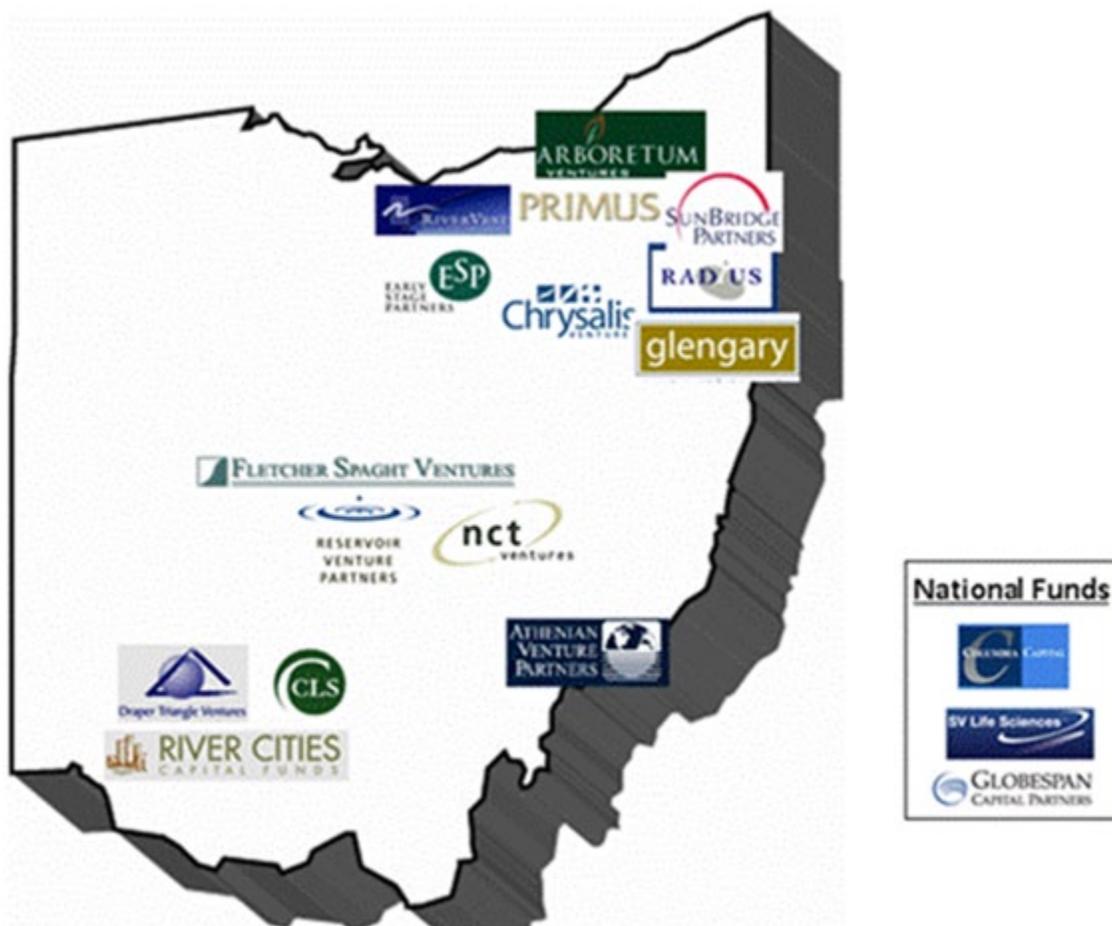
¹⁷ Buckeye Venture Partners is a joint venture between the private equity division of Cincinnati-based Fort Washington Investment Advisors, Inc., and Peppertree Partners, LLC, of Cleveland.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The OCF/OVCA is capitalized with \$150 million. The Fund issues bonds backed by tax credits to fund its investments and expenses. Fifth Third Bank is the agent bank which raises financing for the Fund. Through December 31, 2008, the Fund had made investment commitments totaling \$98.5 million in 18 venture capital funds.¹⁸ Approximately 89 percent of the Fund's commitments were to 15 Ohio-based venture capital funds and 11 percent were to three national venture capital funds. This exceeds the Fund's requirement of at least 75 percent of the Fund's investments going to Ohio-based venture capital funds. However, the Fund's March 2009 quarterly letter indicated active diligence on multiple national venture capital funds, and a closing on one or more of these funds would increase the weighting of non-Ohio funds.¹⁹

Figure 8. Location of Underlying Venture Capital Funds Attracted through OCF/OVCA, 2003-2008



Source: OCF/OVCA

¹⁸ It should be noted that although the Ohio Capital Fund was enacted in 2003, the Fund's first investment was not until December 2005. This lag is due to the time required to organize the Ohio Venture Capital Authority, develop the Fund's Investment Policy, select a company to manage the Fund, and screen and select the first underlying funds for investment.

¹⁹ Buckeye Venture Partners (February 2008). *Report to the Ohio Capital Fund*, Quarter Ended December 31, 2008, p.5.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Although \$98.5 million of the total \$150 million available has been committed, the underlying funds had drawn down only \$34.1 million from the Fund by the end of 2008. Eight of the 18 underlying funds have already exceeded their commitment to invest at least 50 percent of the capital in Ohio-based technology companies. Only four of the funds have drawn more than 50 percent of the committed funds. Of these four underlying funds, three have not met their Ohio commitment and one has.

In total, 30 Ohio companies received venture capital financing through the OCF/OVCA's underlying funds from 2006 through 2008. The underlying funds drew down \$34.1 million from the Fund and invested a total \$74.9 million in Ohio-based technology companies. In addition, other private investors invested an additional \$115 million into these same investment rounds. Therefore, each \$1 invested by the OCF/OVCA leveraged \$2.19 of additional investment in Ohio-based companies by the underlying funds and an additional \$5.56 from other outside investors. Further analysis of the impact of the OCF/OVCA on the availability of early-stage risk capital for Ohio companies follows in Section IV of this report.

ALIGNMENT OF TBED PROGRAMS

The State of Ohio is focused on supporting the innovation and growth of Ohio companies along the entire technology commercialization continuum. At the transition between each phase and the next is the need to mobilize resources. Collectively, Ohio's four TBED programs support the advancement of entrepreneurs and companies across the technology commercialization continuum, as depicted in Figure 9. Location of Ohio TBED Programs along Technology Commercialization Framework.

Figure 9. Location of Ohio TBED Programs along Technology Commercialization Framework



In the Imagining Phase of Commercialization, programs under the OTF, such as the Ohio Research Scholars, the OTF's Wright Centers and Wright Projects, are directed toward building world-class centers of excellence in targeted fields with strong commercial relevance to key industry sectors. The attraction

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

of new talent to Ohio universities and increased university-industry research collaboration resulting from these investments are expected to yield many new commercial opportunities.

The Edison Technology Incubators, the Ohio Technology Investment Tax Credit, and the OCF/OVCA support and extend the entrepreneurial assistance of the OTF's Pre-Seed Funds and ESP Program in the Incubating Phase.

The OTF's direct investments in Ohio companies, such as the Research Commercialization Program, Fuel Cell Program and Advanced Energy Program, provide commercialization support to companies in the Demonstrating Phase.

The Edison Technology Centers provide technical assistance to existing Ohio companies as they grow and diversify into new markets (Growth and Sustainability Phase). In addition, the state makes available loans for new equipment purchases and other investments through the Innovation Ohio Loan Fund, Job Creation Tax Credits for operation expansions, and so on.

Each of Ohio's TBED programs had a separate, time-delineated derivation particular to the political, fiscal and economic policy context of that time. Building on the inherent complementarities among the TBED programs, alignment will create a greater breadth and depth of coverage across the innovation continuum.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

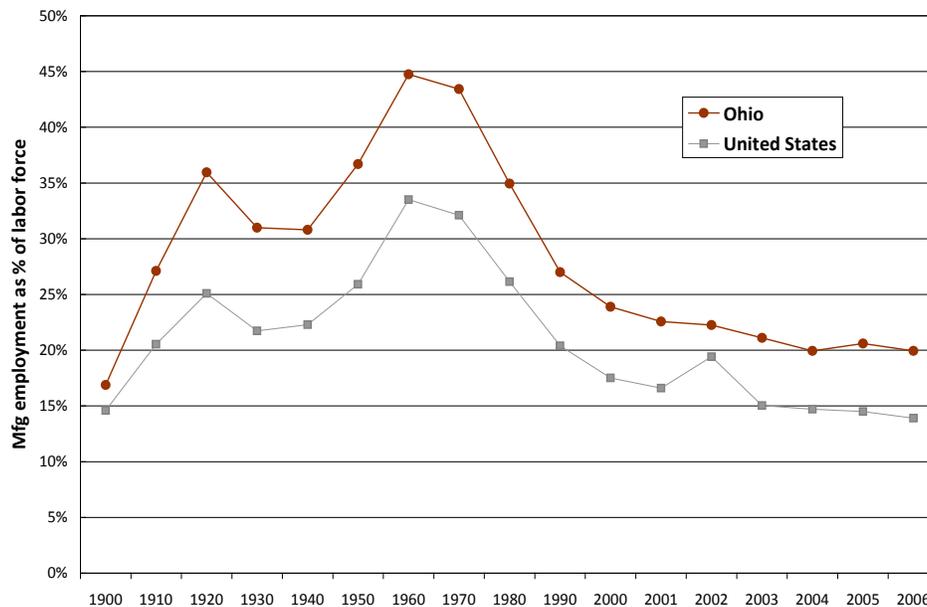
ASSESSING THE FOUNDATIONS FOR INNOVATION-BASED GROWTH IN OHIO'S ECONOMY

This section discusses the long-term economic and R&D trends in the State of Ohio. The first chapter examines Ohio's economic growth and employment trends and the performance of its high-tech sector, in comparison to national trends and trends in peer states. The second chapter analyzes trends in Ohio's R&D expenditures, patenting and workforce development.

MAJOR STRUCTURAL CHANGES IN OHIO'S ECONOMY AND RECENT HIGH-TECH SECTOR GROWTH

During the late 19th and early 20th centuries, northeast Ohio was the "Silicon Valley" of the Second Industrial Revolution where technologically creative individuals and companies created the fabric for a very successful manufacturing economy.²⁰

Chart 3. Comparison of U.S. and Ohio Manufacturing Employment as Percentage of Labor Force, 1900-2006



Source: Integrated Public Use Microdata Series: Version 4.0. Minneapolis, MN: Minnesota Population Center, 2008.

²⁰ Lamoreaux, N.R., Levenstein, M.C. and K.L. Sokoloff (2004), "Financing Invention During the Second Industrial Revolution: Cleveland, Ohio, 1870-1920," NBER Working Paper No. W10923. (November 2004).

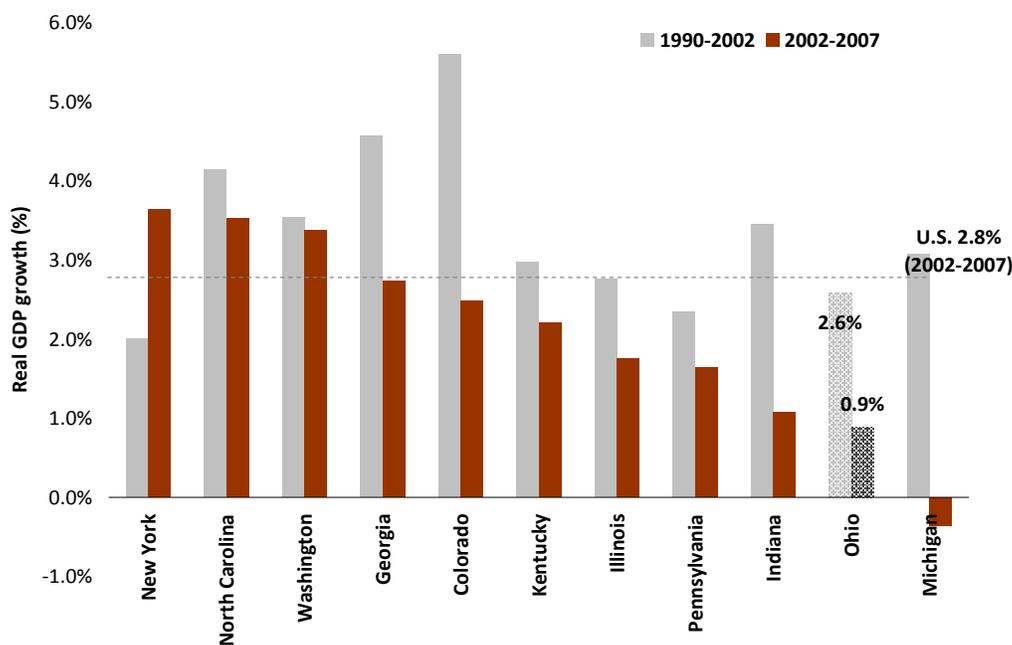
Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Chart 3, above, illustrates the rise of manufacturing's share of total employment in the state from 1900 to 1960, with a modest dip in the employment share of manufacturing during the Great Depression. From the 1960s to the present, manufacturing employment has declined continuously in Ohio, in the United States, and in nearly all developed economies.

The decline of the manufacturing sector, and relative weakness in developing new industries, has dampened Ohio's gross state product (GSP) and per capita income growth. Ohio's manufacturing sector shed over 300,000 jobs from 1980 to 1990, 12,000 jobs during the global economic expansion of 1990-2000, and 200,000 from 2000 to the present.²¹ These massive job losses in the manufacturing sector have had a negative impact on the statewide economy: young people have left Ohio; consumer spending, which drives 70 percent of U.S. gross domestic product (GDP), has fallen; and Ohio's GSP growth has suffered.

Chart 4. Real Average Annual GDP Growth in Ohio and Select States, 1990-2002 and 2002-2007



Source: U.S. Bureau of Economic Analysis

From 1990 through 2007, Ohio's economy grew by an average 2.1 percent per year in real terms (adjusted for inflation), lagging national economic growth of 3.0 percent over the same time period. In the most recent 2002-2007 period, Ohio's real GSP growth averaged only 0.9 percent per year compared to US GSP growth of 2.8 percent.

²¹ Integrated Public Use Microdata Series: Version 4.0. Minneapolis, MN: Minnesota Population Center, 2008.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Sluggish GSP growth has dampened per capita GSP growth in the state. In 2007, Ohio's per capita GSP was \$34,000 compared to \$38,000 nationally. Ohio's real GSP per capita ranking fell from 23rd in 1997 to 33rd among the 50 states and the District of Columbia in 2007.

Nationally and globally, the past few decades have indicated that knowledge and skill-intensive services industries and technology-based manufacturing industries will be the drivers of future economic growth. The growth of these industries is driven by increased consumer demand for healthcare, education, and so on, but also by technology development and innovations in high-tech industries. For example, the creation of the "World Wide Web" has spawned countless online businesses, which in turn increase demand for broadband and wireless connectivity services, web designers, software, database programmers, logistics services, etc. The creation of medical magnetic resonance imaging (MRI) technology creates demand for medical MRI technicians, imaging software, printers, MRI machine servicing, etc. The technology also supports new biomedical research in a variety of fields.

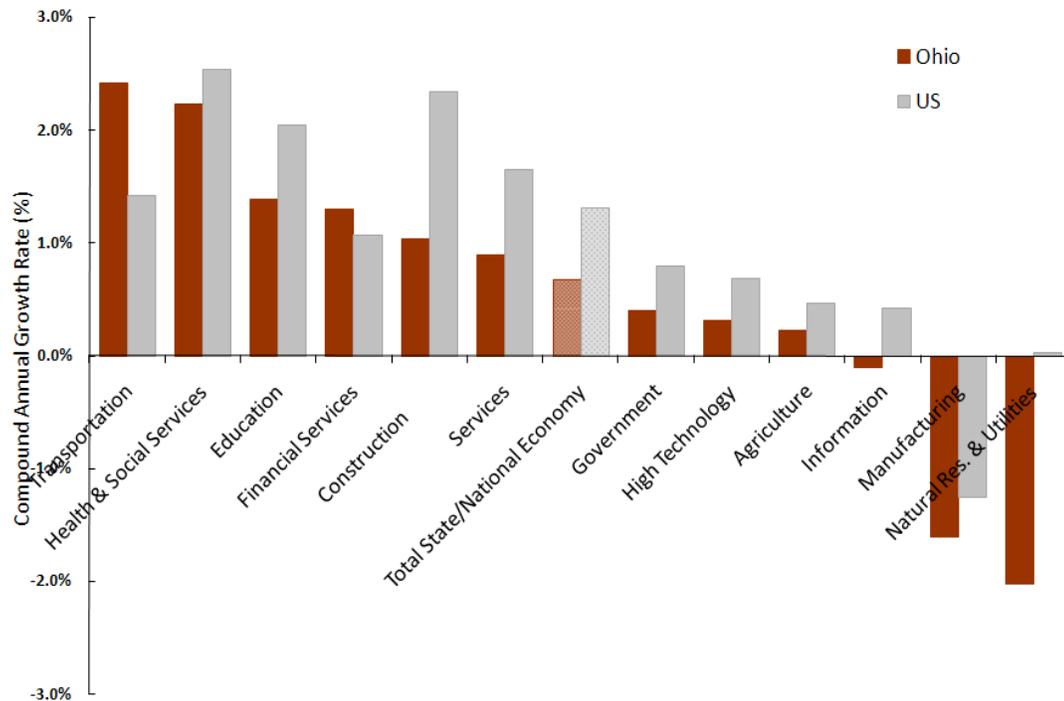
RECENT ECONOMIC PERFORMANCE BY MAJOR INDUSTRY SECTOR

To examine major drivers of Ohio state economic growth from 1990-2006, SRI's analyzed U.S. Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages data for Ohio and the United States as a whole. We segmented Ohio's economy into 14 major industry sectors. SRI's analysis of the BLS data reveals that Ohio's five fastest growing industry sectors (measured by compound annual growth rates in employment) were: (1) Transportation (2.4 percent per year), (2) Health & Social Services (2.2 percent), (3) Education (1.4 percent), (4) Financial Services (1.3 percent), and (5) Construction (1.0 percent).

The Ohio industries which experienced the largest employment declines over this period were Natural Resources & Utilities (-2.0 percent) and Manufacturing (-2.6 percent). These two industry sectors contracted more strongly in Ohio than in the country as a whole. Rapid technological change, intense foreign competition and two recessions (in 1990-91 and 2001) drove the steep declines in manufacturing employment.

Making an Impact

Chart 5. Compound Annual Growth Rates (CAGR) of Industrial Sector Employment in Ohio and the U.S., 1990-2006



Source: US Bureau of Labor Statistics, calculations by SRI

RECENT TECHNOLOGY SECTOR PERFORMANCE

The U.S. government defines a high-tech industry in terms of the percentage of employees in R&D-related occupations. To qualify as a “high-tech” industry, an industry must have at least twice the national average of R&D-related employment of 4.9 percent. Currently, 46 NAICS codes are classified as high-tech using this definition.

While an extremely important source of employment, establishment and wage information (all business establishments with employees covered by unemployment insurance are required to report), there are some challenges in using government economic data based on NAICS (e.g., ES-202 or BLS Quarterly Census of Employment and Wages data) to monitor high-tech industry growth. Chief among these is that there are no industry codes that capture high-tech industry sectors where a great deal of convergence is occurring, such as the biosciences, advanced energy, electronics, and advanced materials. (See box.)

Challenges to Using NAICS-based Data to Analyze High-Tech Industrial Activity

The North American Industrial Classification System (NAICS) is used by government statistical agencies to measure economic activity over time. While an extremely important source of employment, establishment and wage information (all business establishments with employees covered by unemployment insurance are required to report), there are some challenges in using government economic data based on NAICS (e.g., ES-202 or BLS Quarterly Census of Employment and Wages data) to monitor high-tech industry growth. The first is that there is no NAICS code for bioscience, advanced energy, advanced materials, and other fields. A recent study performed by Tripp Umbach for BioOhio identified 38 six-digit NAICS codes that include parts of the Biosciences Industry.¹ The second challenge is that many startup companies are not represented in the data, because it can take five to ten years before these companies have employees. Before then, these companies are sole proprietorships or limited liability partnerships which are not covered by unemployment insurance. Thirdly, NAICS are an arbitrary classification. More than one NAICS classification might be appropriate for a large company, or even a small company. In addition, companies migrate from one NAICS to another over time. So, for example, a pharmaceutical company that one might logically think would fall under Pharmaceuticals and Medicine Manufacturing (NAICS 3254) might actually classify itself as Drugs Wholesalers (NAICS 4222), because the bulk of its payroll (which is used to assign NAICS codes) is going to employees engaged in marketing and wholesale activities. Given these difficulties in focusing on specific sectors of interest, we tracked the 46 high-tech NAICS codes and the changes in total technology sector employment.

For example, the biosciences sector draws on technologies and companies which span information technology, biotechnology, chemicals (e.g., pharmaceuticals and specialty chemicals), advanced materials, electronics, scientific R&D services, contract research organizations, hospitals, agriculture, aquaculture, and so on. Therefore, for conducting analysis across time and across states and regions, it is most time efficient and cost effective to track the 46 high-tech NAICS codes and changes in total technology sector employment.

A recent analysis of Ohio high-tech sector employment commissioned by NorTech and performed by the Center for Economic Development at Cleveland State University (CSU) Maxine Goodman Levin College of Urban Affairs identified the following key employment trends and findings:

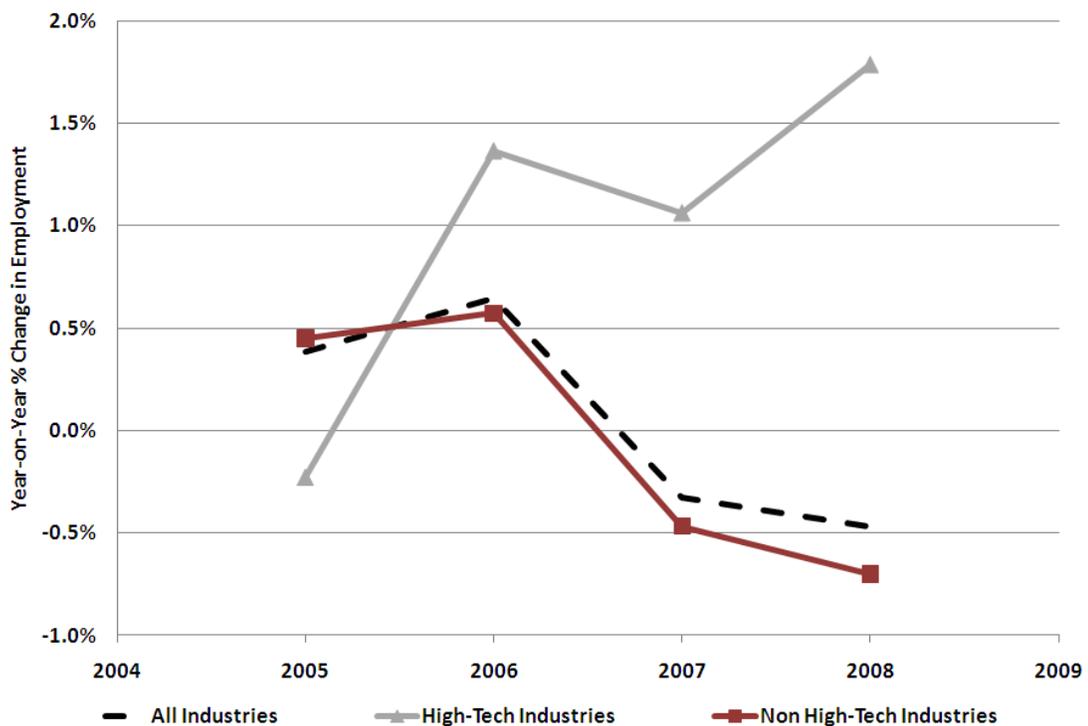
- Ohio's high-tech sector employed 495,088 people accounting for 9.5 percent of total employment in 2008. This is on par with the high-tech sector's representation at the

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

- national level. High-tech jobs accounted for 9.5 percent of total employment in the U.S. economy in 2008.
- Between 2004 and 2008, high-tech employment in Ohio grew 4.0 percent, adding 19,198 jobs, while employment in Ohio's non-high tech sector declined 0.2 percent, shedding 7,247 jobs (see Chart 4).
- The average wage in Ohio's high-tech sector is double that of the rest of the economy: \$76,694 versus \$37,803.

Chart 6. Ohio High-Tech and Non High-Tech Employment Growth, 2004-2008



Source: NorTech and the Center for Economic Development at Cleveland State University's Maxine Goodman Levin College of Urban Affairs.

Looking at the breakdown of the 46 high-tech industries, Table 3 shows that strong employment growth in a number of industry segments contributed to overall high-tech sector growth between 2004 and 2008. The top ten industry segments ranked by the number of jobs added during this five-year period were:

- Computer Systems Design and Related Services (added 8,310 jobs)
- Management, Scientific, and Technical Consulting Services (added 4,354 jobs)
- Aerospace Product and Parts Mfg (added 3,033 jobs)
- Architectural, Engineering, and Related Services (added 2,765 jobs)

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

- Scientific Research and Development Services (added 2,256 jobs)
- Other General Purpose Machinery Mfg (added 1,473 jobs)
- Management of Companies and Enterprises (added 1,056 jobs)
- Electric Power Generation, Transmission and Distribution (added 960 jobs)
- Other Transportation Equipment Mfg (added 804 jobs)
- Industrial Machinery Mfg (added 650 jobs)

Some of the high-growth, high-tech industry classifications during the 2004-08 period—e.g., Management of Companies and Enterprises—encompass growth in industry sectors targeted by the OTF. The OTF targets Biomedicine, Advanced Materials, Advanced and Alternative Energy, Advanced Propulsion, and Instruments, and Controls & Electronics (ICE). Information Technology and Advanced Manufacturing have also received OTF support, because of the role they play as cross-cutting enabling technology platforms.

The Management of Companies & Enterprises industry classification (NAICS 5511) includes several biomedical imaging and medical device companies (e.g., Cardinal Health, Ethicon Endo-Surgery, Philips Medical Systems, and STERIS), and key component suppliers in the advanced energy cluster (e.g., Pilkington in photovoltaic cells, Owens Corning in wind turbine blades, and Trimco in building-integrated photovoltaics).

Similarly, the Scientific Research & Development Services industry classification (NAICS 5417) includes a large number of startup companies across a variety of high-tech sectors targeted by Ohio's Third Frontier, e.g., AcelleRX and in biomedicine; NexTech Materials and UltraCell in fuel cells; Applied Sciences, Cornerstone Research Group, and MetaMateria Partners in advanced materials; and Mound Laser Photonics in instruments, controls and electronics.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Table 3. Growth in Ohio High-Tech Industries Employment, 2004-2008

NAICS CODE	NAICS DESCRIPTION	EMPLOYMENT 2004	EMPLOYMENT 2008	CHANGE, 2004-08	% CHANGE, 2004-08
5415	Computer Systems Design and Related Services	43,057	51,367	8,310	19.30
5416	Management, Scientific, and Technical Consulting Services	19,855	24,209	4,354	21.93
3364	Aerospace Product and Parts Mfg	13,601	16,635	3,033	22.30
5413	Architectural, Engineering, and Related Services	42,206	44,970	2,765	6.55
5417	Scientific Research and Development Services	13,264	15,520	2,256	17.01
3339	Other General Purpose Machinery Mfg	23,370	24,843	1,473	6.30
5511	Management of Companies and Enterprises	107,348	108,404	1,056	0.98
2211	Electric Power Generation, Transmission and Distribution	17,187	18,147	960	5.59
3369	Other Transportation Equipment Mfg	1,961	2,765	804	41.02
3332	Industrial Machinery Mfg	9,426	10,076	650	6.90
5612	Facilities Support Services	2,368	2,906	538	22.74
3254	Pharmaceutical and Medicine Mfg	4,526	5,036	510	11.26
5172	Wireless Telecommunications Carriers (except Satellite)	3,843	4,249	406	10.56
5191	Other Information Services	19,017	19,246	230	1.21
3241	Petroleum and Coal Products Mfg	3,905	4,134	229	5.87
3252	Resin, Synthetic Rubber, & Artificial Synthetic Fibers & Filaments Mfg	6,094	6,186	92	1.52
4234	Professional & Commercial Equipment & Supplies Merchant Wholesalers	24,757	24,824	67	0.27
4861	Pipeline Transportation of Crude Oil	351	412	61	17.27
2111	Oil and Gas Extraction	2,514	2,553	39	1.55
5112	Software Publishers	4,432	4,469	36	0.82
4869	Other Pipeline Transportation	199	233	34	16.89
4862	Pipeline Transportation of Natural Gas	352	374	21	6.06
5232	Securities and Commodity Exchanges	4	7	3	83.25
3336	Engine, Turbine, and Power Transmission Equipment Mfg	4,733	4,726	-8	-0.16
3343	Audio and Video Equipment Mfg	136	125	-11	-8.09
5174	Satellite Telecommunications	76	48	-28	-37.28
3341	Computer and Peripheral Equipment Mfg	1,702	1,636	-66	-3.88
3259	Other Chemical Product and Preparation Mfg	6,459	6,373	-86	-1.33
3344	Semiconductor and Other Electronic Component Mfg	7,035	6,927	-108	-1.54
3353	Electrical Equipment Mfg	9,743	9,601	-142	-1.46
3346	Mfg and Reproducing Magnetic and Optical Media	459	220	-239	-52.07
3253	Pesticide, Fertilizer, & Other Agricultural Chemical Mfg	2,491	2,164	-327	-13.14
8112	Electronic and Precision Equipment Repair and Maintenance	3,351	2,977	-374	-11.16
3251	Basic Chemical Mfg	11,236	10,838	-398	-3.55
3255	Paint, Coating, and Adhesive Mfg	7,698	7,280	-418	-5.43

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Table 3. Growth in Ohio High-Tech Industries Employment, 2004-2008

NAICS CODE	NAICS DESCRIPTION	EMPLOYMENT 2004	EMPLOYMENT 2008	CHANGE, 2004-08	% CHANGE, 2004-08
5182	Data Processing, Hosting, and Related Services	5,686	5,121	-565	-9.94
3345	Navigational, Measuring, Electromedical, and Control Instruments Mfg	10,713	10,094	-619	-5.78
5179	Other Telecommunications	4,753	4,019	-734	-15.44
1131	Timber Tract Operations	NA	NA	NA	NA
1132	Forest Nurseries and Gathering of Forest Products	NA	NA	NA	NA
5211	Monetary Authorities-Central Bank	NA	NA	NA	NA
TOTAL		475,890	495,088	19,198	4.03

Source: Center for Economic Development, Cleveland State University (2009).

SUMMARY

Ohio's high-technology sector has demonstrated impressive growth, adding 19,198 jobs over the 2004-2008 time period, in spite of a severe global recession which began toward the end of 2007. The employment growth of Ohio's high-tech companies suggests these companies are operating competitively in high-growth markets with strong global demand. Moreover, a breakdown of the 46 NAICS industry comprising the high-tech sector indicates that many of the high-tech industry segments experiencing particularly strong growth are sectors targeted by Ohio's Third Frontier: Computer Systems Design and Related Services, Aerospace Products and Parts Mfg (Advanced Propulsion), Management of Companies and Enterprises (Bioscience and Advanced and Alternative Energy), Scientific R&D Services (Bioscience, Advanced and Alternative Energy, Advanced Materials), Resins, Synthetic Rubber and Other Mfg (Advanced Materials), and so on.

ANALYSIS OF OHIO'S RESEARCH & DEVELOPMENT CAPACITY, 1980-2007

As Ohio's manufacturing and high-tech capabilities have grown, so has the state's research and development (R&D) capacity. The state currently boasts numerous university laboratories and two large Federal R&D labs: the NASA Glenn Research Center in Cleveland and the U.S. Air Force Research Lab at Wright-Patterson Air Force Base. The state's public and private laboratories work across the research continuum from basic research to application-oriented development. Ohio's R&D labs create new knowledge and also commercialize existing knowledge spurring economic diversification and development within the state. For Ohio to remain competitive in an increasingly knowledge-based global economy, it is crucial to continue building the state's capacity for R&D and research-based innovation.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

SECTION OVERVIEW

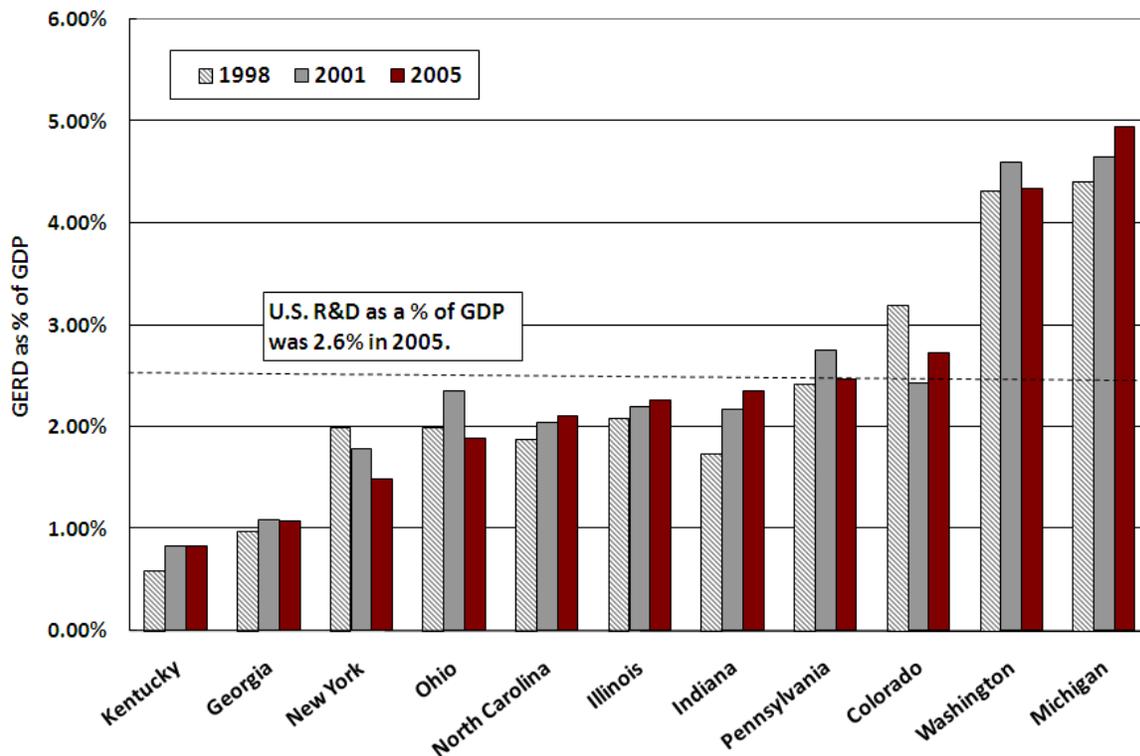
This section discusses Ohio's capacity for R&D and benchmarks Ohio against peer states and the U.S. as a whole. First, the section presents several indicators that measure "inputs" to R&D, such as R&D expenditures and workforce indicators. Then, several R&D "output" indicators—patenting activity, technology licensing revenue, and number of technology startups—are presented and discussed. Recent trends in these indicators and their implications for the State of Ohio will be discussed, along with several caveats associated with these indicators. Throughout the section, Ohio is benchmarked against ten other U.S. states (Colorado, Georgia, Illinois, Indiana, Kentucky, Michigan, New York, North Carolina, Pennsylvania, and Washington). These benchmark states were selected based on their being traditional regional competitors, possessing similar industrial profiles, and/or having similar demographic profiles to Ohio. The analysis that follows indicates that, despite some decline in R&D input trends, Ohio has maintained (and in some cases improved) its R&D output trends.

RESEARCH AND DEVELOPMENT PERFORMANCE

In examining Ohio's R&D capacity, it is important to look at the institutional factors that allow R&D to take place: the state's "inputs" to R&D. The foremost input is the amount of money (from funding sources both within and outside of the state) spent on R&D performed within the state. This input is measured by the "R&D Performance" indicator, which includes R&D performed by federal agencies, industry, universities, and other nonprofit organizations. In Chart 7, below, the "R&D Performed" in Ohio and benchmark states is scaled to state GDP, to represent the percentage of each state's GDP that is devoted to R&D spending. This R&D/GDP figure is a common measure in innovation studies, and most modern countries, including the U.S., members of the European Union, and East Asian countries (Japan, South Korea, Taiwan, Hong Kong) strive to spend 3 percent of GDP on research and development. Chart 4 indicates that Ohio's R&D/GDP increased from 2.0 percent (1998) to 2.3 percent (2001) before falling back to 1.9 percent (2005). The decline in Ohio's R&D/GDP over the 2001-2005 period is due to the combination of both falling R&D performance (\$8.8 to \$8.3 billion) and rising GDP (\$374 to \$439 billion). R&D expenditures and performance has not kept pace with GDP growth in Ohio. This level of R&D performance puts Ohio ahead of Southern states like Kentucky and Georgia, but lagging its manufacturing peers (Illinois, Indiana, Pennsylvania and Michigan) and falling below the national average of 2.6 percent.

Making an Impact

Chart 7. R&D Performed as a Percent of GDP for Ohio and Benchmark States (1998, 2001, 2005)



Source: National Science Foundation and U.S. Bureau of Economic Analysis

It is important to note the sources of funding for R&D in the state. Table 4 below shows how the funding sources (Federal, state, industry, higher education sources) for R&D performed in Ohio changed over the 1999-2005 period. The shares of R&D funding in Ohio roughly match the national trend: in 2006, the national breakdown of R&D funding in the U.S. was 28 percent from government, 66 percent from industry, and 7 percent from other sources. These figures resemble international benchmarks as well: in most developed countries, the share of R&D financed by industry is in the 60-70 percent range.²²

From 1999-2005, the amount of Federal R&D funding attracted by Ohio declined, while the amount of R&D funding coming from the state, industry, higher education and other rose. Overall, these figures reflect a nationwide trend that has seen industry's share of R&D funding increase over several decades (50 years ago, less than 40 percent of U.S. R&D was funded by industry). The impact of Ohio's Third Frontier can be seen in the growth of state R&D funding from \$68.1 million in 1999 to \$168 million in 2005. It will be interesting to analyze the impact of Ohio's Third Frontier on the level of Federal R&D

²² Organization for Economic Co-operation and Development (2002). Benchmarking industry-science relationships. Paris: OECD, p 88-9.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

funding and industry R&D funding in Ohio over the next five to ten years. A major goal of the OTF is to help Ohio companies and research institutions build the world-class technology platforms which then positions the state to attract more Federal and private research dollars.

Table 4. Source Of Ohio R&D Funding, 1999, 2002, 2005

Year	Total R&D Money Spent by Ohio Research Performers	Funding Source							
		Federal Government		State Government		Industry		Higher Education	
		\$ million	%	\$ million	%	\$ million	%	\$ million	%
1999	\$8,082,000	2.36	29%	0.07	1%	5.45	67%	0.15	2%
2002	\$8,310,000	2.43	29%	0.08	1%	5.48	66%	0.25	3%
2005	\$8,267,000	2.18	26%	0.17	2%	5.54	67%	0.25	3%

Source: National Science Foundation and SRI calculations

SCIENCE & ENGINEERING WORKFORCE

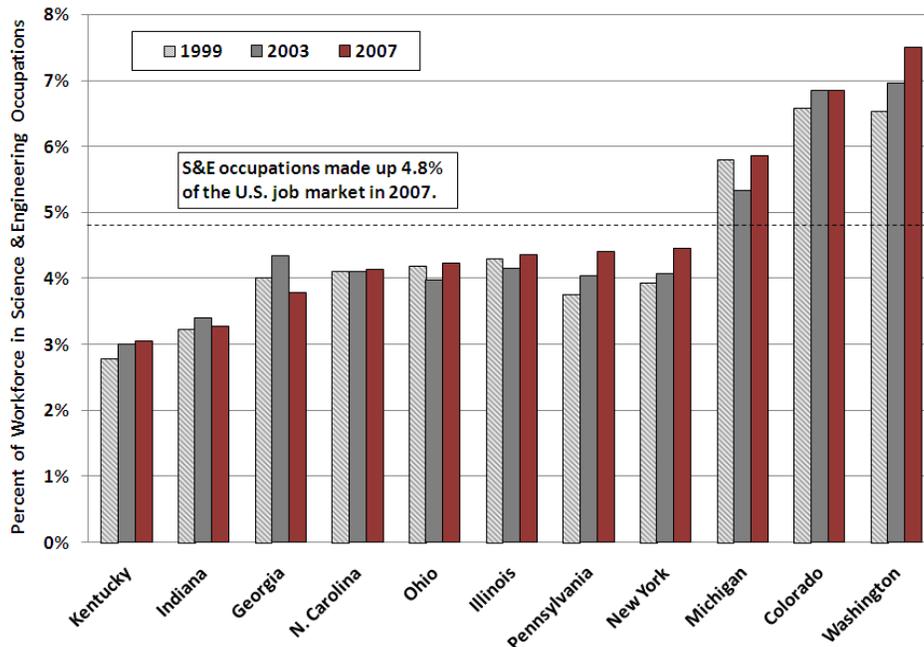
The mix of occupations and workforce skills in a state can readily influence the state's R&D capacity. The indicators presented here measure the share of the workforce dedicated to science and engineering (S&E) occupations, from both an employer and employee perspective. High values for these indicators would show that a state's economy has a high percentage of technical jobs or technically trained employees, relative to other states. High values for these indicators also demonstrate a readiness to absorb and engage with technically-oriented companies. In other words, states with a technically trained work force appear more attractive to high-tech companies, since they can offer a skilled workforce base and the support services appropriate to high-tech industry.

Chart 8 depicts the percentage of the benchmark states' workforce engaged in S&E-related occupations. The chart shows that about 4 percent of Ohio's workforce is engaged in science and engineering-related work. Furthermore, the chart shows that the percentage of S&E-related occupations in Ohio's job market did not grow significantly between 1999 and 2007. Five of the benchmark states (Colorado, Kentucky, New York, Pennsylvania and Washington) experienced significant growth in S&E's share of total occupations. For the U.S. as a whole, S&E occupations accounted for 4.4 percent of the national job market in 1999, growing to 4.8 percent in 2007.

Making an Impact

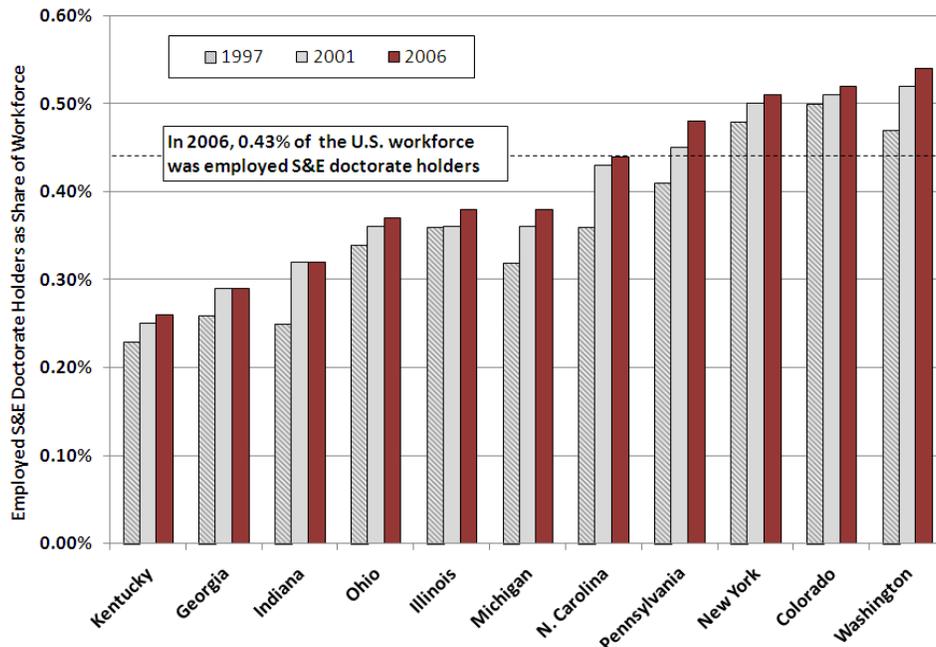
Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Chart 8. Percent of Workforce in Science & Engineering Occupations, for Ohio and Benchmark States (1999, 2003, 2007)



Source: Bureau of Labor Statistics, Occupational Employment Statistics

Chart 9. Science & Engineering Doctorates as a Percent of the Workforce, for Ohio and Benchmark States (1997, 2001, 2006)



Source: National Science Board, Science & Engineering Indicators 2008

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

When discussing the occupational mix of Ohio's job market, the skill set of the workforce desired for that job is also critical. One commonly used indicator of a state's innovative capacity is the percentage of a state's workforce that holds a S&E doctorate degree. Individuals with S&E doctorates frequently conduct research and are engaged in knowledge-intensive activities. Rather than measuring the degrees *awarded* in the state (the holders of which may relocate to other labor markets), this indicator uses the current workforce as a gauge of the state's ability to attract and retain highly trained scientists and engineers. This figure deserves attention, because, as mentioned above, these occupations are fundamental to a knowledge-based, technology-driven economy. Chart 9 shows the proportion of the workforce that holds a doctorate in S&E fields. The chart shows that this indicator has been increasing in Ohio and in all of the benchmark states. Though Ohio falls below the national average for this indicator, the state is in the second highest quartile nationally; it has a higher percentage of workforce S&E doctorates than many other Southern and Midwest states.

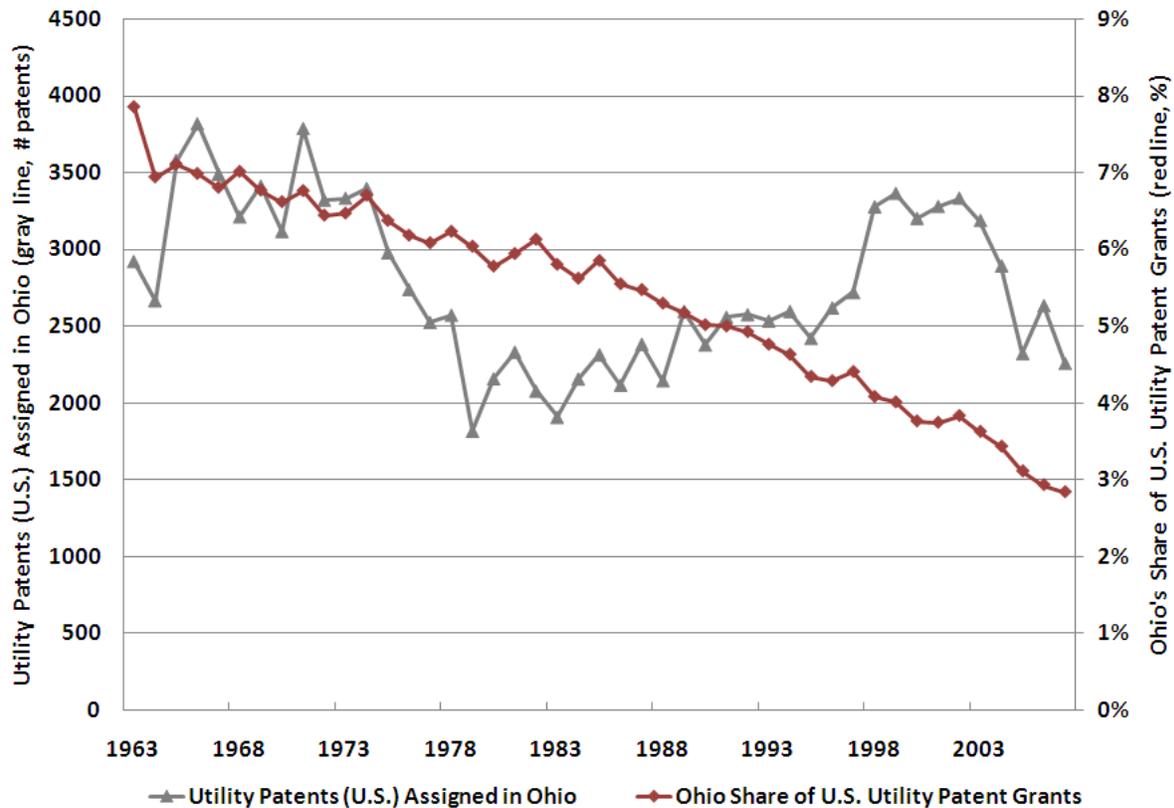
PATENTING ACTIVITY

The number of patents awarded in a state is an indicator of inventive activity in the state. Chart 10 shows Ohio's patenting activity (in patents assigned/year) in gray and Ohio's share of nationwide patenting (percentage) in red. The chart shows two distinct trends. First, Ohio's patenting activity has remained relatively stable for four decades. Second, Ohio's share of national patent activity has consistently declined over that same time period. The gray line indicates that, with few exceptions, Ohio's patenting activity has remained in the range of 2,000-3,500 patents per year. The late 1960s and late 1990s were active patenting periods compared to the 1980s, the early 1990s and the most recent five years. But while Ohio's annual patenting has remained in the range of 2,000-3,500 patents per year, the red line in Chart 10 indicates that the state's share of national patenting activity has steadily decreased over the past 45 years. Ohio has not seen the same growth in patent activity that the nation as a whole has experienced.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Chart 10. Ohio's Patenting Activity and Share of U.S. Patenting Activity (1964-2007)²³



Source: U.S. Patent and Trademark Office

Ohio's share of total U.S. patents granted from 1963-2007 (see red line) declined consistently throughout this four decade period, although there have been sizeable fluctuations in the total number of patents awarded to Ohio inventors on an annual basis (see grey line). The decrease in Ohio's share of national patents can be partly explained by two factors: (1) the rise in major innovation centers such as Silicon Valley, Boston, Austin, and Research Triangle Park; and (2) the growth of the information technology sector. Both of these trends saw heavy patenting activity outside of Ohio.

Although Ohio has not kept pace with the *overall* national patenting activity, it has kept pace with national patenting in several strategic technology fields. Table 5 shows the 10-year change in patenting activity for Ohio and the U.S. in the fields of fuel cells, photovoltaics and composite materials. From the "10-year Change" columns, we can see that Ohio has met or exceeded the national patenting activity growth in these fields.

²³ The reader should note that this graph charts Ohio's share of the U.S. patents assigned to U.S. companies and individuals. International patent awards and assignees are not included in these figures.

Making an Impact

Table 5. Ten-Year Change In Patenting Activity In Three Technology Fields For Ohio And The U.S.

Technology Field	Ohio			U.S. Total		
	Patents Granted		10-year Change	Patents Granted		10-year Change
	1995-97	2005-07		1995-97	2005-07	
Fuel Cells	12	144	1200%	272	2022	743%
Photovoltaics	34	87	256%	763	1849	242%
Composite Materials	2089	2755	132%	978	1305	133%

Source: U.S. Patent and Trademark Office, Thompson Reuters Delphion Service

The patent figures in this section are offered with caution, because patents have limitations as a measure of innovation. First, patent statistics do not capture all new inventions. Some businesses and inventors choose not to patent their inventions, choosing instead to protect their inventions through trade secrets or copyrights (in the case of software). Secondly, patents have a geographical assignment that may vary from where the actual R&D takes place. For example, a company with R&D operations in Ohio that is headquartered elsewhere (such as General Electric, Inc.) would typically have all of its patents assigned to its headquarters rather than to the Ohio location where they were invented. Third, patents are considered to be a “lagging indicator.” It may take two or three years for the research investment to yield patentable results, and then a further two years or more for the patent application, review and approval process. Because of this time lag, it is unlikely that the effects of Ohio’s recent increase in state support for R&D would be reflected in the patent statistics in the near term. Finally, patenting practices vary by organization and technical field in a way that do not correlate with innovative output. In some fields, such as pharmaceuticals, patents are much more important than in others, such as high-tech services. Some companies try to get as many patents as they can from their inventions, while others are more selective in what they patent.

In spite of these shortcomings of patent statistics, we can extract the following broad lessons from this examination of patenting in Ohio: (1) While the U.S. as a whole has outpaced Ohio in terms of overall growth in patenting activity, Ohio’s annual patenting activity has remained steady in the range of 2,000-3,500 patents per year. (2) Ohio has kept pace with the rate of growth in U.S. patenting activity in several key technology areas, such as fuel cells, photovoltaics and composite materials.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

**Table 6. Tech Transfer Indicators At Ohio Universities
And Research Institutions, 2002 And 2007**

Institution	R&D Performance (\$M)		Licensing Income (\$M)		Startups		Industry-sponsored R&D	
	2002	2007	2002	2007	2002	2007	2002	2007
Case Western Reserve Univ	\$233.0	\$372.2	\$3.0	\$11.2	1	3	10.1%	1.6%
Cleveland Clinic	\$185.2	\$244.8	\$3.3	\$8.6	3	5	17.5%	11.4%
Univ of Akron	\$17.9	\$50.8	\$0.3	\$6.3	2	2	10.3%	16.3%
Cincinnati Children's Hospital	\$111.7	\$202.3	\$1.2	\$5.1	0	1	11.9%	6.6%
Ohio University	\$36.6	\$28.6	\$0.1	\$4.4	1	1	7.5%	13.9%
Ohio State University	\$361.1	\$720.2	\$0.8	\$1.2	8	3	12.7%	19.7%
Miami University	-	\$31.0	-	\$0.9	0	0	-	1.6%
University of Toledo	\$24.8	\$52.4	\$0.0	\$0.7	1	2	8.0%	4.1%
Univ of Cincinnati	\$115.9	\$143.2	\$6.5	\$0.6	1	1	8.7%	3.9%
Kent State University	\$14.6	\$19.6	\$0.4	\$0.4	0	1	4.4%	3.0%
Wright State Univ	\$30.9	\$47.7	\$0.1	\$0.1	1	0	12.3%	7.7%
University of Dayton	\$46.9	\$74.7	\$0.3	\$0.1	0	1	6.5%	5.8%
Bowling Green	\$5.3	\$9.1	-	-	0	0	1.1%	2.6%
Medical University of Ohio	\$16.2	-	\$0.1	-	0	0	6.4%	-

Source: Association of University Technology Managers, 2007 Licensing Activity Survey

COMMERCIALIZING THE PRODUCTS OF R&D

In addition to patent statistics, “technology transfer” statistics are another way to track the outputs of R&D investments. Technology transfer is the process of converting scientific findings from R&D labs into useful products for the commercial sector. The two major channels of technology transfer are: (1) cooperative R&D projects and (2) technology licensing by the private sector. Many universities have technology transfer offices to help their schools’ research labs liaise with industry and license the products of their research. Table 6 includes some statistics on technology transfer from Ohio’s top 14 (in terms of R&D performance) research universities and institutions. Several observations from these statistics are listed below:

- Nearly all of Ohio’s top universities and research institutions saw an increase in R&D performed in their institutions between 2002 and 2007.
- Total licensing income to Ohio’s universities more than doubled from \$16.1 million in 2002 to \$39.6 million in 2007. Case Western Reserve University, Cleveland Clinic, and the University of Akron were the top three Ohio research institutions in licensing revenue in 2007 (see Table 6).

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

- Ohio State University's R&D commitments nearly doubled in the period 2002-07. In 2007, OSU spent more on R&D than any other Ohio research university and had the largest percentage of their R&D sponsored by industry. However, OSU performed less well on other technology transfer measures, e.g., licensing revenue and startup activity.

While technology licensing revenue, industrial sponsorship of university research, and startup companies are each imperfect indicators of university technology commercialization, collectively they are indicative of an institution's overall technology transfer activity. Individually, these indicators may not convey a complete picture for the following reasons: First, licensing revenue has a highly skewed distribution—a small number of lucrative licenses accounts for a large portion of the total revenue. Secondly, there may be an inverse relationship between industry-sponsored R&D and licensing revenue—when a company pays for the research it may have greater rights to the resulting technologies. Nevertheless, the combination of these indicators suggests that Ohio's research institutions are improving their mechanisms for technology transfer. Ultimately, this should allow the state to utilize its university-based R&D more efficiently.

SUMMARY

Total R&D performance as a share of GDP in Ohio declined between 2001 and 2005 (the latest year for which data are available). The source of R&D funding has shifted slightly from the Federal government to industry and universities, reflecting a national trend. Ohio's supply and demand for S&E labor positions it behind half of the benchmark states and below the national average for those workforce indicators.

In terms of innovative output, Ohio has maintained patenting activity in the range of 2,000-3,500 patents per year for the past four decades. Although the state's share of nationwide patenting activity has declined, Ohio has met or exceeded the national growth rate for patents awarded in several of the state's key technology sectors. The state has also improved its performance in technology transfer indicators, which will help Ohio to perform R&D more efficiently.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

IMPACTS OF OHIO'S MAJOR TECHNOLOGY-BASED ECONOMIC DEVELOPMENT PROGRAMS

This section presents the evidence about each of the hypotheses and the effects of Ohio's TBED Programs. Information is presented on economic impacts of TBED programs, effects on early-stage capital, effects on entrepreneurial activity, effects on R&D capacity and industry-university research collaboration, effects on manufacturers, effects on new technology industry clusters, and effects on the attractiveness of Ohio to non-Ohio companies.

GENERATING A POSITIVE RETURN ON THE OHIO THIRD FRONTIER INVESTMENT

ABSTRACT

What has been the economic impact of Ohio's Third Frontier investment to date? From 2003-2008, the State's expenditures of \$681 million generated \$6.6 billion of economic activity, 41,300 jobs, and \$2.4 billion in employee wages and benefits as a result of the Ohio Third Frontier. This represents a nearly \$10 return on every dollar of the State's investment. We compared these impacts with an alternative scenario wherein the State of Ohio returned this \$681 million to taxpayers in the form of a "tax rebate." This would have increased disposable income and hence, spending, generating an estimated \$1 billion in economic impact. This is much smaller than the economic impact resulting from OTF investments, primarily because the OTF investments attracted an additional \$4.2 billion Federal, private, and other investments to the state. The OTF and follow-on investments, by increasing R&D activity, product sales, and new construction, generated more than seven times the level of economic activity, more than six times the employment, and more than 11 times the wages and compensation for Ohio's economy than that generated by a hypothetical tax rebate.

From 2003-2008, approximately \$681 million of State money was spent as a result of the OTF. These expenditures include \$403 million of OTF award money (out of the total \$898 million awarded), \$173 million in direct matching dollars (or cost share) contributed by Ohio public universities and other state

Making an Impact

Assessing the Benefits of Ohio’s Investment in Technology-Based Economic Development Programs

agencies,²⁴ and \$104 million of follow-on investments made by Ohio public universities and other state agencies.

Significantly, during this period, the OTF awards attracted an additional \$4,153 million in resources to Ohio, including \$730 million of cost share and \$3,413 million of follow-on investments by the private sector, Federal government agencies, and local (non-state) government organizations. In total, \$681 million in State expenditures, related to the OTF, leveraged a total \$4,833 million of investment funds to Ohio in the five target technology sectors.

To examine the economic impact of this investment, it is necessary to look into how the funds were being spent. Investment expenditures from the OTF awards, follow-on investments and matching/cost share are primarily spent in four major categories: (1) expenditures on R&D and engineering activities, (2) increased sales of products, (3) new construction, and (4) capital expenditures.

To calculate the economic impact of the OTF programs in each of these categories, SRI conducted an economic impact analysis based on an input-output model that captures the **direct, indirect** and **induced impacts** of these investments in Ohio.²⁵ Economic impact models are based on the concept of “multiplier”—i.e., every dollar spent in the economy is re-spent one or more times in the local economy, thereby generating additional economic activity and impact. In practice, when an Ohio company is awarded a \$1 million grant by the OTF, this money is spent on hiring or retaining company employees engaged in the commercialization project, which constitutes the *direct impact* of this investment. In addition, this money is used to purchase secondary inputs and services, e.g., materials and components, marketing consultants, intellectual property lawyers, etc., which produces an *indirect impact* on the economy. An additional round of spending is generated when the researchers employed by the company spend their incomes on goods and services in totally unrelated sectors of the Ohio economy, e.g., restaurants, lawn services, preschool, etc., which produces an *induced impact*. The total economic impact stimulated by the OTF grant is the sum of these direct, indirect and induced impacts.

R&D Impact on Ohio Manufacturers

Rolls-Royce Fuel Cell Systems estimates that 92 percent of its R&D expenditures stay in Ohio in the form of small orders to approximately 200 Ohio suppliers. When one considers that Ohio fuel cell companies have attracted Federal grants approaching \$100 million for applied fuel cell research, this is a significant impact on Ohio’s economy.

²⁴ All OTF grants require matching of OTF award money. OTF staff estimate approximately 30 percent of the Wright Centers of Innovation and Wright Projects cost share dollars came from state funds, and approximately 10 percent of Research Commercialization Program and other TF awards came from state funds.

²⁵ SRI conducted the economic impact analysis using IMPLAN, proprietary economic input-output (I-O) modeling software widely used by researchers in academia, government and other research organizations to conduct economic impact analysis.

Making an Impact

Assessing the Benefits of Ohio’s Investment in Technology-Based Economic Development Programs

The total impacts of the OTF investments are summarized in Table 7 below.²⁶ In this table, the Total Economic Impact column is derived from applying the appropriate multiplier to the various categories of Total Direct Investment.

INVESTMENTS	STATE OF OHIO INVESTMENTS	PRIVATE, FEDERAL AND OTHER INVESTMENTS	TOTAL DIRECT INVESTMENTS	TOTAL ECONOMIC IMPACT*
Ohio Third Frontier	\$403.0	--	\$403.0	
OTF Cost share	\$173.2	\$739.6	\$912.9	
OTF Leveraged investments **	\$104.3	\$3,412.9	\$3,517.2	
TOTAL	\$680.6	\$4,152.5	\$4,833.1	
Expenditure Breakdown				
R&D/Operating Expenditures			\$2,758.2	\$5,111.7
Product Sales			\$605.8	\$1,098.0
Construction			\$236.0	\$401.6
Non-operating items***			(\$1,233.0)	--
TOTAL			\$3,600.0	\$6,611.3

* The data for this impact analysis comes from the OTF surveys of program participants. These data were supplemented with ODOD detailed accounting data (based on invoices) that were used to disaggregate the expenditure data into categories, i.e., construction, equipment purchases, and research and development operations. Ohio ES-202 data and online company research was used to assign NAICS codes to company product sales data.

** These are follow-on investments in OTF-funded projects and companies. All of these investments are assumed to be spent in the 2003-2008 timeframe.

*** Consists mostly of capital equipment purchases which are conservatively assumed to be “imported” into Ohio with minimal economic impact. Therefore, the SRI team did not include this group of expenditures in the economic impact analysis.

Using economic impact analysis, the SRI team calculated that the OTF investments generated a total economic impact of \$6,611.3 million in Ohio. Other economic impacts include \$2,370.1 million in employee wages and benefits, as well as 41,293 jobs.

²⁶ Note that the “multiplier”—the ratio between the direct spending and the total economic impact—is different for the different categories of spending (research, product sales, and construction), and therefore were calculated separately before they are summed.

Making an Impact

OPPORTUNITY COST: HYPOTHETICAL TAX REBATE

To assess whether the State's investment in the OTF was a worthwhile investment, it is important to consider alternatives for how this money could have been used. The SRI team analyzed an alternative scenario wherein the State of Ohio returned this \$681 million to taxpayers. This hypothetical "tax rebate" would also have stimulated economic activity by increasing incomes and consequently would result in multiplier impacts. Using input-output analysis, we estimated that this alternative spending would have generated a total economic impact of \$934.6 million in economic activity, 6,400 jobs, and \$214.2 million in wages and benefits. This is significantly less than the economic impact of the OTF investments, which generated more than seven times the level of economic activity, more than six times the employment, and more than 11 times the wages and compensation compared to returning this money to taxpayers. The comparison of the economic impacts between the OTF and the hypothetical tax rebate is summarized in Table 8 below.

	Total Economic Impacts		Ratio
	Increased Income From Tax Rebate	Ohio Third Frontier Investment	
Output	\$934,580,000	\$6,611,270,000	7.07
Employee Compensation	\$214,180,000	\$2,370,150,000	11.07
Employment	6,400	41,293	6.45

It is important to note that the \$6.6 billion impact is only for the OTF expenditures to date. These investments are likely to generate larger impacts in the years to come for several reasons. First, a majority of OTF funds remain to be spent. Some OTF funds have not yet been awarded, and some funds awarded have not yet been entirely spent. The economic impact of the program is expected to increase significantly over the next five to ten years. Second, the OTF is generating successful outcomes in spite of the longest U.S. recession in the post-World War II era.²⁷ The diminished demand, financial capital, business activity and job losses associated with the recession weigh down the net economic impacts generated by the OTF investments. However, it is likely that the new products and processes being commercialized by Ohio companies and the new industries that are emerging will be in a position of strength during the next global expansion. The Federal Reserve Board Open Market Committee anticipates a U.S. recovery in 2010.²⁸ A meeting of the Group of Twenty Finance Ministers and Central

²⁷ According to the National Bureau of Economic Research (NBER), the average post-World War II recession in the United States is 10 months.

²⁸ Board of Governors of the Federal Reserve System. Minutes of the Federal Open Market Committee, April 28-29, 2009, <http://www.federalreserve.gov/monetarypolicy/fomcminutes20090429ep.htm>

Making an Impact

Assessing the Benefits of Ohio’s Investment in Technology-Based Economic Development Programs

Bank Governors also predict a gradual recovery beginning during 2010.²⁹ Thirdly, many intermediate impacts of the OTF, such as new products and services resulting from university research and better linkages among research institutions, companies, and financial institutions are long term in nature. Although many of these impacts have not had large economic effects yet, they are likely to have much more significant impacts in the long run.

The calculation of economic impacts in each expenditure category—R&D activity, increased product sales, and construction—is detailed below.

ECONOMIC IMPACT OF R&D ACTIVITY

The OTF supports technology commercialization leading to new companies, new products, and new manufacturing processes. Therefore, a significant share of the OTF awards and leveraged investment dollars go toward supporting R&D activity. Because the companies and research institutions performing this R&D purchase inputs and services directly from Ohio’s existing manufacturing base—e.g., machine shops, electrical and installation services, engineering and design services, materials and component manufacturers, etc.—this activity stimulates substantial indirect economic impact for the state economy. Table 9 shows the direct output (R&D activity) of about \$2.8 billion (net of construction, capital investment and product sales) is estimated to generate over \$5.1 billion in economic activity and support employment of over 28,600 persons.

	Direct Impact	Total Economic Impact
Output	\$2,758,201,084	\$5,111,690,000
Employee Compensation	\$931,740,000	\$1,718,190,000
Employment	7,757	28,604

ECONOMIC IMPACTS OF PRODUCT SALES

Some of the Ohio companies receiving funding or involved with the OTF-funded research commercialization projects have already increased product sales as a result of their involvement with the program. The OTF survey data indicate that these product sales totaled \$605.8 million from 2003-2008, and were spread across a variety of industries. Table 10 shows the direct economic output, employment, and wages and benefits supported by these company product sales and the total impact on Ohio’s economy when the indirect and induced impacts are calculated. These product sales support a total economic impact of nearly \$1.1 billion in economic activity, 9,201 jobs, and \$505.1 million in wages

²⁹ The Group of Twenty includes Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, UK, USA and European Union. Group of Twenty Meeting of the Ministers and Central Bank Governors in London, UK, March 13–14, 2009, Global Economic Policies and Prospects. <http://www.imf.org/external/np/g20/pdf/031909a.pdf>

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

and benefits. As discussed above, these figures would likely be higher if the overall economic environment was healthier.

Table 10. Economic Impacts of Product Sales		
	Direct Impact	Total Economic Impact
Output	\$605,808,484	\$1,098,030,000
Employee Compensation	\$341,330,000	\$505,120,000
Employment	4,736	9,201

ECONOMIC IMPACTS OF CONSTRUCTION

Detailed invoice data indicate that approximately 5.58 percent of overall OTF expenditures, from 2003-2008, were used for construction. Applying this percentage to total expenditures of \$4,227.3 million (the OTF investment plus matching and follow-on investment) yields the \$236.0 million estimate for the value of construction, which was then used to estimate the economic impact. New construction of research and manufacturing facilities is estimated to support over \$400 million in new economic activity, 3,488 jobs, and \$1446.8 million in wages and benefits.

Table 11. Economic Impacts of Construction		
	Direct Impact	Total Economic Impact
Output	\$236,042,585	\$401,550,000
Employee Compensation	\$91,840,000	\$146,840,000
Employment	2,141	3,488

INCREASING THE AVAILABILITY OF EARLY-STAGE CAPITAL

ABSTRACT

Have Ohio's TBED programs led to an increase in early-stage capital for Ohio technology companies? Risk capital is the lifeblood of new technology companies, and institutional venture capital is but one part of a larger continuum of capital sources which come into play at different periods in a company's development. The availability of early-stage capital is critical for ensuring that a sufficiently large number of early-stage companies are being funneled into the venture capital pipeline. The OTF's Pre-Seed Funds and ESP Program, the Ohio TITC, and the OCF/OVCA aim to directly increase the availability of early-stage capital for Ohio technology startups and to indirectly affect the overall risk capital environment within Ohio. The early quantitative evidence is that early stage capital investment in Ohio has expanded significantly during the five-year period from 2004-2008.

According to data collection and analysis by Ohio State University's Center for Entrepreneurship, total pre-seed/seed and early-stage venture capital investment in Ohio expanded by 18.5 percent per year between 2004 and 2008 (from \$127.9 million to \$298.3 million). Total venture capital investment in Ohio grew by 13.2 percent per year (from \$243.0 million to \$445.6 million)—more than double the growth rate of U.S. total venture capital investment (5.1 percent per year) from 2004-2008.

It has long been recognized that risk capital is the lifeblood of technology-based ventures.³⁰ However, the question of which comes first, the high risk capital dollars or the investment-worthy deals, is hotly debated. Pre-seed funds, angel investors, and venture capitalists will say they go where the deals are. Technology entrepreneurs will say many good technologies and business ideas are stifled by the absence of high-risk, early-stage capital. As Frank Samuel, the former Ohio Governor's Science and Technology Advisor, stated, "The reason you want venture capital dollars is not just for the investment in one firm, but to make possible the work [of venture capitalists] to identify deals. The venture capital activity is what's critical."³¹ This is to say that early-stage investors and venture capital firms are a critical part of the techno-entrepreneurial equation for three important reasons: (1) to bring early-stage

³⁰ See Hellmann, T.F. & M. Puri (2000). "Venture Capital and the Professionalization of Start-up Firms: Empirical Evidence," Research Papers 1661, Stanford University, Graduate School of Business, and Engel, Dirk (2002), The Impact of Venture Capital on Firm Growth: An Empirical Investigation, ZEW Discussion Paper No. 02-02, Mannheim.

³¹ Interview with Frank Samuel on February 3, 2009.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

financing to startup companies, (2) to provide these startups with the professional management assistance required to scale up operations, and (3) to attract follow-on investments from other private investors and to bring more venture capital funds to Ohio.

Despite the critical importance of experienced early-stage capital, the national trend has been for venture capitalists to move increasingly toward later stage deals. According to MoneyTree data, nationally, the share of total venture capital investments in startup/seed-capital stage investments declined from 16 percent in 1995 to 2 percent in 2001 and the years immediately thereafter. In 2008, startup/seed-capital stage investments still accounted for only 5 percent of total venture capital investments and early-stage investments for 19 percent. Ohio has followed this national trend with startup/seed-capital and early-stage investments accounting for a similarly small fraction (0-2 percent and 13-19 percent, respectively) of total venture capital investments pre-OTF and OCF/OVCA.³²

Venture capital is part of a larger continuum of capital sources which come into play at different periods in a company's development (see Figure 10). Ideally, a region would like to see a large pool of startup companies entering the commercialization and venture capital pipeline. If the number of startups is severely constricted by lack of early-stage funding (and business support services), then it is unlikely that a region will see the handful of companies that emerge at the end as the Google or the Genzyme Corporation—where much of the economic development impact is seen. Numerous studies point to the fact that states are missing out on job and revenue opportunities by failing to provide adequate seed capital to bolster emerging startup companies.³³

Bringing Out-of-State Venture Funds to Ohio

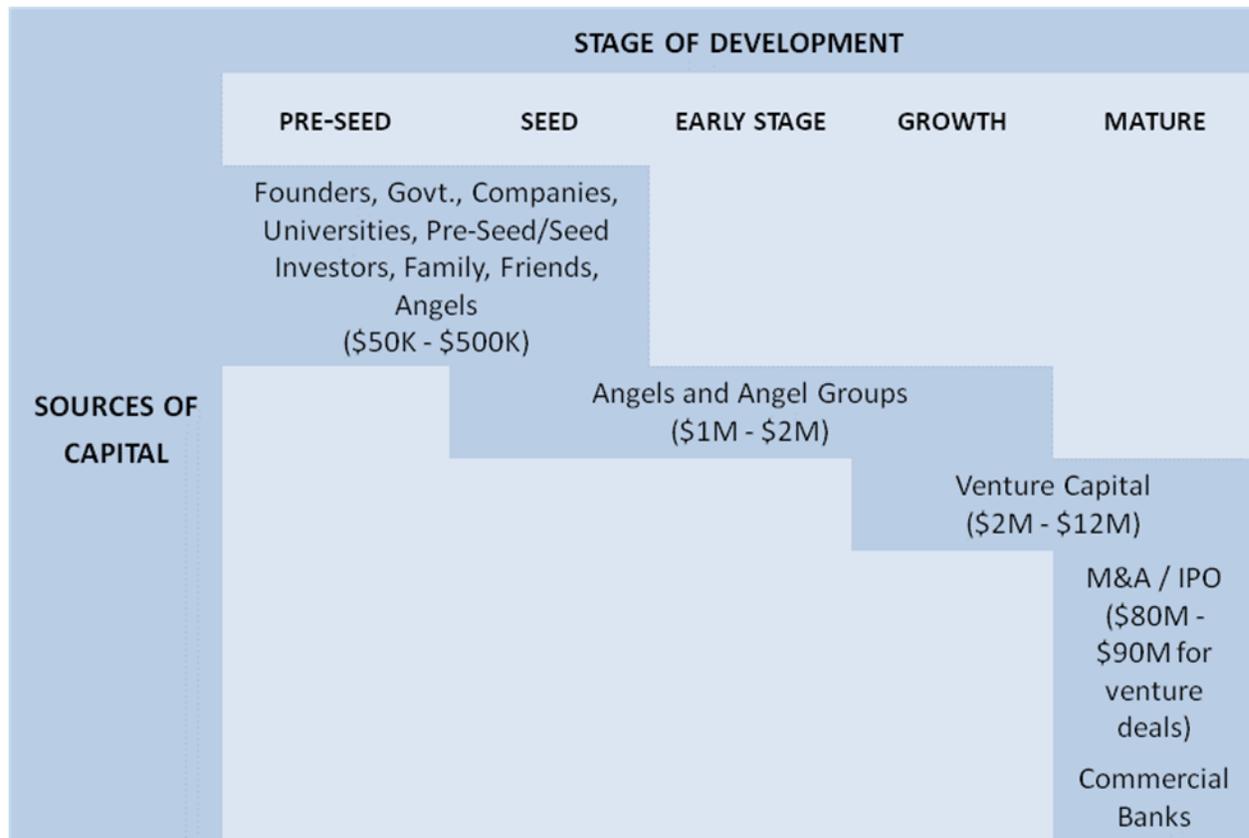
A \$6 million commitment from the OCF/OVCA enticed Menlo Park, CA-based Draper Fisher Jurvetson (Draper Triangle Ventures) to open two offices in Ohio. Since then, Draper Triangle has been a lead investor in many Ohio startups including a \$750,000 seed investment in CardioInsight Technologies, a Cleveland-based medical device company. The investment enabled CardioInsight to conduct clinical trials to validate its technology and to devise a market entry strategy.

³² MoneyTree database (2008). PricewaterhouseCoopers, National Venture Capital Association, Thomson Financial survey of institutional venture capital investments.

³³ See "Start-ups are key to growth, but need funding study says: Excell Partners' report says New York needs to do better," *The Buffalo News*. 2 July 2009, <http://www.buffalonews.com/145/story/711822.html>

Making an Impact

Figure 10. Sources of Capital at Different Stages of New Company Development



Note: Estimated deal size range or average in parentheses. K: thousands of dollars; M: millions of dollars; M&A: Mergers and Acquisitions; IPO: Initial Public Offering

Source: Data from Excell Partners (2007), “Company Start-Up Stages,” <http://www.excellny.com/> and Thomson Venture Economics, National Venture Capital Association, Center for Venture Research, and PwC MoneyTree in NGA Center for Best Practices, “State Strategies to Promote Angel Investment for Economic Growth,” *Issue Brief*. 18 February 2008.³⁴

In response to the need for increasing the availability of risk capital at all stages of company development, the State of Ohio instituted a number of programs via the OTF and related initiatives, including the OTF’s Pre-Seed Funds and ESP Program, the Edison Technology Incubators, the Ohio TITC, and the OCF/OVCA.

³⁴ Sources of capital data come from Thomson Venture Economics, National Venture Capital Association, Center for Venture Research, PwC MoneyTree.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The impacts of the entrepreneurial assistance programs are discussed in the following chapter. The assistance programs were designed to provide the disciplined screening and guidance to promising startup companies which help them attract equity investments from inside and outside the state.

On the risk capital supply side, the OTF has helped establish 46 new Pre-Seed Funds since 2001.³⁵ The aim of this Initiative is to expand the number of professionally managed, pre-seed/seed investment funds to support promising Ohio startup technology companies at the earliest stages. Importantly, this pre-seed/seed investment and business assistance prepares portfolio companies for early-stage investment from angel or venture capital investors. Between 2001 and 2008, Ohio's Third Frontier invested \$34.8 million in pre-seed funds across the state. These pre-seed funds have, in turn, invested \$24.2 million of this money in 206 Ohio companies and leveraged a cumulative \$619.1 million in follow-on investments which has resulted in \$316.1 million in product sales since 2001. Again it is important to note the product sales will lag investment by several years as products are commercialized and enter the market.

The state also established the Ohio TITC in 1996 and the OCF/OVCA in 2003. Both of these programs provide incentives to encourage private investors to look for Ohio-based investment opportunities. The TITC provides a tax credit to Ohio residents and companies for early-stage capital investments in Ohio technology companies. As mentioned earlier, angel investors fill a critical investment space today, a space that was largely filled by institutional venture capitalists 15 years ago—seed and early-stage capital. A 2005 Kauffman Foundation study found that angel investors are responsible for up to 90 percent of early-stage equity investment in startup companies not obtained from friends or family.³⁶ Angel investors are not bound by state borders. To encourage angels to look for investment

CleveX ExiClip Device Poised to Seek FDA Approval

CleveX, Inc., a Columbus-based dermatological medical device company, was able to leverage Ohio's TITC to raise a \$1.65 million first round of financing led by the Ohio TechAngels Fund. This pre-seed fund was capitalized with support from the Ohio Third Frontier. The early-stage investment enabled CleveX to complete its flagship product's design and testing, and to seek FDA approval. A follow-on \$1.65 million investment was led by Reservoir Venture Partners, a Columbus-based venture capital fund leveraging the OCF/OVCA.



Image (above): ExiClip
Source: CleveX

³⁵ Some of the State funding for the Pre-Seed Funds pre-date the OTF, but were folded into the OTF along with Technology Action Fund (also referred to as the Third Frontier Action Fund).

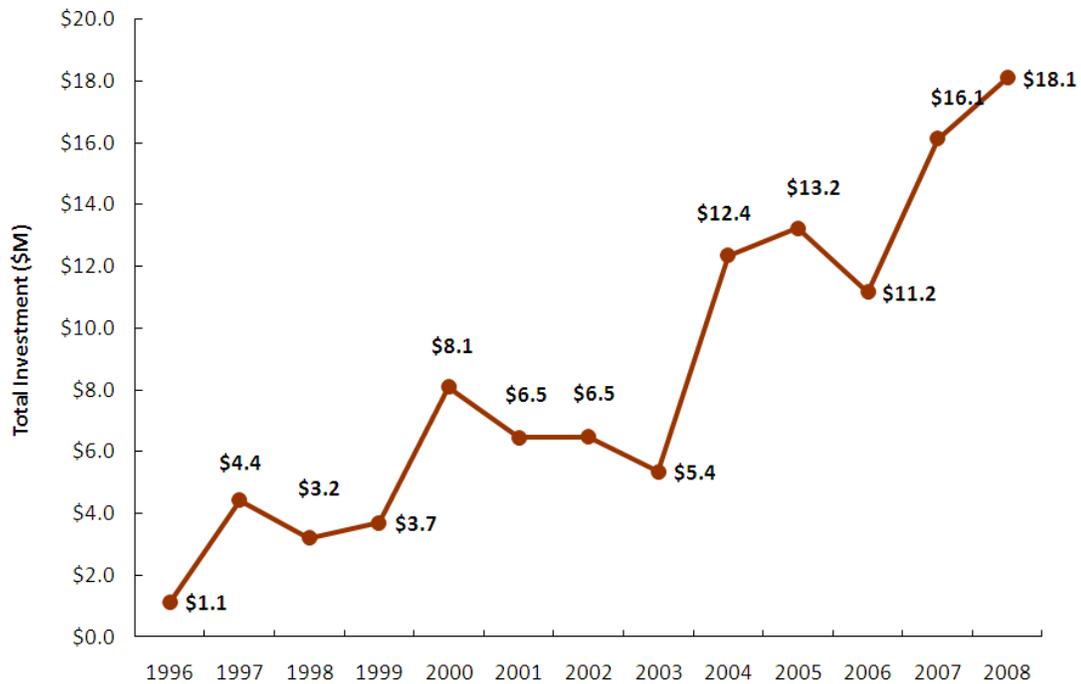
³⁶ Marianne Hudson (2006), "Why Entrepreneurs Need Angels—and How Angels Are Improving," in *Kauffman Thoughtbook 2005*, pp. 156–160.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

opportunities in their home states, many states have established angel investment tax credits for individuals and/or companies that invest in startup technology companies meeting certain requirements. In 2008, 20 states had implemented such programs, including Ohio.³⁷

Chart 11. Annual Private Capital Investment-Leveraged by the Ohio Technology Investment Tax Credit, 1996-2008



Source: Ohio Department of Development

Between 1996 and 2008, \$28.5 million in tax credits supported total investment by private investors of \$109.8 million in 422 early-stage Ohio technology companies. This represents a nearly \$4 return on every \$1 of state investment. Chart 11 tracks the total annual private investments leveraged by the program. Total annual investments in technology startups doubled from 1997-2000, during the dotcom bubble buildup, to \$8.1 million. With the bursting of the bubble, leveraged investments trended downwards through 2003 to \$5.4 million. In 2004, investments recovered strongly to \$12.4 million and trended upwards growing to \$18.1 million in 2008.

The strong, positive growth of investments leveraged through the TITC program over its 12-year lifespan suggests growing technology-based entrepreneurial activity, the ability of angel and other private investors to find these investment opportunities, and positive returns resulting from some of these

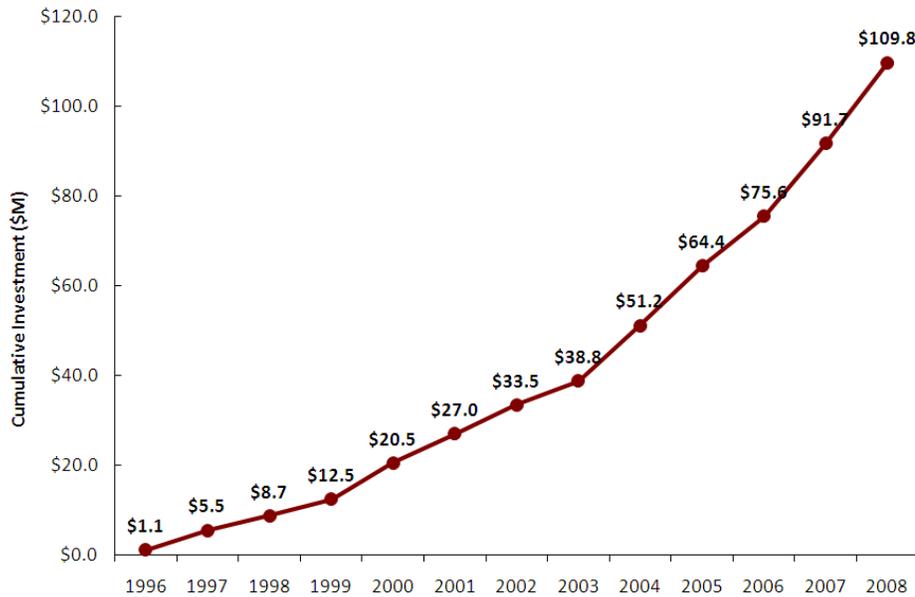
³⁷ States with angel investment tax credits include Arizona, Hawaii, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Michigan, New Jersey, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Vermont, Virginia, West Virginia, and Wisconsin.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

investments—if investors were consistently losing money, one would expect investments to level off or decline over time. At the aggregate level, the impacts of the OTF Pre-Seed Funds and ESP Program and TITC are reflected in the impressive growth of pre-seed/seed and early-stage venture capital investments (\$127.9 million in 2004 to \$298.3 million in 2008), which experienced average annual growth of 18.5 percent compared to 8.9 percent growth nationally.

Chart 12. Cumulative Private Capital Investment-Leveraged by the Ohio Technology Investment Tax Credit, 1996-2008



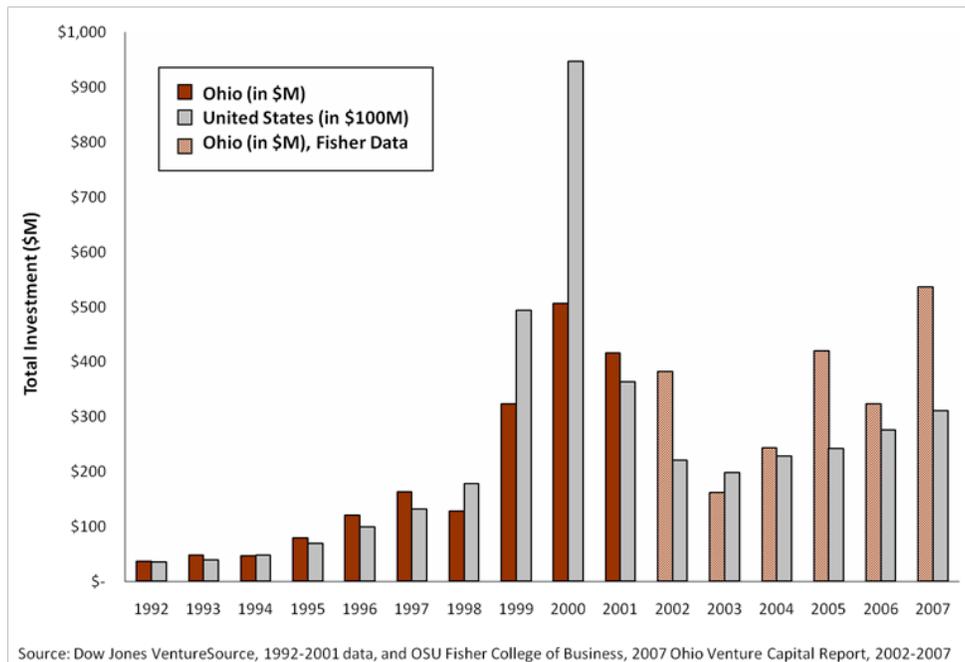
Source: Ohio Department of Development

Ohio's third key program, the OCF/OVCA, seeks to counter the historic tendency of venture capital firms and investments to concentrate in a small number of regions. According to VentureSource data, in 2007, nearly 60 percent of total U.S. venture capital investments went to two states: California and Massachusetts. Another 13.2 percent went to New York, Washington, and Texas. Therefore, five states accounted for nearly three-quarters of venture capital investment in 2007. Studies have found a number of reasons for this geographic concentration of venture capital on the East and West coasts and in Texas: outside of these regions there is more limited deal flow, higher costs per investment, and more limited opportunities for exiting deals.

Ohio has historically attracted only a very small share of total U.S. venture capital investment—smaller than Ohio's share of the U.S. economy. In 2003, the OCF was created through the OVCA as a "fund of funds" to attract more venture capital and venture capital firms to the state. The OCF screens and makes investments of up to \$10 million in third-party venture capital funds. Seventy-five percent of OCF monies must be invested in venture capital firms with an Ohio presence. All firms in which the OCF commits funds agree to invest at least half of these funds in early-stage, Ohio-based companies.

Making an Impact

Chart 13. Comparison of US and Ohio Venture Capital Investment Trends, 1992-2007



From program creation through December 31, 2008, the OCF's underlying funds had drawn \$34.1 million from the OCF and invested \$74.9 million in 30 early-stage Ohio technology companies. Other investors invested an additional \$115 million into these same investment rounds. Therefore, each \$1 invested by the OCF/OVCA leveraged \$2.19 of additional investment in Ohio-based companies by the underlying funds and an additional \$5.56 from other investors.

Looking at broader venture capital trends in the state, Chart 13 compares U.S. and Ohio venture capital investment over the period 1992-2007. The data is scaled so that U.S. venture capital investment is read in hundreds of millions of dollars and Ohio venture capital investment is read in millions of dollars. From 1992-1997, Ohio represented between 1.0 and 1.2 percent of total U.S. venture capital investment. By comparison, Ohio's economy accounted for 4 percent of U.S. gross domestic product in 1997. Ohio missed the 1998-2000 buildup of the dotcom bubble, dropping to one half of 1 percent of total U.S. venture capital investment in 2000. Following the bottoming out of the venture capital market in 2003, notable improvement is then seen from 2004 onwards. Venture capital investment in Ohio grew from \$243 million in 2004 to \$536 million in 2007, reflecting a compound average annual growth rate of 21.9 percent compared to 5.1 percent growth nationally.³⁸ The significant growth of venture capital investment in Ohio over the past five years has increased Ohio's share of total U.S. venture capital investment, pushing it close to 2 percent of total U.S. venture capital investments in 2005 and 2007.

³⁸ Camp, M., K. Parekh, and T. Grywalski (2008). *2007 Ohio Venture Capital Report*. Fisher College of Business, Ohio State University.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Comparing the periods before and after the dotcom bubble peak in 2000, Ohio has made considerable progress in attracting venture capital investments in a short period of time. According to the OCF/OVCA and ODOD, 50 percent of the OCF underlying funds' investments have gone to companies that received previous investments from pre-seed funds capitalized with support from the OTF.

At the state level, the data reflect significant growth in both pre-seed/seed and early-stage investments, as well as total venture capital investment in Ohio companies during the 2004-2007 period, which is significantly higher than pre-OTF and OCF/OVCA activity. This finding supports the state's efforts to provide a comprehensive set of programs which address both the demand side (getting technology startups to the point where they can attract angel and institutional venture capital investment) and supply side (providing incentives to increase angel and venture capital presence and activity in the state and connecting these investors to companies).

"Green" Lighting for the Darkest Places

Wireless Environment is a Northeast Ohio company making LED lighting products. Wireless received Ohio Third Frontier-supported pre-seed capital investments from the Great Lakes Innovation and Development Enterprise (GLIDE), an Edison Incubator, and from the Lorain County Community College Innovation Fund to develop its technology and products. The company then received \$400,000 in early-stage investment from JumpStart, an Ohio Third Frontier-supported ESP, to develop patents and prototypes. The company believes this early funding helped get it to the point where it could attract significant downstream venture capital funding.



Images: Wireless Environment co-founder and President, David Levine, and Wireless outdoor portable fixtures which debuted in April 2009

Photo Credit: JumpStart and Wireless Environment, LLC.

IMPROVING THE ENVIRONMENT FOR TECHNOLOGY ENTREPRENEURS

ABSTRACT

Have Ohio's TBED programs led to an increased number of technology startups and entrepreneurial activity? Entrepreneurship is a driving force of innovation and economic growth, yet entrepreneurs face significant challenges in transforming a commercial opportunity into a viable business. In Ohio, the OTF Pre-Seed Funds, the OTF ESP Program, and the Edison Technology Incubators are key resources for helping translate innovative ideas into investment-worthy companies through business assistance and pre-seed investments. Survey and investment data indicate these programs are having a positive impact on Ohio's entrepreneurial activity.

OTF-supported Pre-seed funds have invested \$24.2 million in 206 Ohio companies and leveraged a cumulative \$619.1 million in follow-on investments and \$316.1 million in product sales between 2001 and 2008. Funded only since 2007, the OTF's six ESPs invested \$35.7 million in providing direct business assistance and pre-seed capital funding to 81 companies. Through December 2008, these investments generated follow-on equity investments and funding for the companies totaling \$150 million. Moreover, most ESPs have found that "deal flow"—i.e., identifying and concluding investments in startup companies—has not been a problem. In fact, some regions reported excess deal flow (more potential deals than they were able to invest in had more funding been available), boding well for the state's innovation pipeline. Finally, for the fiscal year ending June 2008, Ohio's 13 Edison Technology Incubators supported 270 startup companies which reported \$262.2 million in product sales, research grant awards (e.g., SBIR, STTR, etc.), and other revenue, and \$120.8 million in equity investments. These three Ohio programs directly aimed at supporting and encouraging growth in technology-based entrepreneurial activity are yielding a high return on the State's investment.

Entrepreneurial activity is critically important to regional economic development, because it drives industrial innovation and new business formation. Almost by definition, the founders of technology-based startup companies are innovators—focused on capitalizing on commercial opportunities arising from introducing a new product, enhancing a service, making a delivery system or production process more efficient, more user-friendly, or less expensive. The founders of startup companies typically come from established, larger companies, motivated by the identification of an unexploited commercial

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

opportunity and willing to take the risk that the larger company is not. It is, therefore, not surprising that entrepreneurial activity and innovation are strongly correlated.

Moreover, recent research by the U.S. Small Business Administration indicates that startups are a key determinant in a state's economic success. The SBA's researchers found that raising the number of small-business startups by 5 percent tended to boost gross state product by 0.465 percent, increase a state's employment growth by 0.435 percent and raise personal income by 0.405 percent. Based on the median number of small-business startups across all 50 states per year, a 5 percent increase was equal to roughly 445 new small businesses.³⁹

Because a high degree of uncertainty accompanies new technology-oriented commercial opportunities (e.g., related to market risk, regulatory approval, or technical or cost challenges in commercializing the technology), these ventures are considered too risky by most traditional sources of capital. In addition—and perhaps especially the case with entrepreneurs in technology companies—the entrepreneurs may be highly knowledgeable about their product or technology, but much less experienced in business planning and development, marketing, human resources, and other aspects of business operation. A lack of both capital and business experience is why most startups fail, and these two reasons are related.

As discussed in the previous chapter, angel investors and venture capital are attracted by investable deals—startups that not only have a proprietary technology, but which also have a solid business plan based on a robust market assessment, the identification of customers, a prototype of their product and validation that cost and technical barriers to production have been overcome. The challenge is in moving from the raw idea to an investable deal, and this is where the OTF Pre-Seed Funds, the OTF ESP Program, and the Edison Technology Incubators are focused.

Reducing Healthcare Costs Through Innovative Software

Columbus-based HealthCare Transaction Processors Inc. (HTP) provides secure software which promotes timely reimbursement for patient services. Twelve-year-old HTP Inc. was acquired by the technology arm of health-care giant McKesson Corp. in 2008. The acquisition followed strong year-on-year revenue growth placing HTP on the Inc. 500 list of the fastest-growing, privately-held companies in 2004 and 2005. Founded in 1996, HTP was one of the first companies to get startup advice and an early loan (later turned into equity) from TechColumbus, an Edison Technology Incubator. It was also the first company in the state to be granted an OTF Innovation Ohio loan.



³⁹ Bruce, D., et al (2007). "Small Business and State Growth: An Econometric Investigation," U.S. Small Business Administration Office of Advocacy.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The OTF's Pre-Seed Fund Program aims to expand the number of professionally managed, pre-seed/seed investment funds to support promising Ohio startup technology companies at the earliest stages. Importantly, this pre-seed/seed investment and business assistance prepares portfolio companies for early-stage investment from angel or venture capital investors. The pre-seed funding may be used by startup companies to develop a prototype, apply for a patent, develop a market opportunity analysis, etc. Between 2001 and 2008, the 46 OTF-supported pre-seed funds invested \$24.2 million in 206 Ohio companies and leveraged a cumulative \$619.1 million in follow-on investments and \$316.1 million in product sales.

The Edison Technology Incubators assist technology-oriented startup companies during their concept definition and business development stages. The incubators connect early-stage companies to business assistance, mentoring, investment capital, and physical space. Annual operating support from the State of Ohio for the Edison Technology Incubators ranges from \$200,000 to \$500,000 per incubator for a total annual investment of approximately \$4 million. The return on this state investment is quite significant. For the fiscal year ending in June 2008, the 270 client companies supported by Ohio's 13 Edison Incubators reported⁴⁰:

- Product sales, research grants (e.g., SBIR, STTR, etc.) and other revenue of \$262.2 million;
- Equity investments by private investors, venture capital funds and others of \$120.8 million;
- Total employment of 2,247 people; and
- Average salaries of \$50,768.

The objective of the OTF's ESP Program is to significantly advance the growth of technology-based entrepreneurial ventures and to focus the effort on strategic technology-based sectors that offer exceptional economic development prospects for the region. The ESPs operate in six defined geographic regions across the State of Ohio.

From 2007 through 2008, the six ESPs were awarded \$84.8 million by the Ohio Third Frontier and invested \$35.7 million in providing direct business assistance and making pre-seed capital investment in 81 companies. These investments have resulted in additional funding and follow-on equity investments by private investors and venture capital funds, totaling \$150 million. Moreover, most ESPs have found that identifying and concluding investments in startup companies, commonly referred to as "deal flow," has not been a problem. In fact, half of the ESPs reported excess deal flow, i.e., deals they would have liked to invest in had even more investment capital been available.

All of Ohio's ESPs are able to point to significant examples of success since their OTF awards in 2007. For example, Akron-based Rexorce Thermionics is an Ohio startup based on a technology to convert "waste"

⁴⁰ Ohio Department of Development, Edison Technology Incubator metrics for FY2008.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

heat into electricity for Ohio homes and businesses. Waste heat recovery solutions are in high demand by the industrial sector looking to offset rising energy costs and gain a competitive cost advantage. The industrial sector accounts for one-third of total energy consumption in the US.

Rexorce began in April 2007 as a two-person startup housed in the Akron Global Business Accelerator, an Edison Incubator. Today, Rexorce has 20 employees, and is working on raising its second round of venture capital to support the expansion of its proprietary heat recovery system to a number of heavy industry and automotive markets.

As a promising startup that could demonstrate the strong commercial potential of its technology, Rexorce received several types of assistance from Ohio's network of technology programs

including the OTF's ESP. Rexorce received \$400,000 in seed capital in 2007 from JumpStart, the Northeast Ohio ESP, which enabled the company to build a 15-kilowatt prototype of its heat engine at the Akron Global Business Accelerator, an Edison Technology Incubator. In mid-2008, the company was directly awarded a \$4.3 million OTF grant which it used to develop an industrial-scale, 250-kilowatt prototype system for deployment at demonstration sites. Rexorce's venture advisors from JumpStart, the Northeast Ohio ESP, have advised the company through some 25 presentations to venture capitalists. The company successfully raised a \$9 million series A round of financing from venture capitalists and is working on raising its second.

In Southeast Ohio, Global Cooling Manufacturing is an Athens-based startup built on vastly more energy efficient and environmentally friendly refrigeration technology. Global Cooling uses a Stirling cooler to move heat as opposed to the compression and expansion of a refrigerant chemical, commonly used in modern refrigerators. Global Cooling's technology is especially good (and comparatively less expensive) for reaching the "ultra cool" range (-135°C to -80°C), which is used in niche markets like biomedical storage.

Global Cooling received advice on licensing and intellectual property from TechGrowth, Southeast Ohio's ESP. The company also received a small grant from the ESP to work on developing their business plan and strategy. In December 2008, Global Cooling was awarded a \$1 million OTF Advanced Energy Program grant to commercialize a larger capacity cooler which can be incorporated into an ultra-low

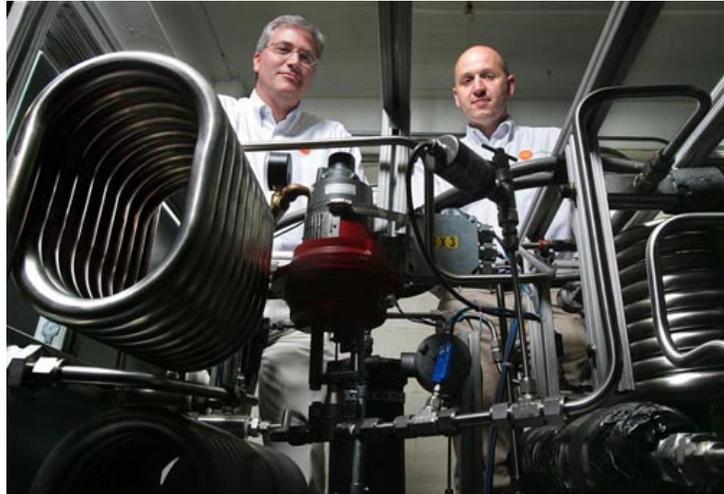


Image: Rexorce co-founders, Michael Gurin (L) and Phil Brennan (R)

Photo credit: Rexorce Thermionics

Making an Impact

Assessing the Benefits of Ohio’s Investment in Technology-Based Economic Development Programs

temperature freezer. Two alpha prototypes will be constructed and tested followed by the production of three beta-level prototypes that will undergo life and reliability testing.

Table 12. Ohio Third Frontier ESP and Pre-Seed Fund Success Stories	
REGION	SUCCESS STORIES
Northeast	Rexorce Thermionics (heat recovery system), founded in 2007 Services received: Akron Global Business Accelerator (Edison Incubator); JumpStart TechLift business guidance and pre-seed investment; TechLift Business Intern program Results: series A financing round of \$9 million, 20 new jobs
Northwest	Xunlight (thin-film PV modules), founded in 2002 Services received: \$1 million early stage funding from Rocket Ventures, OTF Research Commercialization Program awards Results: \$40 million in follow-on equity investment resulting in installation of first production lines in June 2009; hundreds of new jobs anticipated over next few years.
Central	HTP (software), founded in 1996 Services received: TechColumbus entrepreneurship assistance and BioOhio loan of \$100,000 in 2000, later converted into equity; \$750,000 loan from Innovation Ohio Loan Fund Results: acquired by McKesson’s RelayHealth (\$30 billion in annual revenues) in 2008; 70 employees in Columbus
Southwest	Akebia Therapeutics (drugs for anemia and peripheral artery disease), founded in 2007 Services received: \$1.15 million pre-seed investment from TF-supported pre-seed funds operated by CincyTech, Queen City Angels and other investors; collaborator on Mega-Wright Global Cardiovascular Innovation Center award (received \$500,000 research grant); entrepreneurial support from BIO/START and BioOhio Results: \$15.1 million early-stage equity investment, Phase I clinical trials; diversification into other therapeutic programs
West Central	Renegade Materials (high-temperature composite fibers for aircraft engines and other applications), founded in 2006 Services received: two OTF Research Commercialization Program grants with the University of Dayton and Zyvex Performance Materials; entrepreneurship assistance and equity investment from ESP Results: construction of manufacturing facility; plans to expand from 12 employees to 65 employees with \$15M in revenue over next five years
Southeast	Global Cooling Manufacturing (energy efficient refrigeration) Services received: \$1 million Third Frontier grant, entrepreneurship assistance Results include: new Ohio-based customer, energy savings

Source: ESP Survey, April-May 2009.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

By bringing risk capital, as well as technical and business assistance to Ohio technology companies in the earliest stages of development, the evidence suggests that the OTF and Edison investments are leading to an increase in technology startups and entrepreneurial activity in Ohio. Such an environment affords the state the opportunity to diversify its economy and stimulate economic growth from within the state, complementing the state's other economic development efforts.

INCREASING R&D CAPACITY AND IMPROVING RESEARCH COLLABORATION

ABSTRACT

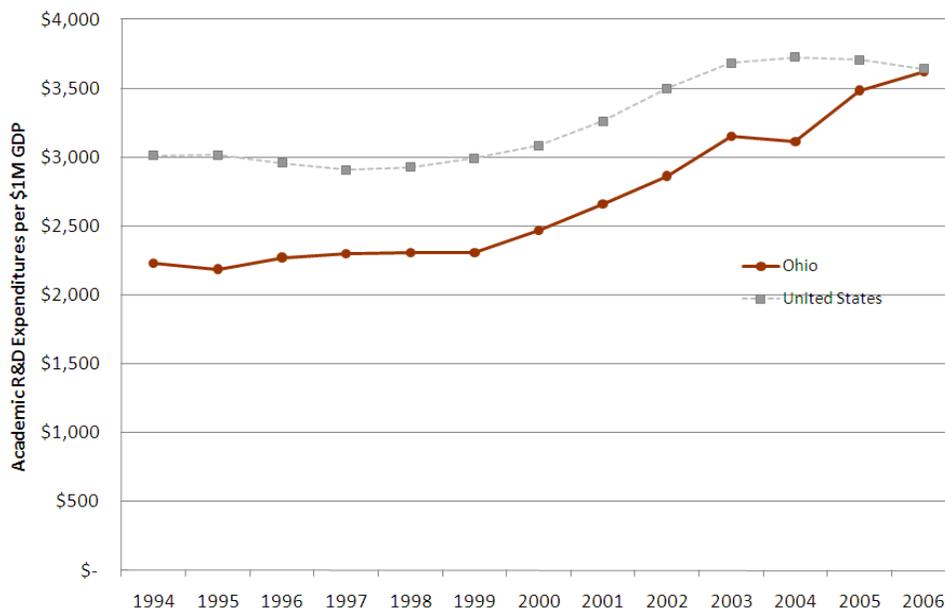
Have Ohio's TBED programs expanded R&D capacity in Ohio, increased university-industry research collaboration, and enhanced the commercial relevance of university research? Several OTF programs, including the Research Commercialization Program, the Wright Projects, the Wright Centers of Innovation, and the Ohio Research Scholars Program are aimed at connecting Ohio university research to Ohio's industrial needs. The state programs have supported a number of organizations that have served to form networks and develop and implement strategies that bring together universities, industry, and other research and business organizations. Indicators of technology transfer, as well as interviews with OTF stakeholders suggest that these programs have encouraged university-industry partnerships and increased the focus of university research on Ohio industrial opportunities. They have also supported improved research facilities and equipment that have enabled Ohio universities to win Federal and other R&D grants.

A key aspect of effective technology-based economic development is to have a region's research institutions strongly connected to local industry. A primary objective of the OTF and related programs is to make Ohio an international leader in research and technology platforms aligned to Ohio's existing and emerging areas of industrial strength. What evidence is there that the OTF and related programs are, or are not, succeeding?

The quantitative data on R&D in Ohio, presented in the previous section "Analysis of Ohio's Research & Development Capacity, 1980-2007," does not fully answer this question. Total state R&D, as shown previously, is relatively flat. This stagnation, however, is primarily due to the decline in manufacturing, which supports most industrial R&D. Academic R&D in Ohio, by contrast, has increased significantly in recent years, as shown in Chart 14. Ohio, which had been lagging behind the national average in academic R&D expenditures as a share of GDP, has now caught up.

Making an Impact

Chart 14. Academic R&D Expenditures Relative to Size of Economy in Ohio and the US, 1994-2006



Source: National Science Foundation and US Bureau of Economic Analysis

Although increasing academic R&D is not the primary goal of the OTF, the OTF's contribution to increased academic R&D is important because it is focused on building academic research in economically important areas and in building connections between academia and industry. Universities that conduct research that is well connected to companies can form the anchor of a region. Such universities both generate new ideas and train people, and, unlike companies, universities are firmly locked to a region.

The data that pertains to university technology transfer, as shown previously in Table 6, also supports the hypothesis that Ohio's research capacity is becoming better connected to industry. Licensing income to Ohio's universities more than doubled from \$16.1 M in 2002 to \$39.6 M in 2007 and the number of university-based startups is increasing. Although there remains work to be done, OTF has significantly strengthened linkages among universities, industry, and research laboratories, especially in the targeted technology areas.

OTF funding is also focused on increasing R&D in specific technology areas. While available data do not provide information on R&D funding in specific technology areas at the state level, the magnitude of the OTF funding, combined with Federal and industrial matching of OTF awards and follow-on funding, makes it highly likely that Ohio R&D has increased academic R&D in the targeted technology areas and in areas that meet the specific needs of Ohio current and emerging industries. The Wright Projects, Wright Centers and Ohio Research Scholar awards have enabled academic institutions to acquire specialized equipment, build special facilities, and hire top faculty to conduct applied research in areas

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

valued by industry research partners. The Wright Projects and Research Commercialization Program have further stimulated and rewarded research collaboration partnerships and specific commercialization projects. These programs have enabled Ohio universities to leverage out-of-state funds, including Federal, industrial, and foundation support, all focused on specific areas of technology.

Although the quantitative data is limited in documenting the effect of the OTF on R&D capacity and university-industry-collaboration, there is substantial evidence coming from the stakeholder interviews and case studies. Interviews with stakeholders clearly indicated that the OTF is improving both the research infrastructure and research collaboration in the state. The vast majority of stakeholders interviewed responded that the Ohio programs had “some” or “a lot” of impact on industrial and academic R&D infrastructure, industrial R&D activity, and the commercial relevance of academic R&D. Many interviewees noted that there is now a strategy that links academic R&D with industrial performance, and that the OTF has stimulated much university-industry collaboration. For example, while university research centers, such as the Liquid Crystal Institute at Kent State University, used to license their technology to overseas companies, now there is a strategy and connection to industry that is leading to technologies being commercialized in Ohio.

Of particular importance, the OTF and Edison Program have supported Wright Centers and Edison Technology Centers that function as “bridging organizations” that build effective state strategies and linkages between companies, universities, Federal laboratories, and other research institutions. Such organizations are widely recognized to be critical in economic development. SRI's interviews and case studies confirm that Wright Centers and Edison Centers have played an instrumental role in bringing together a broad array of actors to support research and commercialization of technologies. For example:

- BioOhio, an Edison Center, has brought together bioscience resources in the state, including leading medical centers, universities, companies, and sources of financing, to accelerate Ohio's bioscience industry development, research, and education.
- PolymerOhio, also an Edison Center, has linked resources from academic institutions, economic development resources and service providers with companies to promote the Ohio polymer industry's global competitiveness and growth.
- The Ohio Fuel Cell Coalition (OFCC), formed with initial funding from the ODOD, is now a consortium of 200 companies, academic institutions, and government organizations that helps to organize the state's fuel cell companies into an industry with shared goals.
- The Institute for the Development and Commercialization of Advanced Sensor Technology (IDCAST), a Wright Center based at the University of Dayton, has helped to connect Ohio sensor technology companies with Ohio universities and laboratories, especially the Air Force Research Laboratory (AFRL), to enable both research collaboration and market development.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

- The Global Cardiovascular Innovation Center, a Wright “Megacenter”, is bringing together a variety of state resources to accelerate innovation in cardiovascular technology (see sidebar).
- The Ohio Bioproducts Innovation Center (OBIC), a Wright Center based at the Ohio State University (OSU), has developed strategies and linkages among Ohio's agriculture and advanced materials industries and research institutions to develop and commercialize renewable, bio-based specialty chemicals, polymers/plastics and advanced materials.
- The Wright Center of Innovation in Biomedical Imaging, based at OSU, serves as the focal point of collaboration between companies and medical researchers in biomedical imaging throughout the state and has helped to bring and retain jobs in Ohio.
- The Center for Multifunctional Polymer Nanomaterials and Devices (CMPND) at OSU, a Wright Center in advanced materials, brings together Ohio State with the University of Akron, University of Dayton, University of Toledo, Kent State University, and Wright State University and more than 60 company collaborators across Ohio. It has made advanced research tools and equipment available for Ohio researchers and companies.
- The Center for Photovoltaics Innovation and Commercialization (PVIC), a Wright Center at the University of Toledo that also includes OSU, Bowling Green State University, multiple Ohio companies, the U.S. Air Force, and NASA. The Center brings together researchers and industry partners to develop second- and third-generation photovoltaic materials for applications in clean electricity generation.

This is not a comprehensive listing, but these examples serve to illustrate the point that the OTF programs and Edison Centers have expanded Ohio's research capacity by building high quality research facilities, procuring world class equipment, and hiring world class faculty, and by linking these research capabilities to Ohio's companies through a variety of networks. Equally importantly, the OTF and Edison programs have brought together the academic and industrial communities to develop strategies and build collaborations to improve the competitiveness of the state in these technology areas.

Making an Impact

Ohio's Global Cardiovascular Innovation Center: Bringing Cardiovascular Innovations to the Market

Located near the main campuses of the Cleveland Clinic, Case Western Reserve University, and the University Hospitals, the Global Cardiovascular Innovation Center (GCIC) is a \$250 million cardiovascular research and product development consortium. GCIC was established in 2007 through a \$60 million OTF Wright Mega-Center of Innovation award. The GCIC is focused on the formation, attraction, expansion and retention of cardiovascular companies to create jobs and facilitate economic development in the State of Ohio. Cardiovascular medicine is estimated to be a \$420 billion market opportunity in the United States. The Center supports innovative companies through research investments, collaborations with clinical scientists, and incubation support. The GCIC consortium is led by the Cleveland Clinic, and includes Case Western Reserve University, The Ohio State University, The University of Cincinnati, The University of Toledo, The University Hospitals of Cleveland, statewide economic development partners, and leading industry partners from across the country.

From 2007-2008, the GCIC has supported the following activities and achievements with OTF award expenditures of \$9.1 million:

- Generated \$24 million in follow-on Federal funding, equity investments and product sales.
- Spun off or made investments in the commercialization activities of 17 portfolio companies representing a range of diagnostic, treatment and monitoring advances in cardiovascular medicine and surgery.¹
- Awarded four patents and have seven patents pending.
- Attracted five companies to Ohio, such as Proxy Biomedical, a tissue engineering company from Galway, Ireland, which is establishing its North American headquarters in Cleveland, Ohio.
- Broken ground on a 50,000 square-foot incubator facility to expand and support companies

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The OTF programs have also increased Ohio's human resources for R&D through their training of students. Through participation in the Wright Centers, Wright Projects, and other OTF funded research, students are able to gain hands-on experience using state-of-the-art equipment to perform applied research in areas that are critical to Ohio industry. This makes them ideal entry-level hires by companies. A good example is the Gas Turbine Lab (GTL), part of the Ohio Wright Center for Advanced Power and Propulsion (OCAPP), based at Ohio State University. The lab conducts research to predict heat transfer loading, aerodynamic loading and other basic data to help validate engine design methods. Nearly all OSU undergraduate and graduate students who have worked in GTL go on to work for GE and other aerospace companies.



Image: Gas Turbine Lab Facility

Photo credit: Gas Turbine Lab, Ohio State University

Another example of students receiving hands-on training is the two-year associate's degree in mechanical engineering with a fuel cell track, offered by Stark State College of Technology in North Canton, Ohio. Students gain hands-on experience working on fuel cell design at Stark State's Fuel Cell Prototyping Center, and go on to work at Rolls-Royce Fuel Cell Systems and other regional employers.

In summary, there is substantial evidence that the OTF and related programs have expanded R&D capacity and improved R&D ties between industry, universities, and other research institutions in Ohio. They have done this through strategic investments in university facilities, equipment, and people, and investments in R&D consortia and networks in targeted technology areas. The result is that existing and emerging industries have better access to knowledge, research facilities, people, and other resources.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

CONTRIBUTING TO THE DIVERSIFICATION AND COMPETITIVENESS OF OHIO MANUFACTURERS

ABSTRACT

Have Ohio's TBED programs contributed to the diversification and competitiveness of Ohio manufacturers? Technology is important to existing manufacturers because of the new products which arise from technology development, and because the adoption of new technologies may result in more efficient (i.e., higher productivity) manufacturing processes. The use of technology by Ohio manufacturers make these companies more competitive and better able to maintain market share in a global marketplace. Ohio's technology programs—the OTF and the Edison Program—support both types of technology uses.

SRI's company case studies indicate that the OTF's direct investments in Ohio companies are helping traditional manufacturers retool and commercialize new products for new markets. On a broader scale, Ohio's seven Edison Technology Centers assist a variety of Ohio manufacturers by providing technical assistance, as well as serving as conduits to expertise in Ohio technology companies, universities, and research institutions.

Technology is important to existing manufacturers, both in terms of the new products which arise from technology development, and in terms of the adoption of new technologies which result in more efficient (i.e., higher productivity) manufacturing. The use of technology leading to product or process innovations by Ohio manufacturers makes these manufacturers more competitive and better able to maintain market share in a global marketplace. Ohio's technology programs—the OTF and the Edison Program—support both types of technology uses.

In the first case, the OTF has made direct investments in Ohio companies which are using R&D to retool to stay competitive. This can clearly be seen in Ohio manufacturers like American Trim. American Trim is a long-standing Ohio metal forming and coating company facing significant competitive pressures. In recent years, the company has won or been a collaborator on OTF grants to develop and commercialize new products. Support from OTF has enabled American Trim to develop a novel high-velocity metal forming technology which allows the company to produce fuel cell bi-polar plates for a fraction of what they currently cost.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The OTF's impact is also being seen in companies, like Pilkington and Owens Corning, which are using R&D to shift from the traditional production of glass and glass fibers to new cutting-edge materials for the photovoltaics and wind turbine markets. Owens Corning was a partner and recipient, along with the Center for Multifunctional Polymer Nanomaterials and Devices (CMPND) at OSU, of an OTF grant in 2007, to develop longer, stronger windmill blades using nanotechnology. Pilkington has been a recipient of OTF investments in Ohio's photovoltaics industry through the Photovoltaics Innovation Center (PVIC) at University of Toledo and direct company investments.

The OTF directly funds technology research and commercialization through a competitive proposal process. On a broader scale, Ohio's Edison Program has been assisting a broad array of Ohio manufacturers by providing on-demand, fee-for-service or membership dues-based technical assistance, as well as serving as conduits to expertise in Ohio technology companies, universities and research institutions. For example, the Center for Innovative Food Technology (CIFT), an Edison Technology Center in Toledo, provides technical assistance to Ohio food production, processing and packaging companies. CIFT made several contributions to the applied development and commercialization of innovative egg sterilization technology patented by OSU and licensed by a joint venture between three Ohio egg producers. Ohio is the second largest egg producer in the nation. CIFT engineers designed and constructed the original prototype for the production-scale sterilization system. CIFT also collaborated in the application and receipt of a USDA grant of \$100,000 which paid for a marketing consultant and the development of business models for launching the Egg Tech system in the marketplace.

ODOD partners with the NIST MEP to enhance the productivity, innovation and growth of small- and medium-sized manufacturers in Ohio. The NIST MEP is a national program whose primary mission is to improve the long-term viability of U.S. manufacturing by providing a wide array of business and

Advanced Technology Revitalizing a Traditional Manufacturer

American Trim is a metal forming and coating company founded as Lima Tool and Die in 1951. American Trim has emphasized innovation through R&D as a strategy to meet the challenge of international competition and the need for environmental responsibility. Support from Ohio's Third Frontier has enabled American Trim to develop a new "chrome-like" coating and a novel metal forming technology for fuel cell plates. As John Swigard, American Trim's Director of Marketing said in a magazine interview, "We're committed to applying the grants that we receive, and focusing our own research and development investments in time and money, to advancing technology in a practical way, so that we create jobs. That's our responsibility, and we intend to live up to it."

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

technical services and process improvements. Ohio's MEP program is administered by ODOD, and OHMEP services are provided through the Edison Technology Centers. These centers are supported by State and Federal funds, as well as funding from regional partners and fees paid by manufacturers for OHMEP services.

Technology programs take time to show results. In the Egg Tech example, the idea for using an ozone-based sterilization technology came about in the mid-1990s, and the first patent for the technology was applied for in 2001 and granted in 2004. It took several years to develop a prototype system, and then to test and refine it. FDA approval is anticipated in 2009, and the company can only begin to sell the system once FDA approval is granted. As a result of these time lags, it is too early to see measurable economic results from many of these technology-based economic development programs.

SUPPORTING THE EMERGENCE OF NEW HIGH-TECH INDUSTRY CLUSTERS

ABSTRACT

Have Ohio's TBED programs catalyzed the emergence of new technology clusters? Economic data, stakeholder interviews, and case studies strongly support the hypothesis that several new industry clusters are emerging in Ohio, fueled by the recent and on-going commercialization of new technologies. These emerging clusters include:

- **Biomedical Imaging:** 91 core companies anchored by Philips Medical, GE Healthcare, Siemens Medical, Hitachi Medical and Toshiba Medical. These five global leaders in biomedical imaging all have manufacturing and/or an R&D presence in Northeast or Central Ohio. Employment in this cluster grew by 86.7 percent between 2004 and 2008.
- **Photovoltaics:** 25 core companies and is anchored by First Solar, the second largest photovoltaics manufacturer in the world, and a number of promising startup companies on the cusp of commercialization-based production. Employment in this cluster grew by 38.4 percent between 2004 and 2008.
- **Fuel Cells:** 49 core companies located in different parts of the state. The cluster is anchored by Rolls-Royce Fuel Cell Systems, and a number of startup companies, several of which have moved to Ohio from California and elsewhere. Significantly, the cluster also includes a number of traditional Ohio manufacturers which are diversifying into the production of fuel cell materials and components, or working to incorporate fuel cell technology in their product lines. Employment in this cluster grew by 26.5 percent from 2004-2008.
- **Flexible Displays and Electronics:** 11 core companies, primarily startups like Kent Displays, Hana, and Alpha Micron, and builds on world-renown research at Kent State University's Liquid Crystals Institute. Employment in this cluster grew by 12.9 percent from 2004-2008.

All of these technology clusters strongly leverage Ohio's existing advanced manufacturing supply chain. Characterized by strong global demand and synergies with existing industries and research institutions in the state, these developing clusters look likely to help position Ohio for long-term, technology-led growth.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Even in an age of Blackberries, instant messaging and video conferencing, companies in similar industries benefit from being clustered in close geographic proximity. Industry clusters offer benefits such as lower cost of doing business, ease of sharing and exchanging workforce talent, and access to specialized material, component, or service providers.⁴¹ Industry clustering is particularly important to the development of emerging high-tech industries. The typical elements associated with emerging industry clusters include: an R&D-intensive industry base, world-class university research, scientific and technical professionals and skilled workers, and complementary and supporting industries.

OHIO'S PHOTOVOLTAIC CLUSTER

The Photovoltaics (PV) industry is based on solar cell technology that converts sunlight to electricity. Companies, suppliers and research institutions comprising Ohio's PV industry cluster are located predominantly in the Northwest region of the state, although the cluster is beginning to expand statewide. The industry is anchored by First Solar, the second largest PV manufacturer in the world, and many startup companies--most notably Xunlight. Ohio's PV industry has its origins in the Toledo region's long-standing glass industry. It evolved from an Edison Program-supported research and commercialization collaboration between the University of Toledo and GlassTech Solar (predecessor to First Solar) in the late 1980s and early 1990s. The state's investments in the industry provided the boost that was needed to commercialize early second-generation PV technology. Today, OTF investments are supporting the commercialization of new PV manufacturing processes and products by Ohio companies, the creation of PV startup companies, and R&D by the University of Toledo.

Ohio has always possessed many of the elements required as foundations for high-tech industry cluster formation and growth, but in many cases SRI's stakeholder interviews and case studies indicate there had been some critical pieces missing that prevented the successful formation of these clusters. Often, the missing pieces were a combination of funding for applied research, development and testing, and mechanisms to bring together all of the actors (various companies, research groups, and funding sources) with an interest in the technology. Many times the scale of the investments required to overcome the risks, including technical and cost barriers related to commercializing new technology, were so great that individual companies would not invest. Therefore, the State of Ohio has played an important role in providing investment for commercialization projects that can demonstrate technical capability and strong commercial potential.

⁴¹ These benefits were cemented by Harvard Business School's Michael Porter in his diamonds of competitiveness schematic that emphasizes the competitive benefits of having in proximity competitive firms, resource and talent inputs to these industries, sophisticated customer demand, and related and supporting industries.

Making an Impact

OHIO'S BIOMEDICAL IMAGING CLUSTER

The Northeast-Central Ohio corridor has a history of inventive biomedical imaging activity which has experienced a resurgence catalyzed by the Ohio Third Frontier's investments. Within the cluster's 91 core companies, all biomedical imaging modalities and applications are represented in Ohio, from molecular imaging to whole body imaging (e.g., MRI). The cluster is anchored by global biomedical imaging equipment leaders, e.g., Philips Medical Systems, GE Healthcare, Siemens Medical, Hitachi Medical and Toshiba Medical, in parallel with significant startup activity and the relocation and co-location of emerging biomedical imaging companies from Florida, New Jersey, China, etc. Ohio's Third Frontier has made critical investments in establishing a Wright Center of Innovation in Biomedical Imaging at OSU and Case Western, as well as through direct investments in Ohio imaging companies (e.g., Philips Medical Systems, Quality Electrodynamics, HyperTech, etc.) for technology commercialization.

OTF and Edison-supported organizations bring both resources and networks to support emerging clusters. The OTF is focused on supporting technical innovation and growth in five technology platforms important to Ohio's economy: Advanced Materials; Advanced and Alternative Energy; Advanced Propulsion; Instruments, Controls and Electronics; and Biomedical. These sectors were selected because they build on existing competitive advantages and industrial and research assets in the state. Through the meaningful level of funding provided by the Ohio Third Frontier and related technology programs, the State of Ohio has been able to strengthen weak links in the state's innovation continuum, be it university-industry or industry-industry research collaboration, technology commercialization funding, experienced entrepreneurial support or early-stage capital investment.

OHIO'S FLEXIBLE DISPLAYS & ELECTRONICS CLUSTER

The flexible display and electronics cluster combines Ohio's world class research capabilities in liquid crystals with Ohio's traditional strengths in polymers. The core capability of the cluster is the ability to develop and manufacture products, such as displays, eyewear, window coatings, photovoltaics, and batteries that put optical and electronic materials on flexible polymer substrates. The cluster is centered in the Kent and Akron area, due to the Liquid Crystal Institute at Kent State University and the College of Polymer Science and Polymer Engineering at the University of Akron, and includes companies such as Kent Displays, Alphamicron, and Akron Polymer Systems. OTF investments have been instrumental in supporting commercialization efforts and manufacturing technologies to ensure that much of the economic value from the university research accrues to Ohio. The cluster is still nascent but has enormous potential for growth, with applications in both information technology and energy.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

The SRI team conducted four in-depth industry cluster case studies and 20 company cases in the course of its analysis. These case studies, as well as stakeholder interviews and economic data, indicate the emergence of several new industry clusters based on recent and on-going commercialization of new technologies. These include: Biomedical Imaging and Medical Devices more broadly, Flexible Displays and Electronics, Fuel Cells, Photovoltaics.

OHIO'S FUEL CELL CLUSTER

The origins of Ohio's fuel cell cluster (currently represented by 48 core companies) lie in its research-based companies and institutions—e.g., British Petroleum, Babcock & Wilcox, NASA Glenn, NexTech, Case Western, OSU and other individual research projects going back 10-15 years. Catalytic investments by Ohio's Third Frontier and related initiatives have attracted out-of-state fuel cell companies (e.g., Contained Energy and UltraCell from California, Rolls- Royce Fuel Cell Systems from the UK, etc.) and also supported existing Ohio manufacturers in developing new technology to diversify into fuel cell component manufacturing. While Ohio's fuel cell companies are at different points in the commercialization process, the industry is distinguished by three compelling characteristics: 1) a strong presence and recognition on the national stage; 2) the ability to leverage state funding in applying for and winning federal grants; and 3) a strong network of potential in-state collaborators for the development of an integrated supply chain.

To estimate the employment size and growth of these emerging clusters, the SRI team compiled lists of Ohio companies in each cluster from OTF and Edison Program stakeholders. SRI then conducted research on each of the companies on these lists to identify those companies whose main line of business⁴² is the manufacture of products or components for this cluster. For example, we included companies that developed biomedical imaging software, but did not include small medical offices specializing in 3-D ultrasounds unless they were involved in clinical research. Similarly, we included startup companies specializing in fuel cell research or design, but not Battelle, even though Battelle has employees who focus on fuel cells. We did not include nonprofit organizations. We also did not include suppliers of materials, equipment or services unless they were highly specific to the sector. The result is a conservative, but robust estimate of the number of "core" companies constituting each cluster and their levels of employment in 2004 and 2008.⁴³ If companies tangentially related to the cluster were included, the size and employment of the cluster would be significantly larger. All of these clusters

⁴² In some cases, a large company might have an individual office or location focused on R&D aligned to one of the four emerging technology clusters. In such cases, we included employment at these single locations and counted the company as part of the cluster.

⁴³ The ES202 database is derived from company level data obtained by each state for unemployment compensation tax collection purposes. Nearly all employers with paid employees are required to file unemployment insurance reports (technically called ES202) to their respective states on a quarterly basis. The ES202 data is maintained by the Bureau of Labor Market Information of the Ohio Department of Jobs and Family services.

Making an Impact

Assessing the Benefits of Ohio’s Investment in Technology-Based Economic Development Programs

strongly leverage Ohio’s existing advanced manufacturing supply chain and specialized service industries, as indicated in Table 13.

EMERGING TECHNOLOGY CLUSTER	# OF OHIO COMPANIES	EMPLOYMENT 2004	EMPLOYMENT 2008	LEVERAGED INDUSTRIES
Biomedical Imaging	91	2,815	5,267	Advanced Materials Biomedical Research Clinical Medicine Software Research and engineering design services
Flexible Displays and Electronics	11	897	1,012	Polymers Research and engineering design services
Fuel Cells	49	3,506	4,435	Polymers Metals Manufactured components Research and engineering design services
Photovoltaics	25	2,327	3,218	Glass Polymers Metals Research and engineering design services

Source: List of companies comprising core cluster compiled with assistance from BioEnterprise, BioOhio, Ohio Fuel Cell Coalition, Taratec, Wright Center for Photovoltaics Innovation and Commercialization. Employment data comes from Ohio ES-202 data and Manta.

The OTF and related programs are serving to not only support the startup of new Ohio companies based around platform technologies for these clusters, but also to attract out-of-state companies. (The recruitment of non-Ohio companies is discussed in more depth in a following chapter.)

The development of emerging and future technology-based clusters in Ohio will be critically important in charting a new growth trajectory for the state in the coming years and decades. First, Ohio’s emerging technology industries are all in sectors that are experiencing strong global demand and growth. Secondly, these clusters can help position a region for subsequent rounds of emerging technologies, in the same way that the information technology strength in Silicon Valley provided for the emergence of biotechnology and nanotechnologies.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

CHARTING A COURSE CONSISTENT WITH SUCCESSFUL TECH-BASED GROWTH IN OTHER REGIONS

ABSTRACT

Are Ohio's technology clusters on a path consistent with successful cluster development in other states? Well-known technology-based clusters share a number of key elements, combining competitive assets (e.g., excellent companies, research capacity, and human capital) with large federal and state investments, risk capital, and effective programs for supporting technology transfer and startup companies. As described in the previous chapters, Ohio Third Frontier and related initiatives are associated with increasing levels of high-risk, early-stage capital investment, an improved entrepreneurial environment and the emergence of new high-tech clusters in the state, among other outcomes. Moreover, stakeholder interviews cite the Ohio Third Frontier's long-term strategic approach, merit-based implementation, and agility in responding to feedback as important characteristics. These are also best practices in successful technology cluster development in other regions.

Regions that excel in technology-based clusters today—Silicon Valley in California; Boston/Route 128 area in Massachusetts; the Research Triangle area in North Carolina; and the greater Austin metro area in Texas—share a number of common historical attributes. They possessed key competitive assets, such as pioneering, research-intensive companies and top research universities that produce world-class research outputs as well as a highly skilled workforce. They also benefitted from the visionary leadership of regional leaders who aggressively sought Federal and state investments in strategic research, including defense technology research investments in Silicon Valley and Boston, state investments in greenfield research parks and biotechnology in Research Triangle and private industry investments to create endowed chairs at the University of Texas.⁴⁴ They typically have strong networks between the research, finance, and business communities. In addition, those regions provide a strong infrastructure for entrepreneurship in the technology sectors including ample early stage capital and programs to support technology transfer and startup companies.

⁴⁴ Since 1984, more than forty \$1 million-endowed chairs have been created at The University of Texas to recruit distinguished faculty and facilitate research in engineering and the natural sciences, with an emphasis on microelectronics, material sciences, physics and computer sciences. This initiative was a significant contributor to the ability of Austin to attract the Microelectronic and Computer Technology Corporation (MCC) and SEMATECH, and it spurred rapid semiconductor and IT-related growth in the regional economy.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

As described in the previous chapters, OTF and related initiatives have helped vitalize the state's tech-based entrepreneurial environment, stimulate venture capital and risk capital investment and catalyze the emergence of new high-tech clusters in the state—important outcomes which are creating an environment in Ohio that is highly supportive of technology-based clusters. In addition, the experience of regions with successful technology sectors suggests that some of Ohio's emerging high-tech clusters (e.g., nano-enhanced materials) could play a catalytic role in the rise of other technology-intensive clusters. Silicon Valley and Boston offer two examples in which early strength in information technology provided the platform to build a region's competitive advantage in biotechnology.

The implementation approach of OTF is highly consistent with the best practices adopted in other technology based clusters. Sustained, significant, merit-based investments in building world-class R&D capacity and supporting commercialization activity are important catalysts to technology-based economic activity. These state investments have helped Ohio companies, universities and research institutions leverage much larger Federal and private investments. It has incentivized research collaboration yielding more commercialization activity and connected small Ohio technology companies with much larger integrators and end users. As these successes accumulate, they create a virtuous cycle of economic activity: the emergence of new companies in a variety of sectors, the attraction of non-Ohio technology companies, the increased market share and expansion of existing Ohio companies, and so on. Significantly, OTF stakeholders cite the initiative's long-term strategic approach, its merit-based allocation of resources and agility in responding to feedback as key program characteristics.

Making an Impact

THE AUSTIN, TEXAS STORY

Forty years ago, Austin was known largely for being the state capital of Texas and the site of the University of Texas at Austin. Today, Austin is home to one of the top engineering schools in the country and reads like a Who's Who of high-tech computer, semiconductor, and electronic component companies. Advanced Micro Devices, Applied Materials, Freescale Semiconductor (formerly Motorola's Semiconductor Products division) and Samsung, four of the largest semiconductor and semiconductor equipment manufacturers, are all located in Austin, as well as Apple, Dell¹ and IBM, three of the leading personal computer manufacturers, and the sizeable software company, Tivoli Systems.

The emergence of Austin as an IT cluster was based on strategic decisions, investments, and marketing efforts that took place in the 1980s. Specifically, the establishment of the semiconductor industry in Austin came about largely because of the success of direct efforts taken by the Greater Austin Chamber of Commerce, the local government and the University of Texas at Austin to attract the Microelectronics & Computer Technology Corporation (MCC), now disbanded, and International SEMATECH¹ to Austin. The dominance of Austin's IT industry's presence today is a direct consequence of research carried out at UT and at key private sector companies, and in many cases the creation of entire companies can be directly linked to a particular university research effort as well. These synergies have not stopped and continue to support the growth of newer high-tech industries in Austin, such as software development, biotechnology and multimedia.



Making an Impact

Table 14. Some of the Most Well-Known U.S. Technology Clusters and Key Elements in Their Development	
REGIONAL TECHNOLOGY CLUSTER	KEY ELEMENTS AND TIMELINE
Silicon Valley, geographically bounded in San Francisco and San Jose	<ul style="list-style-type: none"> Origins often traced to the founding of Hewlett Packard in 1937, and post-World War II federal defense investments Prior strength in information technology provided an advantage in positioning in biotechnology Financing via venture capital is central characteristic. Key factors in cluster development include core resources – companies (hardware, software companies); top universities, five national laboratories, and private sector R&D firms – and social factors such as inter-organizational knowledge networking, flexible labor markets, non-hierarchical management, and a culture accepting of entrepreneurial risk-taking
Boston, geographically centered in Boston and broader metro area, e.g., Route 128 and beyond	<ul style="list-style-type: none"> Began in information technology efforts at MIT in the 1920s, and post-World War II defense investments (MIT professor ran the World War II formed Office of Scientific Research and Development) Financial support via private banking is an early characteristic. Information technology industry (e.g., Wang, DEC, Data General) suffered restructuring especially in mini-computing in the late 1980s Regional attributes support biotechnology cluster development, especially Harvard University startups (e.g., Biogen) and founding of private non-profit Whitehead Institute Key attributes: top universities, early federal defense investments, ongoing entrepreneurship (e.g., MIT Enterprise Forum)
Research Triangle, geographically localized in the Raleigh-Durham metro area	<ul style="list-style-type: none"> Deliberate state plan for the creation of a greenfield research park in 1959 in the Raleigh-Durham metropolitan area. Designed to leverage multi-university (Duke University, University of North Carolina at Chapel Hill, North Carolina State University) R&D Emergence of private sector R&D (Research Triangle Institute) Attraction of corporate R&D facilities of IBM, Cisco Systems, GlaxoSmithKline Financial support via state investment and incentives is central characteristic. Reputational visibility efforts also important. Prior strength in information technology provided an advantage in

Making an Impact

Table 14. Some of the Most Well-Known U.S. Technology Clusters and Key Elements in Their Development	
REGIONAL TECHNOLOGY CLUSTER	KEY ELEMENTS AND TIMELINE
	<p>positioning in biotechnology</p> <ul style="list-style-type: none"> Estimated state investment of \$1.2 billion in biotechnology in the past 10 years⁴⁵
Austin, Texas	<ul style="list-style-type: none"> Microelectronics industry focus began from Austin Chamber of Commerce initiative in the late 1950s High profile attraction of two major industry consortiums in the 1980s: Microelectronics & Computer Technology Corporation (formerly MCC, now disbanded), and International SEMATECH. Financial support via state and local investment is central characteristic. Key attributes include the leadership of the local chamber in attracting and supporting this cluster, investment in endowed chairs at the University of Texas and in the community college system, leveraging spillovers from the industry consortia, and reputational visibility efforts.

⁴⁵ “North Carolina: Pipettes at the ready,” *The Economist*, April 18-24, 2009, p.32.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

RECRUITING NON-OHIO COMPANIES

ABSTRACT

Have Ohio's TBED programs enhanced recruitment of non-Ohio companies? There is substantial evidence that Ohio's TBED programs have improved the attractiveness of Ohio as a site for technology-based companies. While corporate site selection decisions weigh many factors, the presence of strong university-industry research centers, supportive state programs, and emerging technology industry clusters all "shift the needle" toward Ohio in site selection decisions. SRI team interviews with several companies spanning the fuel cell, advanced materials, photovoltaic, and medical imaging industries confirm that Ohio TBED programs were important factors in their corporate decisions to locate in Ohio.

Modern-day economic development practitioners employ three basic strategies to retain and create jobs in their state or region: the support of local startup companies, the retention of existing companies, and the recruitment of companies from outside the state. Attracting companies is part art and part science, but the cost of doing business, workforce considerations, the proximity to suppliers and customers, and the cost of living and quality of life are all important considerations for expanding companies seeking new sites. For technology companies, the cost of doing business, the regulatory environment, the amount of world-class R&D activity occurring in a key field (industrial, academic and Federal), and state incentives are also critical.

For example, when Vestas America chose Houston, Texas, as the site for a \$25 million investment in 2008 for a wind turbine facility, Wally Lafferty, Vice President of Technology R&D, explained the decision this way, "Houston provides a very unique crossroad between offshore technology and aerospace. With NASA in Houston and with Boeing, Lockheed Martin and Bell Helicopter in Dallas-Fort Worth, there are a lot of heavy hitters in Texas. Also, Texas A&M is very close by and has large departments in various energy sectors. And, as everyone knows, Houston is the energy capital of the country." In addition, Lafferty noted that it didn't hurt that Texas leads the nation in installed wind energy capacity. "Texas is a state that knows how to get things done. So much wind capacity is being generated in Texas, because they have figured out how to get through the regulatory process. Cape Wind has been bogged down in Massachusetts for nine years. I can't see Texas letting that happen."⁴⁶

⁴⁶ <http://www.siteselection.com/issues/2009/mar/Top-Metros/>

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

This is increasingly the story of Ohio in advanced energy, biomedicine, advanced materials, power and propulsion, and other sectors. First, the State has worked to increase its competitive position with a five-year plan to improve its tax structure⁴⁷—previously a major impediment to company attraction efforts. As Neil Hensley, senior director of economic development for the Cincinnati USA Partnership, stated in an interview, "Changes in Ohio's tax structure have had a very positive impact on manufacturers considering Ohio. One company I know was considering locating an aerospace manufacturing facility here. Cincinnati went from being the most expensive city on their short list to the least expensive after the tax changes."⁴⁸

Second, a broad array of public and private actors, including ODOD, Edison Technology Centers (e.g., BioOhio and PolymerOhio, which promote particular statewide technology industries), Edison Incubators, Ohio Third Frontier ESPs, industry trade associations, and local and regional economic development organizations partner on an on-going basis to bring non-Ohio companies to the state. Each partner organization brings to the table a compelling reason for locating in Ohio: direct links to potential customers, connections and knowledge of the local supply chain, solid understanding of the technology, networks with Ohio researchers working in the field (academic, industrial, Federal), links to angel and venture capital investors in the case of startups, and the ability to pull together appropriate financing packages to assist companies in establishing R&D and manufacturing facilities (loans, tax credits, etc.).

In some cases, the existence of Ohio Third Frontier funding for technology commercialization (via a merit-based competitive process) has also been an important and persuasive factor in location decisions. Overall, the coordination and collaboration among a large number of actors and the positive effects of this collaboration are evidenced by the state's success in attracting a significant number of fuel cell, medical device, biopharmaceutical and advanced materials companies to establish headquarters, R&D and manufacturing facilities in Ohio in just the past four to five years. In 2008, for the third straight year, *Site Selection* magazine awarded Ohio the prestigious Governor's Cup for the most new and expanded large-scale capital projects (503 projects) beating out Texas, North Carolina, Illinois and Tennessee. In addition to winning recognition as the nation's top state for new facility locations and expansions, Ohio's cities also received recognition. Cincinnati, Columbus and Cleveland ranked in the Top 10 metropolitan areas (with population over 1 million) in the country for their number of new facility projects; and Dayton, Akron, Toledo and Youngstown-Warren ranked in the Top 10 for metropolitan areas with populations between 200,000 and 1 million.

⁴⁷ In 2005, Ohio enacted a five-year tax reform and reduction plan. http://www.ohiomeansbusiness.com/cost/tax_reform.php

⁴⁸ <http://www.siteselection.com/issues/2008/mar/topMetros/>

Making an Impact

FUEL CELLS

Ohio's commitment to fuel cell technology via competitive-based technology commercialization funding, workforce, and inclusion of fuel cells in the state's alternative energy portfolio standard as a renewable energy source have prompted several out-of-state companies to locate in Ohio.⁴⁹ The ease of sourcing fuel cell components and materials from local manufacturers has been an added competitive asset for the state.

- Rolls-Royce, a world-leading provider of power systems and service, decided to locate the North American headquarters and technology center for its fuel cell business in North Canton in 2006. In making this decision, Charles Coltman, Chairman and CEO of Rolls-Royce Fuel Cell Systems Ltd. (RRFCS) said "Ohio is at the forefront of fuel cell development and demonstrations, and we are delighted to be here working with an industry leader such as American Electric Power (AEP)."⁵⁰ RRFCS is partnering with AEP to test its prototype stationary fuel cell systems.
- Also in 2006, UltraCell Corp., a producer of fuel cells for remote and mobile applications, based in Livermore, CA, chose Dayton as the location for a new manufacturing facility. Frank Beafore, Vice President of Ohio Operations at UltraCell, cited Ohio's good business environment, strong resource base, and strong workforce as reasons why Ultracell chose Dayton. Close proximity to a key customer, Wright Patterson Air Force Base, was also a consideration.
- Contained Energy Inc. is developing direct carbon fuel cells with technology licensed from Lawrence Livermore National Laboratory. The company's president, Alex Perwich, said OTF and TBED programs were the deciding factors that landed them in the Cleveland area in 2005.
- In 2005, GrafTech Intl., a manufacturer of carbon and graphite products for fuel cell and other applications, decided to move its global corporate headquarters from Wilmington, Delaware, to Parma, Ohio.

Attracting Fuel Cell Companies to Ohio

GrafTech Intl. is a manufacturer of carbon and graphite products for fuel cell and other applications. "A major factor in GrafTech's decision to relocate to Ohio is the state's favorable technology, tax and business climate created by the Department of Development and Ohio's Third Frontier Project," said CEO Craig Shular. "Ohio is a strong supporter of research and development and one of the leading states supporting fuel cell technology development and commercialization."

(<http://www.nema.org/media/ind/20051110a.cfm>)

⁴⁹ In 2008, the Public Utilities Commission of Ohio ruled that fuel cells can be included in the state's alternative energy portfolio standard as a renewable energy source. The alternative energy portfolio standard requires that 12.5 percent of the state's energy come from renewable sources by 2025, which significantly increases the local market for fuel cells.

⁵⁰ "Rolls-Royce Launches U.S. Fuel Cell Business," http://www.starkstate.edu/fuelcell/fuelcell_rolls-royce.htm

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

BIOMEDICAL

The dynamic clustering of multinational and startup biomedical companies and world-class research strengths in many biomedical fields has resulted in significant facility expansions by some of the state's pillar bioscience companies (e.g., Ben Venue Laboratories, Cardinal Health, Philips Medical, etc.) and attraction of non-Ohio companies:

- In 2008, ViewRay, a University of Florida biomedical imaging startup company, decided that the company could start up faster in Cleveland given the proximity to Case Western Reserve's physics and biomedical department, the ability to negotiate use of the equipment and researchers at the Wright Center of Innovation in Biomedical Imaging based at OSU, and clustering of imaging companies in Northeastern and Central Ohio.
- In 2005, San Diego, California-based Amylin Pharmaceuticals, a manufacturer of therapeutics for treating diabetes, obesity and cardiovascular disease chose West Chester (near Cincinnati) as the site of its new manufacturing facility over North Carolina, Massachusetts, California and Kentucky.
- In 2008, Santa Clara, California-based Affymetrix, a global leader in genechip technology for biomedical research and drug discovery, decided to expand manufacturing at its Warrenville Heights facility and close its West Sacramento, California, facility as part of a corporate restructuring plan.

ADVANCED MATERIALS

Ohio has tremendous assets in advanced materials based on its world class research centers and its long history of providing polymers, composites, and other advanced materials for the automobile and aerospace industries. These assets, combined with OTF investments, have served to attract advanced materials companies:

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

- Zyvex Performance Materials (ZPM) produces nano-enhanced composite materials for all the applications in which traditional composites are currently used, e.g., golf shafts, boat masts, aircraft and auto body parts. A Texas-based spinoff, ZPM selected Columbus, Ohio, as a strategic decision to be close to the epicenter of Ohio's advanced materials industry. Other key factors attracting ZPM to Ohio included an OTF Targeted Industry Attraction Grant, support from PolymerOhio and the Center for Multifunctional Polymer Nanomaterials and Devices (CMPND), a n Ohio Third Frontier Wright Center of Innovation.
- Renegade Corp. manufactures adhesive products and pre-impregnated composite fibers, commonly referred to as "prepreg," for use in aircraft engines. According to Renegade co-founder and President, Dr. Gray, the decision to locate Renegade in Dayton, Ohio, was made "because of its synergistic proximity to Wright-Patterson Air Force Base, the University of Dayton Research Institute and the National Composite Center." The state's existing manufacturing base, the end users located in Ohio (e.g., aircraft propulsion systems and parts manufacturers) and the world-class composite and nanomaterials research being conducted in Ohio represent a compelling value proposition for advanced materials technology companies and manufacturers. Renegade has collaborated on two OTF Research Commercialization Program grants with the University of Dayton and Zyvex Performance Materials. The company has also received support from the West Central ESP Program.

Creating Stronger, Lighter Composites with Nanotechnology

Zyvex Performance Materials did not have a manufacturing capability for the nano-enhanced composite technology it had developed. Instead of investing money in its own manufacturing equipment, PolymerOhio connected the company with Akron-based APV Engineered Coatings, which agreed to manufacture the products that ZPM developed. "This example demonstrates why we moved here: there is already a strong advanced materials infrastructure in place, and almost our entire supply chain is in Ohio," commented ZPM President Lance Criscuolo.



Image: Golf shaft, manufactured by Aldila using Zyvex composite materials and used by PGA Tour players.

Photo credit: Zyvex Performance Materials

Making an Impact

SUMMARY AND CONCLUSIONS

SIGNIFICANT ECONOMIC IMPACTS OF OHIO'S TBED PROGRAMS

The OTF initiative was launched in 2002. In a very short period of time, the OTF has achieved significant impacts:

1. The State of Ohio's expenditures of \$681 million generated \$6.6 billion of economic activity, 41,300 jobs, and \$2.4 billion in employee wages and benefits as a result of the OTF. This represents a \$10 return on each dollar of State investment. To put these figures into context, the SRI team also modeled a hypothetical scenario in which, instead of expending \$681 million on OTF projects, the State of Ohio returned the dollars to taxpayers. The estimated impact associated with this tax rebate is sizeable, generating \$935 million in economic activity. However, the OTF investments resulted in \$4.2 billion of follow-on Federal, private, and other investments which increased R&D activity, products sales, and construction generating more than seven times the economic activity, more than six times the employment, and more than 11 times the wages and benefits than that of a hypothetical tax rebate.
2. The OTF ESP Program, the Edison Technology Incubators, and related initiative are having a positive impact on Ohio's entrepreneurial environment. From 2007 to 2008, the six ESPs invested \$35.8 million in direct business assistance and pre-capital funding to 81 companies which then resulted in product sales, follow-on equity investments, and funding totaling \$145.1 million. For the FYE2008, the 13 Edison Technology Incubators supported 270 startup companies which reported \$262.2 million in products sales, research grants, and other revenue, and \$120.8 million in equity investments. If Ohio's ESP and Edison Incubator programs achieve a net increase of 450-500 technology startups over the next 10 years, they will contribute an estimated one-half of one percent to Ohio's GSP growth. Ohio's economy grew 1.9 percent from 2007-2008.
3. The OTF Pre-Seed Funds, the OTF ESP Program, the Ohio TITC, and the OCF/OVCA aim to dramatically increase the availability of early-stage capital for Ohio technology startups. The early evidence is that these programs are meeting with success. According to a study by the Center for Entrepreneurship at Ohio State University, total pre-seed/seed and early-stage venture capital investment in Ohio expanded by 18.5 percent per year between 2004 and 2008 (from \$127.9 million to \$298.3 million). According to the same study, total venture capital investment in Ohio grew by 13.2 percent per year during the same five-year period (\$243 million to \$445.6 million)—more than double the growth rate of U.S. total venture capital investment (5.1 percent per year).
4. Ohio's technology sector is growing. A recent study commissioned by NorTech and conducted by the Center for Economic Development at Cleveland State University found that between 2004 and 2008, total employment in Ohio's high-tech industries grew 4.0 percent, adding 19,198 jobs. This is in spite of the current recession which began in 2007. By contrast, all other industry sectors in Ohio experienced a net total decline of 7,247 jobs. In 2008, Ohio's technology sector

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

employed approximately 495,000 people, accounting for 9.5 percent of total employment in Ohio mirroring the high tech sector's representation nationally.

5. The OTF and related initiatives are catalyzing economic activity in emerging technology clusters which build on the state's existing industrial strengths and world-class research institutions. These developing technology clusters include Biomedical Imaging and Medical Devices more broadly, Liquid Crystals/Flexible Displays, Fuel Cells, and Photovoltaics. From 2004 to 2008, these clusters experienced significant employment growth, ranging from 12.9 percent growth in Liquid Crystals/Flexible Displays to 86.7 percent in Biomedical Imaging.
6. Ohio's seven Edison Technology Centers are assisting a variety of Ohio manufacturers by providing technical assistance, as well as serving as conduits to expertise in Ohio technology companies, universities, and research institutions.
7. The OTF and related initiatives are raising Ohio's visibility and contributing to company recruitment efforts. For the past three straight years, *Site Selection* magazine has awarded Ohio the prestigious Governor's Cup for the most new facility locations and expansions, with 503 projects. Ohio beat out Texas, North Carolina, Illinois and Tennessee to take the top spot in 2008. Ohio's cities also received notoriety. Cincinnati, Columbus and Cleveland ranked in the Top 10 metropolitan areas (with population over 1 million) in the country for new facility projects; and Dayton, Akron, Toledo and Youngstown-Warren ranked in the Top 10 for metropolitan areas with populations between 200,000 and 1 million.

There are many reasons to believe that the OTF investments will generate substantially larger and more significant impacts in the years to come. First, a majority of OTF funds remain to be spent. Some OTF funds have not yet been awarded, and some funds awarded have not yet been entirely spent. The economic impact of the program is expected to increase significantly over the next five to ten years. Second, the OTF is generating successful outcomes in spite of the longest U.S. recession in the post-World War II era.⁵¹ The diminished demand, financial capital, business activity and job losses associated with the recession weigh down the net economic impacts generated by the OTF investments. However, it is likely that the new products and processes being commercialized by Ohio companies and the new industries that are emerging will be in a position of strength during the next global expansion. The Federal Reserve Board Open Market Committee anticipates a U.S. recovery in 2010.⁵² Thirdly, many intermediate impacts of the OTF, such as new products and services resulting from university research and better linkages among research institutions, companies, and financial institutions are long term in nature. Although many of these impacts have not had large economic effects yet, they are likely to have much more significant impacts in the long run.

⁵¹ According to the National Bureau of Economic Research (NBER), the average post-World War II recession in the United States is 10 months.

⁵² Board of Governors of the Federal Reserve System. Minutes of the Federal Open Market Committee, April 28-29, 2009, <http://www.federalreserve.gov/monetarypolicy/fomcminutes20090429ep.htm>

Making an Impact

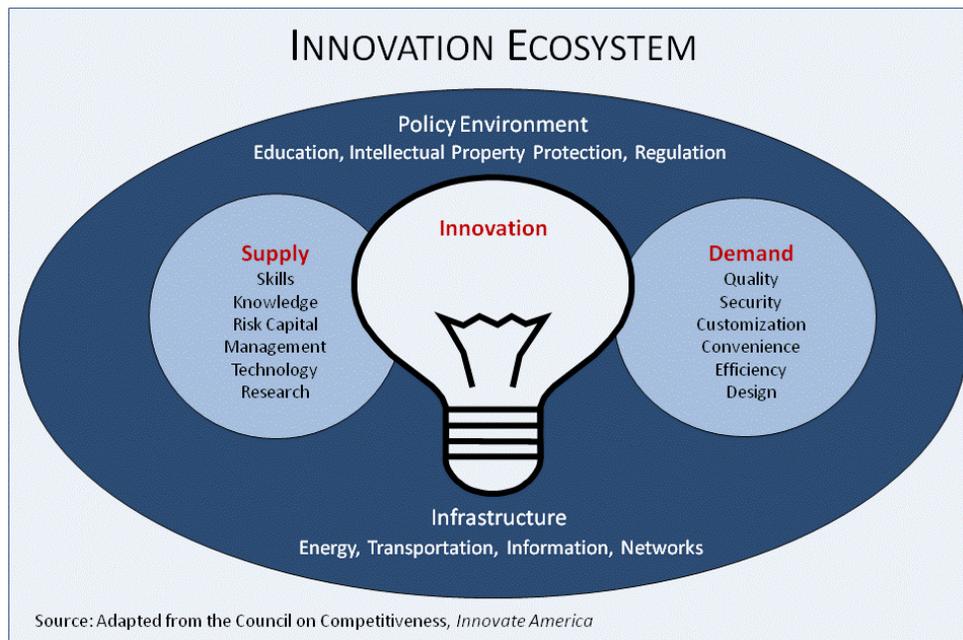
CREATING AN EFFECTIVE AND INTEGRATED INNOVATION SUPPORT SYSTEM

Although the economic impacts to date are substantial, the more important effect of the OTF is likely to be its long-term effects on Ohio's system of supporting innovation. OTF and related initiatives have created an effective, integrated system for supporting innovation at all levels and by all actors, including companies, entrepreneurs, universities, research institutions, and Federal labs.

Innovation is important to Ohio's long-term economic growth, because new products, services and production processes provide Ohio companies with opportunities to enter new markets and to gain greater market share. Innovation affords Ohio's economy the opportunity to diversify into higher growth, higher value-added economic activities that can move Ohio to a better growth trajectory. Ultimately, this will generate higher quality jobs and higher incomes for current and future generations of Ohio citizens.

It is now well understood that a region's capacity for innovation depends on an effective system that involves many elements, including research and development, skilled people, financing, market pull, a supportive policy environment, and other elements.⁵³ Figure 11 presents one depiction of the elements of an effective innovation system.⁵⁴ The lack of any element can cripple the overall functioning of the system.

Figure 11. Determinants of the Supply and Demand for Innovation



⁵³ Nelson, Richard R. *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press. 1993.

⁵⁴ Council on Competitiveness. *Innovate America*. National Innovation Initiative Report. Washington. 2004.

Making an Impact

Assessing the Benefits of Ohio’s Investment in Technology-Based Economic Development Programs

Within Ohio’s innovation ecosystem, OTF is focused primarily on the supply of side of the diagram (skills, knowledge, risk capital, management, technology and research). Other programs in the state address the policy environment and infrastructure. The demand side is mostly a function of the private market, but the demand for innovation is affected by other companies attracted to the state as well as the policy environment, such as policies to support demand for alternative energy.

How have Ohio’s investments in the OTF and related initiatives improved Ohio’s innovation support system? Before the OTF, there was substantial university research in Ohio as well as existing manufacturing companies and traditional sources of finance. There was not, however, a systematic approach to developing the knowledge networks connecting universities and industry, the risk capital necessary for innovation, or the entrepreneurial management skills needed to commercialize technologies. A major theme throughout the stakeholder and company interviews that SRI conducted was that there had been missing pieces in the Ohio innovation system, but that there is now a more complete and systematic approach. Previously, risk capital was often not available or entrepreneurs did not have the skills to develop solid business plans. Often small technology companies were not aware that nearby universities or other companies could provide the knowledge or market opportunities they needed to succeed.

Table 15. How the Ohio Third Frontier and Related Investments Match Up To The Elements Of The Innovation System		
Capacity Factor	Strategic State Investments	Outcome
Skills	Wright Centers of Innovation Wright Projects Ohio Research Scholars Internship Program	Students gaining hands-on applied research experience and internships at research-intensive companies Leading scholars attracted to Ohio in strategic technologies
Knowledge Networks	ESPs Wright Centers of Innovation Wright Projects Edison Incubators Edison Technology Centers	Technology companies better connected to universities and markets
Risk Capital	Pre-Seed Funds TITC OCF/OVCA Innovation Ohio Loan Fund	Funds available to develop, start, and grow companies
Management	Entrepreneurial Signature Program Edison Incubators	Better managed early-stage technology companies are able to attract significant follow-on VC investments
Technology	Research Commercialization Program	Companies able to have funds to develop innovative technologies

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

	Fuel Cell, Advanced Energy, ORCGP Innovation Ohio Loan Program Edison Technology Centers/NIST MEP Program	and introduce them into the market. Small manufactures able to upgrade technologies and processes.
Research	Wright Centers of Innovation Wright Projects Ohio Research Scholars	World-class research in fields aligned to Ohio's industrial needs and strategic technologies

The OTF looked strategically at the key factors which determine innovation capacity and made investments on a scale that could make a difference. Historically, Ohio has had significant research assets and skill sets in its industrial sectors, manufacturing supply chains, universities, Federal labs and other research institutions. The OTF has successfully filled in the missing elements of risk capital and entrepreneurial skills, and catalyzed the connections between the various elements in the technology commercialization continuum ensuring that the whole is greater than the sum of its individual parts. The result is a comprehensive system to support the development and commercialization of new technologies that can change Ohio's growth trajectory in the coming decades.

LOOKING TOWARD 2012: DEVELOPING OHIO'S THIRD FRONTIER

As is the case with geographic frontiers, the economic benefits of new technological frontiers come not from the initial exploration but from the subsequent development. This is the case with the OTF. The initial stages have developed research capacity and partnerships, ideas and intellectual property, and fledgling technology-based companies and industries. Most of the economic benefit, however, will come from the subsequent development and growth of these companies, along with supporting industries.

With any frontier development, the path forward is unknown and involves trial and error. Developing new technology industries is an experimental process, because each technology and technology-based industry is different. The art of such development is not to do things perfectly the first time, but to learn quickly from mistakes. Similarly, the success of the OTF depends not on doing everything right at the beginning, but adapting quickly and effectively over time.

The evidence presented in the previous chapters suggests that the OTF is off to a good start and has a substantial record of accomplishment. As it goes forward, there is a need for both continuity and change. This chapter outlines some observations and suggestions for strengthening the OTF as it matures. We believe that the program needs continuity and consistent effort to grow the businesses and clusters that have been started. We also believe that the program can be enhanced with greater communication efforts, both about the program and about Ohio's unique strengths. The program can

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

also be made more cohesive across the different institutions and regions of the state, and may consider expanding its scope to include more creative industries.

CONTINUITY

The biggest need for the program is continuity. The experience of other states and clusters, such as Silicon Valley, Research Triangle Park, or Austin, Texas is that it takes 20 to 30 years for regions to achieve the critical mass that become self sustaining. It takes time to take a new technology from the laboratory to a product, and time to grow companies, and to develop the supporting manufacturing and service firms. It takes time to build new institutions and change the culture of existing institutions to support technology-based economic growth. It takes time to establish the networks among organizations and to develop the national and international reputation that attracts talent and resources. Many TBED efforts have failed due to lack of long-term support and vision.

The consistent message from our interviews with the OTF's stakeholders is that the program is well-designed and well structured, and that it is evolving intelligently over time, reflecting competent program staff and a good management structure. The OTF has adapted as weaknesses became apparent. For example, as it became apparent that providing capital funds for research equipment without providing operating funds was a problem, programs adapted to provide operating funds. Stakeholders have praised the program for allocating funds based on merit; the biggest fear of some stakeholders was that the program would become more politicized over time, with pressure to make sure each region gets its fair share, regardless of quality. Keeping the program merit-based is a top priority.

COMMUNICATION

One consistent message throughout our interviews with program stakeholders is that few people understand the OTF in its entirety. The programs are complex in structure and not well understood. Most people understand the programs they have direct knowledge of, and attest to the effectiveness of those programs, but they do not understand the effectiveness of other elements of the OTF. There is a need for everyone to develop a common understanding of the programs and how they fit together, so that people can understand and support the whole system.

One aspect of the Ohio programs that make this understanding more difficult is the complexity of programs and subprograms, described earlier. The complexity of the programs and the diversity of names in part reflect the diverse funding sources of the programs. It should be recognized, however, that this makes it more difficult for small companies to understand where they can gain resources, and makes it more difficult for legislators to explain the program to their constituencies. It may be time now to rationalize the programs in accordance with a clear strategy. Reorganizing the programs along the lines of the Department's Technology Commercialization Framework, with a smaller number of programs in each category, would make the program as a whole easier to communicate to stakeholders.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

Another communications issue is a need for a broader message and even attitude change for the state. Throughout our study, we heard negative expressions about Ohio, suggesting that nobody really wants to come to the state because it does not have a warm climate, ocean beaches or mountains. We view this sentiment as self defeating. Ohio has great assets: great lakes and rivers, great universities and colleges, livable cities, a long tradition of innovation, a rich cultural tradition of arts and music. Other regions, such as Austin, Texas, or Research Triangle Park, North Carolina, have no better physical and cultural assets, but nevertheless have become places attractive to technology based companies. In part, Ohio needs to develop and communicate its identity as a place with a tradition of innovation as well as a great lifestyle and culture.

PROGRAM FOCUS

An issue that has come up frequently in meetings with stakeholders is that of the program balance and focus. Does the program have the right balance between university research versus support for entrepreneurship, commercialization, and company relocation? Should the program be focused on specific technology areas and emerging clusters, or should it be open to supporting good ideas in any technology areas? There are different views on both of these issues.

There are reasons for having support for universities at the core of the program. Universities can form the anchor of a region—they produce both new ideas and trained people, and, unlike companies, are firmly locked to a region. Universities cannot outsource their work to China or move to California. Funding of universities can also produce economic benefits to the state by enabling it to leverage other out of state funds, including Federal research grants and contracts as well as industrial and foundation support. This leverage accounts for a significant portion of the OTF's economic impact to date.

On the other hand, universities do not directly produce commercial technologies or economic growth. Entrepreneurial support programs appear to be more cost-effective in creating new jobs. Similarly, efforts to support relocation of growing technology companies can move many jobs to Ohio quickly.

In our view, university programs, entrepreneurial support programs, and company relocation programs are all part of an effective system. The question is one of balance. The university programs should be maintained, but there should be a modest readjustment to place greater emphasis on entrepreneurial support programs and efforts to attract new growing technology companies, especially in the expanding technology clusters, to Ohio.

With respect to the importance of a focused strategy versus broader support of enabling technology, most stakeholders believed that the focus on a limited number of technologies was appropriate, and that it was important to avoid spreading funding thinly over too many technologies, which lead to having a limited affect on any technology. On other hand, focusing on specific technologies may lead to

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

missing some emerging opportunities. There is some debate about whether it is better to plan industrial clusters, or support those that emerge.

In our view the OTF has done a good job of both focusing resources and supporting some opportunities that are outside of the targeted clusters. The clusters that have been supported are appropriate ones, given Ohio's assets, although there can always be arguments about whether other clusters could have been better.⁵⁵ The program has been flexible enough to provide support to promising technologies that are outside of the designated clusters, as such as flexible displays and electronics.

We also believe that the OTF should be on the lookout to support technologies or industry clusters that are closely related to Ohio's strengths in areas such as agribusiness and consumer products. With respect to the latter, much innovation today is not purely driven by the physical and biological sciences and engineering, but also by the social sciences (e.g. Facebook) and design (e.g., the iPod). Ohio has substantial expertise in consumer design and market intelligence, based on the expertise of Ohio companies in consumer products. OTF may want to consider technology clusters that are based not only on physical technologies, but also on a combination of physical technologies with social sciences and the arts.

EXPANDING NETWORKS

The program has done an excellent job in building networks throughout the state that has enabled many companies to find partners in other companies or resources in universities, Federal laboratories, and financial institutions that they otherwise would not have known about. Although the formation of these networks may be less tangible and visible compared to a new R&D project, such networks are the key to technology-based economic development. Many stakeholders commented that the formation of these networks has been one of the most, if not the most, important result of the program.

It is important that these networking efforts continue and expand. Different regions of the state do not communicate as well as they should. Cities that are only an hour's drive apart, such as Columbus and Dayton, view themselves as different regions rather than as part of the same region. Some parts of the state, such as the Southwest and Southeast, do not feel they are as much a part of the program as the North and Central regions. Efforts to overcome these divisions need to continue.

It is also important to continue to work to make the major institutions in Ohio full partners in the program. Ohio State University has excelled at attracting industry-sponsored R&D funds but, although it has made progress, still lags in spinning off new companies and in licensing technology. Battelle has been a major source of managerial talent, but stakeholders commented that much of Battelle's

⁵⁵ For example, some interviewees suggested that advanced batteries might have been a better choice than fuel cells, but it is difficult to know which choice would have been better for the long-run.

Making an Impact

Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs

technology and talent seems to go to the coasts rather than staying in Ohio. The Air Force Research Laboratory has made great strides in connecting to the state, especially around Dayton, but more still can be done. Major companies, such as Procter and Gamble, which are highly innovative in design and consumer products, do not appear to be as connected to the program as they could be. Although all of these organizations have been involved in the programs, it is important to continue efforts to use their assets more fully.

CONCLUSION

Based on the findings of the analysis laid out in this report, SRI believes that the Ohio Third Frontier has been an effective program. If Ohio's goal is to continue to support the growth and emergence of technology-based industries in the state, SRI believes the continuation of the Ohio Third Frontier is an effective strategy and is well warranted. We believe that the program can be enhanced with greater communication efforts, both about the program and about Ohio's unique strengths. The program can also be made more cohesive across the different institutions and regions of the state, and may consider expanding its scope to include more creative industries, such as consumer products. With regard to program balance, university programs, entrepreneurial support programs, and company relocation programs are all part of an effective system. SRI believes the university programs should be maintained, but there should be a modest readjustment to place greater emphasis on entrepreneurial support programs and efforts to attract new growing technology companies, especially in the expanding technology clusters, to Ohio.