BEST PRACTICE IN
STATE AND REGIONAL INNOVATION

Best Practices in State and Regional Innovation Initiatives

Competing in the 21st Century

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

Best Practices in State and Regional Innovation Initiatives

Competing in the 21st Century

Charles W. Wessner, Editor

Committee on Competing in the 21st Century:
Best Practice in State and Regional Innovation Initiatives

Board on Science, Technology, and Economic Policy

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For the National Research Council (NRC), this project was overseen by the Board on Science, Technology and Economic Policy (STEP), a standing board of the NRC established by the National Academies of Sciences and Engineering and the Institute of Medicine in 1991. The mandate of the Board on Science, Technology, and Economic Policy is to advise federal, state, and local governments and inform the public about economic and related public policies to promote the creation, diffusion, and application of new scientific and technical knowledge to enhance the productivity and competitiveness of the U.S. economy and foster economic prosperity for all Americans. The STEP Board and its committees marshal research and the expertise of scholars, industrial managers, investors, and former public officials in a wide range of policy areas that affect the speed and direction of scientific and technological change and their contributions to the growth of the U.S. and global economies. Results are communicated through reports, conferences, workshops, briefings, and electronic media subject to the procedures of the National Academies to ensure their authoritativeness, independence, and objectivity. The members of the STEP Board* and the NRC staff are listed below:

continued

*As of May 2013.

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Preface

Responding to the challenges of fostering regional growth and employment in an increasingly competitive global economy, many U.S. states and regions have developed programs to attract and grow companies as well as draw the talent and resources necessary to develop innovation clusters. These state and regionally based initiatives have a broad range of goals and increasingly include significant resources, often with a sector focus and often in partnership with foundations and universities. They often take advantage of complementary federal programs to develop regional centers of innovation, entrepreneurship, and high-technology development. It is significant to note that in many states and regions, both Democratic and Republican governors and legislatures have agreed on similar strategies and have undertaken substantial public investments in education, skills training, and infrastructure to create technology-based growth clusters.

STATEMENT OF TASK

An ad hoc committee, under the auspices of the Board on Science, Technology, and Economic Policy (STEP), has conducted a study of selected state and regional programs to identify best practices with regard to their goals, structures, instruments, modes of operation, synergies across private and public programs, funding mechanisms and levels, and evaluation efforts. The committee reviewed selected state and regional efforts to capitalize on federal and state investments in areas of critical national needs. This review included both efforts to strengthen existing industries as well as specific new technology focus areas such as nanotechnology, stem cells, and energy in order to improve our understanding of program goals, challenges, and accomplishments.

As a part of this review, the committee convened a series of public workshops and symposia involving responsible local, state, and federal officials and other stakeholders. These meetings and symposia enabled an exchange of views, information, experience, and analysis needed to identify best practice in the range of programs and incentives adopted.

Drawing from discussions at these symposia, fact-finding meetings, and commissioned analyses of existing state and regional programs and technology focus areas, the committee has produced this final report with observations focused on lessons, issues, and opportunities for complementary U.S. policies created by these state and regional initiatives.

THE CONTEXT OF THIS PROJECT

Since 1991, the National Research Council, under the auspices of the Board on Science, Technology, and Economic Policy, has undertaken a program of activities to improve policymakers' understandings of the interconnections of science, technology, and economic policy and their importance for the American economy and its international competitive position. The Board's activities have corresponded with increased policy recognition of the importance of knowledge and technology to economic growth.

One important element of STEP's analysis concerns the growth and impact of foreign technology programs.[1] U.S. competitors have launched substantial programs to support new technologies, small firm development, and consortia among large and small firms to strengthen national and regional positions in strategic sectors. Some governments have chosen to provide public support to innovation to overcome the market imperfections apparent in their national innovation systems.[2] They believe that the rising costs and risks associated with new potentially high-payoff technologies, and the growing global dispersal of technical expertise, underscore the need for national R&D programs to support new and existing high-technology firms within their borders.

Similarly, many state and local governments and regional entities in the United States are undertaking a variety of initiatives to enhance local economic development and employment through investment programs designed to attract knowledge-based industries and grow innovation clusters.[3] These state and regional programs and associated policy measures are of great interest for their potential contributions to growth and U.S. competitiveness and for the "best practice" lessons that they offer for other state and regional programs.

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[1]For a review of growth of national programs and policies around the world to support research and accelerate innovation, and the resulting challenges facing the United States, see National Research Council, *Rising the Challenge: U.S. Innovation Policies for the Global Economy*, C. Wessner and A. Wm. Wolff, eds., Washington, DC: The National Academies Press, 2012.

[2]For example, a number of countries are investing significant funds in the development of research parks. For a review of selected national efforts, see National Research Council, *Understanding Research, Science and Technology Parks: Global Best Practices—Report of a Symposium*, C. Wessner, ed., Washington, DC: The National Academies Press, 2009.

[3]For a scoreboard of state efforts, see Robert Atkinson and Scott Andes, *The 2010 State New Economy Index: Benchmarking Economic Transformation in the States,* Kauffman Foundation and ITIF, November 2010.

STEP's project on State and Regional Innovation Initiatives has generated an improved understanding of the challenges associated with the transition of research into products, the practices associated with some successful state and regional programs, and their interaction with federal programs and private initiatives. This better understanding has been realized through a series of complementary assessments of state, regional, and federal initiatives; analyses of specific industries and technologies from the perspective of how supportive public policy at all three levels was crafted; and outreach to multiple stakeholders. Based on this knowledge, this project seeks to improve the operation of federal, state and regional programs and, collectively, enhance their impact.

ACKNOWLEDGMENTS

On behalf of the National Academies, we express our appreciation and recognition for the insights, experiences, and perspectives made available by the many participants of conferences and meetings held over the course of this study. Thomas Howell played a key role in assisting the Committee both in the preparation of this report and though the Report Review cycle. Dr. Sujai Shivakumar of the STEP staff prepared multiple responses to review, making the many substantive changes to the original text required by the review process. We are also indebted to David Dawson of the STEP staff for his contributions to the preparation of this report.

SPONSORS

The National Academies Board on Science, Technology, and Economic Policy would like to express its appreciation for the sustained support of the following agencies and departments: the Economic Development Administration, the National Institute of Standards and Technology, the National Cancer Institute, and the Department of Energy. Their contributions of time, expertise, and financial support were essential to the success of the project.

ACKNOWLEDGMENT OF REVIEWERS

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies' Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of this report: John Burris, Burroughs Wellcome Fund; Maryann Feldman, University of North Carolina; Robert Genco, Science, Technology Transfer and Economic Outreach; Howard Gobstein, Association of Public and Land-grant Universities; David Goldston, Natural Resources Defense Council; Mark Gorenberg, Hummer Winblad Venture Partners; Susan Hackwood, California Council on Science and Technology; George Heaton, Worcester Polytechnic Institute; Edwin Przybylowicz, Eastman Kodak Company (Retired); Andrew Reamer, The Brookings Institution; and Howard Rosen, Stanford University.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Maxine Savitz, Honeywell Inc. (Retired) and Stephen Fienberg, Carnegie Mellon University. Appointed by the National Academies, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Charles W. Wessner Mary L. Good

Executive Summary

Most of the policy discussion about stimulating innovation has focused on the federal level. This study focuses on the significant activity at the state level, with the goal of improving the public's understanding of key policy strategies and exemplary practices. Based on a series of workshops and conferences that brought together policymakers along with leaders of industry and academia in a select number of states, the study highlights a rich variety of policy initiatives underway at the state and regional level to foster knowledge based growth and employment. Perhaps what distinguishes this effort at the state level is most of all the high degree of pragmatism. Operating out of necessity, innovation policies at the state level often involve taking advantage of existing resources and recombining them in new ways, forging innovative partnerships among universities, industry and government organizations, growing the skill base, and investing in the infrastructure to develop new technologies and new industries. Many of these initiatives are being guided by leaders from the private sector and universities.

The objective of the study is not to do an empirical review of the inputs and outputs of various state programs. Nor is it to evaluate which programs are superior. Indeed, some of the notable successes, such as the Albany nanotechnology cluster, represent a leap of leadership, investment, and sustained commitment that has had remarkable results in an industry that is actively pursued by many countries. The study's goal is to illustrate the approaches taken by a variety of highly diverse states as they confront the increasing challenges of global competition for the industries and jobs of today and tomorrow.

Faced with the challenges of fostering regional growth and employment in an increasingly competitive global economy, many U.S. states and regions have developed programs to attract and grow companies as well as draw the talent and resources necessary to develop innovation clusters. These state and regionally based initiatives have a broad range of goals and increasingly include significant resources, often with a sector focus and often in partnership with foundations, universities and the private sector. Increasingly, they seek to leverage complementary federal programs to support the development of regional centers of innovation, entrepreneurship, and high-technology development.

These developments mark a significant change in paradigm. For much of the Twentieth Century states pursued economic development by seeking to recruit companies from other states by offering a more competitive business and regulatory environment, lower taxes, supportive government policies, and financial and infrastructure incentives. States still do this and sometimes see other states as competitors, but increasingly they see them as partners as well. Indeed, many states are shifting their policy focus to address the competition that has emerged from other regions of the world for leadership in the industries of the future.

To better understand these policies and their impacts, a committee of the National Academies Board on Science, Technology, and Economic Policy (STEP) reviewed regional and state innovation programs across a limited number of highly diverse states. These conferences, held in Arkansas, Hawaii, Michigan, Ohio, Illinois and New York, have generated an improved understanding of the challenges associated with the transition of research into products, the practices associated with some successful state and regional programs, and their interaction with federal programs and private initiatives.

The common element in each of the regional meetings is the growing determination of the state and regional authorities and the private sector to enhance technological capacity, university-industry connections, and economic growth in the region for current and future generations.

OBSERVATIONS FROM THE CASES

The experience of states and regions examined in this study show that:

- **Leadership** by the public and private sectors, including elected officials, university presidents and industry representatives, is crucial to bring together public and private stakeholders in a region.
- **Investment of substantial public funds** by the states over a substantial period, along with the development of intermediating institutions provides the foundation for progress. These investments also often have a catalytic effect, attracting private investments, as well as support from foundations and the federal government.
- **Sustained support by states for educational institutions** can be important for long-term economic development. They provide the research facilities, a trained workforce, a flow of ideas for commercial development, and the branding that characterize successful regions.

- **Community colleges** play an essential role in providing a trained workforce able to adapt to changing technologies and enable new opportunities.
- **Public-private partnerships** facilitate the collaboration needed to develop the necessary workforce, provide and enrich research facilities and agendas, help develop new ideas, and support bringing the resulting products to the market.
- **Funding from philanthropic foundations** can play a significant and often catalytic role in initiating, complementing, and sustaining action, by regional and state authorities.

I

INNOVATION AND PLACE-BASED ECONOMIC DEVELOPMENT

Chapter 1

Innovation in the States

Over the past 30 years, a global consensus has formed on the importance of innovation as the principal way to address the challenges of economic development, public health, national security, and protection of the environment. Many of the world's leading countries are making unprecedented investments in promoting innovation through increased funding for research and development and through sustained support for universities and innovative small and large businesses. They are also implementing new programs and public-private partnerships to encourage the commercialization of new ideas in the marketplace.[1]

Box 1-1
The New Focus on the Innovation Ecosystem

Reviewing the evolution of thinking about the rationale for public policies to support growth, a recent OECD paper[2] documents the move:

- From: "a traditional approach based largely on product market interventions (production subsidies, state ownership, tariff protection), through market failure-correcting taxes and subsidies operating mainly on factor markets (R&D incentives, training subsidies, investment allowances, help with access to finance.)"
- To: "A focus on interventions that help build systems, create networks, develop institutions and align strategic priorities."

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[1]For a comparative review of the challenges and opportunities faced by the United States in the face of global competition for the next generation of innovation, see National Research Council, *Rising to the Challenge: U.S. Innovation Policy for the Global Economy*, C. Wessner and A. Wm. Wolff, eds., Washington, DC: The National Academies Press, 2012.
[2]Ken Warwick, "Beyond Industrial Policy, Emerging Issues and New Trends," *OECD Science, Technology, and Industry Policy Papers*, No. 2, Paris: OECD Publishing.

Box 1-2
Statement of Task

Responding to the challenges of fostering regional growth and employment in an increasingly competitive global economy, many U.S. states and regions have developed programs to attract and grow companies as well as attract the talent and resources necessary to develop a knowledge-based economy. These state and regionally based initiatives have a broad range of goals and increasingly include significant resources, often with a sectoral focus and often in partnership with foundations and universities.

An ad hoc committee, under the auspices of the Board on Science, Technology, and Economic Policy (STEP), will conduct a study of selected state and regional programs in order to identify best practices with regard to their goals, structures, instruments, modes of operation, synergies across private and public programs, funding mechanisms and levels, and evaluation efforts. The committee will review selected state and regional efforts to capitalize on federal and state investments in areas of critical national needs. This review will include both efforts to strengthen existing industries as well as specific new technology focus areas such as nanotechnology, stem cells, and energy in order to better understand program goals, challenges, and accomplishments.

The committee will convene a series of public meetings and fifteen symposia involving responsible local, state, and federal officials and other stakeholders. These meetings and symposia will enable an exchange of views, information, experience, and analysis to identify best practice in the range of programs and incentives adopted. Eleven symposium summaries will be prepared. Drawing from discussions at these symposia, fact-finding meetings, and commissioned analyses of existing state and regional programs and technology focus areas, the committee will subsequently produce a final report with findings and recommendations focused on lessons, issues, and opportunities for complementary U.S. policies created by these state and regional initiatives.

Innovation clusters— localized groups of companies developing creative products and services within an active web of collaboration that includes specialized suppliers and service providers, universities, and research institutes and organizations— are now widely associated with higher levels of economic growth and competitiveness.[3] Based on this recognition, there is an

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[3]Richard R. Nelson and Nathan Rosenberg, "Technical Innovation and National Systems" in Richard R. Nelson, ed., *National Innovation Systems: A Comparative Analysis*, Oxford: Oxford University Press, 1993; Michael Porter, "Clusters and the New Economics of Competition," *Harvard Business Review,* 1998. For more discussion, see Chapter 2.

increasing global competition for the investment, knowledge, skills and resources associated with innovation clusters.[4]

PARAMETERS OF THIS STUDY

The scope of this report is limited in terms of focus and opportunity. The Committee chose to spotlight noteworthy initiatives underway in a limited set of states and regions. Arkansas and Hawaii provide examples of two states that have not traditionally been leaders in high-technology innovation, but are now investing in education and are seeking to harness their universities as engines of regional growth. Illinois, Michigan, and Ohio are three Midwestern states that are rapidly shedding their "rust belt" image by investing in emerging sectors such as biotechnology, advanced batteries, and flexible electronics and by leveraging and reorienting existing assets to once again become global manufacturing hubs. The development of a nanotechnology cluster in New York's Albany region is a significant development: one based on a public-private initiative that has grown to attract large investments by semiconductor firms in the region, and related initiatives by federal, state, university, and non-profit organizations that are generating further positive synergies. It is important to note that while the report does make a number of references to individual state programs, it does not address the operational details of state and regional programs to advance innovation. This report focuses on the policy level, abstracting a broader set of best practice lessons in policy from the programs reviewed.

The choice of regions and states selected in this study was, to a considerable degree, also driven by the willingness of leading policymakers, business leaders, and academics in these states and regions to engage with the Committee in an in-depth dialogue on these issues. The selection of regions and states reviewed is necessarily limited; our purpose here is to use the experiences of these states to highlight some of the emerging strategies, new types of investments, and new policies that states are deploying to address the innovation challenge.

Based on the strong interest and positive participation in the workshops and conferences that the committee has held in the course of this study, we believe that this report and the associated conference summaries can serve as a valuable reference to many state and federal legislators, state and federal officials in the executive branch, and others who may not have had the opportunity to review the experiences of other states.

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[4]Mary Jo. Waits, "The Added Value of the Industry Cluster Approach to Economic Analysis, Strategy Development and Service Delivery," *Economic Development Quarterly* 14(1):35-50, February 2000. Mark Muro and Bruce Katz, *The New 'Cluster Moment': How Regional Innovation Clusters Can Foster the Next Economy,* Washington, DC: The Brookings Institution, September 2010, p. 20. For more discussion, see Chapter 2 of this report.

Box 1-3
Meetings and Reports in this Series

The Future of Photovoltaics Manufacturing in the United States
Conference held on April 23, 2009, in Washington, DC
Report published by The National Academies Press, 2011

Growing Innovation Clusters for American Prosperity
Conference held on June 3, 2009, in Washington, DC
Report published by The National Academies Press, 2011

Clustering for 21st Century Prosperity
Conference held on February 25, 2010, in Washington, DC
Report published by The National Academies Press, 2012

Building the Arkansas Innovation Economy
Conference held on March 8-9, 2010, in Little Rock, Arkansas
Report published by The National Academies Press, 2012

Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities
Conference held on July 26-27, 2010, in Livonia, Michigan
Report published by The National Academies Press, 2012

Building Hawaii's Innovation Economy
Conference held on January 13-14, 2011, in Honolulu, Hawaii
Report published by The National Academies Press, 2012

Building the Ohio Innovation Economy
Conference held on April 25-26, 2012, in Cleveland, Ohio
Report published by The National Academies Press, 2013

Building the Illinois Innovation Economy
Conference held on June 28-29, 2012, in Evanston, Illinois
Report published by The National Academies Press, 2013

Building the New York Innovation Economy
Conference held on April 3-4, 2013, in Troy, New York
Report published by The National Academies Press, forthcoming

STATE-LED DEVELOPMENT OF INNOVATION CLUSTERS

In the United States, in contrast to a number of other advanced countries, until very recently virtually all initiatives to promote innovation clusters took place at the state and regional level, albeit generally with the benefit of federal R&D funding. States confront stark economic challenges in the global era, including the growing competition from foreign enterprises, often backed by comprehensive government industrial policies, erosion of traditional manufacturing sectors, the wholesale movement offshore of industrial chains, rising unemployment and ultimately, declining population.[5] Efforts at industrial revival using traditional policy tools, including industrial recruitment and financial incentives to industry are now being complemented by more technology-based indigenous growth strategies.[6] Since the early 1990s, a number of states have increasingly viewed support for innovation clusters as a leading policy tool for fostering the international competitiveness of local industries.

The Emergence of Cluster Strategies

For much of the Twentieth Century states pursued economic development by seeking to recruit companies from other states by offering a more competitive business and regulatory environment, lower taxes, supportive government policies, and financial and infrastructure incentives.[7] States saw

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[5]Jason Forcier, Vice President of Automotive Solutions for A123 Systems, a U.S.-based maker of lithium batteries commented at one of the symposia convened for this project that “in terms of where the battery industry will be based, the competition is no longer only between states and Michigan, Mississippi and Alabama. This is a case of the United State competing against countries. China has a very aggressive subsidy policy. They continue to amaze me with new announcements.” China pays a direct subsidy of $8,800 per vehicle to electric vehicle manufacturers in five cities. Municipal governments have announced credits of up to an additional $5,000 per car. Jason Forcier, “The Battery Industry Perspective,” National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium*, Washington, DC: The National Academies Press, 2012. In October 2012, A123 Systems filed for bankruptcy and accepted a bailout from Wanxiang Group Corp., China's biggest maker of automotive components. "Troubled Battery Maker A123 Fell Short on Job Creation, Defaulted on Some of its Debt," *Grand Rapids Press*, October 17, 2012. U.S. state and federal government initiatives have provided substantial financial support for the development of electric vehicles, including state tax credits, federal funding of R&D and investment, and federal extension of $25 billion in debt capital to finance the development of more energy-efficient vehicles pursuant to the Advanced Vehicles Manufacturing Program (ATVM). See Chapter 4, "The Michigan Battery Initiative," in National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium*, op. cit.
[6]For a recent review of state and regional policies on innovation-led growth, see David B. Audretsch and Mary L. Walshok, eds., *Creating Competitiveness, Entrepreneurship and Innovation Policies for Growth*, Northampton, MA: Edward Elgar, 2013.
[7]Walter H. Plosila, “State Science and Technology-Based Economic Development Policy: History, Trends and Developments and Future Directions,” *Economic Development Quarterly*, 18(2):114,

Box 1-4
Innovation and Jobs

In a widely cited recent book, Enrico Moretti, Professor of Economics of the University of California at Berkeley, argues that innovation has a disproportionately powerful impact on job creation—for each new hi tech job created in a city, five additional jobs are created in the same city outside the high tech sector, both in skilled and unskilled occupations. While jobs in most sectors have some multiplier effect, "the innovation sector has the largest multiplier of all: about three times larger than that of manufacturing."[8] High tech jobs also pay considerably higher levels of compensation than the average wage levels, so that expansion of such jobs increases a region's standard of living.[9] States' recognition of the nexus between innovation, job creation, and rising standards of living underlies many of the state and regional development efforts described in this report.

Measuring the impact of innovation-based development programs on direct and indirect job creation is necessarily an inexact and subjective exercise, but the record if some state and regional efforts over time is impressive. A 2009 study of Philadelphia's University City Science Center (an urban research park and high tech incubator) found that 155 companies had originated, incubated, and received mentorship there which were still in existence, and accounted for 15,512 direct jobs and 25,825 indirect and induced jobs.[10] A recent assessment of Arkansas' 15-year effort to promote innovation based economic growth found that between 2008 and 2011 the states innovation-based programs had fostered 135 new companies directly employing 1,259 workers and that job gains in knowledge-intensive industries during the same period exceed 6,000.[11] New York's nanotechnology initiatives attracted investments from 300 companies accounting for an annual in-state payroll of $1.4 billion annually as of 2012.[12]

2004. For more discussion on the role of economic development incentives, see Chapter 4 of this report.

[8]"The Multiplier Effect of Innovation Jobs," *MIT Sloan Management Review* June 6, 2012; Enrcico Moretti, *The New Geography of Jobs,* Houghton-Mifflin, 2012.

[9]A benchmarking study of the Purdue Research Park conducted in 2011 found that employees of companies located in the Park received annual wages of $63,000 in 2010, 65 percent higher than the Indiana average. Thomas Miller and Associates, *Purdue Research Park: Driving Today's Economy—An Economic Impact Study of the Purdue Research Park Network*, May 2011, p. xv.

[10]At the time of the study the Center had been operational for 46 years. Most of the firms included in the survey had less than five employees during their incubation phase; by 2009, four of these firms had over 2,000 employees. Economy League of Greater Philadelphia, *The University City Science Center: An Engine of Growth for Greater Philadelphia*, September 2009, pp. 6, 23-28.

[11]See Chapter 8, "Arkansas—Workforce and Wind Power."

[12]See Chapter 7, "New York Nanotechnology Initiative;" "Nanotech Makes U.S. Job-Creation Special," Albany *The Times Union,* September 13, 2012.

Ohio's Third Frontier program had given rise to 15,945 direct jobs and 79,565 indirect jobs as of mid-2012.[13]

While innovation-based job creation is well documented, innovation initiatives are not a panacea for unemployment. We note that in New York's Capital region, where state and industry investments in nanotechnology has created thousands of new jobs in the past decade, unemployment in January 2013 was 8.4 percent and rising, the highest figure for any month since figures were collected starting in 1990.[14] State and regional economies confront dramatic challenges, including foreign competition and the destabilization of traditional industries by technological change. Innovation initiatives may not compensate for ongoing job losses but they can lay the seeds for future growth.

their primary competitors as other states.[15] At present, states' focus is shifting from intramural rivalries to competition with other regions of the world for leadership in the industries of the future.

Reflecting this new focus, states are fostering the development of local innovation clusters through long-term investments in human capital, scientific infrastructure, and knowledge-based entrepreneurship. They are seeking to leverage private and federal investments in research and infrastructure, in some cases with dramatic success—for example, the State of New York's investment of some $1.2 billion in Albany's emerging nanotechnology cluster has drawn an estimated $13 billion in private nanotechnology investments into the region as of 2012.[16] States are engaged in sectoral industrial promotion policies in promising emerging technologies—Michigan in electric energy storage, Arkansas in wind energy, Kansas in biotechnology, Ohio in flexible electronics, photovoltaics, and biomedicine. They are building research parks, research institutes with common infrastructure within universities, and incubators. Interestingly, a number of states have undertaken studies of best practices in other states and foreign countries.[17]

The federal role in state and regional economic development is changing. Traditionally the federal government influenced regional development through regulatory and legal policies that defined the economic environment with respect to intellectual property, the rules of competition, taxation levels and international trade. The federal government spent heavily on research, primarily by universities, often in a fragmented and uncoordinated

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[13]See Chapter 6, "Rebuilding Ohio's Innovation Economy;" Ohio Third Frontier, *2012 Annual Report.*

[14]See Chapter 7, "New York Nanotechnology Initiative;" "Area Jobless Rate Rises," Albany *The Times Union,* March 13, 2013.

[15]Lawrence W. Reed, "Time to End the Economic War Between the States," *Regulation* No. 2, 1996.

[16]Albany *The Times Union*, "Nanotech Makes U.S. Job Creation Special," September 19, 2012.

[17]Theresa McLendon, *Building a Knowledge-Based Economy in Arkansas: Strategic Recommendations by Accelerate Arkansas*, 2007.

manner.[18] Federal programs associated with regional economic development were a confused jumble of roughly 200 largely disconnected initiatives.[19] A few key sectors related to agriculture, energy, national security and public health benefitted from very substantial federal support for research that enhanced their position in international competition, but in most manufacturing and services sectors, the federal government was reluctant to make comparable investments. Procurement by the federal government provided critical early stage demand for some new industries, enabling them to achieve economies of scale and to enter commercial production, but these were exceptions largely limited to defense-related or dual use technologies.[20]

In many cases, states and regions promoted innovation clusters without concerted federal support in the years after the mid-1990s. Since 2009, however, the federal government has begun to augment state programs with its own explicit cluster-promoting initiatives. Examples would include "energy-innovation hubs," established under the auspices of the Department of Energy; financial support for cluster development by the Economic Development Administration and the Small Business Administration; and a newly launched National Network for Manufacturing Innovation (NNMI), a multi-agency collaboration to establish regional hubs of manufacturing excellence engaging universities, companies, and government.[21]

Most—albeit not all—state and regional cluster initiatives seek to build on existing local industrial competencies and natural resources to establish industries of the future rather than creating those industries entirely from scratch. (See Table 1-1.) Susan Crawford, then of the National Economic Council, has observed that an effective cluster "seems to require the preexistence of something successful on the ground that needs to be encouraged."[22]

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[18]National Research Council, *Research Universities and the Future of America: Ten Breakthrough Actions Vital to Our Nation's Prosperity and Security,* Washington, DC: The National Academies Press, 2012.

[19]Otis Graham Jr, *Losing Time: The Industrial Policy Debate,* Cambridge, MA: Harvard University Press, 1992. For further discussion of the nature of federal spending on research see Part VI of this report.

[20]David C. Mowery, Chapter 29—"Military R&D and Innovation," in *Handbook of the Economics of Innovation* Volume 2, Elsevir, 2010, pp. 1219-1256.

[21]See NSTC, "National Network for Manufacturing Innovation: A Preliminary Design," Washington, DC: The White House, January 2013. The report notes that "The Federal investment in the National Network for Manufacturing Innovation (NNMI) serves to create a manufacturing research infrastructure for U.S. industry and academia to solve industry-relevant problems. NNMI will consist of linked Institutes of Manufacturing Innovation (IMIs) with common goals, but unique concentrations."

[22]See Susan Crawford, National Research Council, *Growing Innovation Clusters for American Prosperity: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2011, p. 35.

TABLE 1-1 Building New Clusters on Existing Competencies

Location	Historic competency/resource	New industry
Toledo	Glassmaking	Photovoltaics
Arkansas	Electric generation and transmission	Wind power generation and transmission
Akron	Polymers	Biomaterials, flexible electronics
Hawaii	Agriculture	Biofuels
Northeast Ohio	Machinery	Medical equipment
Kansas	Agriculture	Biosecurity
Maine	Boat building	Composite-based high performance boats

IDENTIFYING BEST PRACTICES

It is clear from the symposia that while historically successful innovation clusters warrant study, there is no magic formula for success. The University of North Carolina's Maryann Feldman, who has extensively studied the cluster phenomenon, warns that innovation clusters are not "economic development sausage machines" where the right ingredients added at one end produce the desired result at the other. She observes that cluster formation reflects the local qualities of the places where it occurs, the most important of which are local social processes that combine with a vision of a new way of doing something to create new products, processes and industries. She concludes that "an economic development strategy that will work has to be predicated on a deep understanding of the location."[23] That said, it also emerged from the symposia that certain practices and techniques had proven successful in more than one or two innovation clusters and might readily be borrowed or adapted elsewhere under different local circumstances.[24] In the present exercise,

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[23]Maryann Feldman, "Cluster Development: A Path to Growth," in *Growing Innovation Clusters for American Prosperity: Summary of a Symposium,* op. cit., pp. 49-50.

[24]Michael Crow of Arizona State University notes that his institution "found that all the things that were important in California and in other innovation clusters made sense but could not be copied in Arizona. If you attempt to replicate what was done in Silicon Valley, it just will not work. You need to learn from them, draw on their lessons, and then work out your own solution." Michael Crow, The Role of Research Universities in the Formation of Regional Innovation Clusters: The

Box 1-5
The Complexity of Innovation[25]

Innovation is the transformation of ideas into new products, services, or improvements in organization or process. Some innovations are incremental; others are disruptive, displacing exiting technologies while creating new markets and value networks. These innovations can lead to new economic opportunities, job growth, and increased competitiveness. A key characteristic of innovation is that it is highly collaborative and often multidisciplinary and multidirectional. To be effective, policies to encourage and accelerate innovation need to recognize this reality.

Innovation is often described in terms of stages: basic research, applied research, followed by development and commercialization. In the real world, this process is often not linear. Indeed, research can sometimes address challenges that are both fundamental and applied at the same time. Many products are the result of multiple R&D iterations and draw upon technical sources other than their immediate R&D progenitors; many research projects generate results that are not anticipated—sometimes the unexpected outcomes are valuable in their own right. Importantly, innovations are often closely tied to the manufacturing process itself.

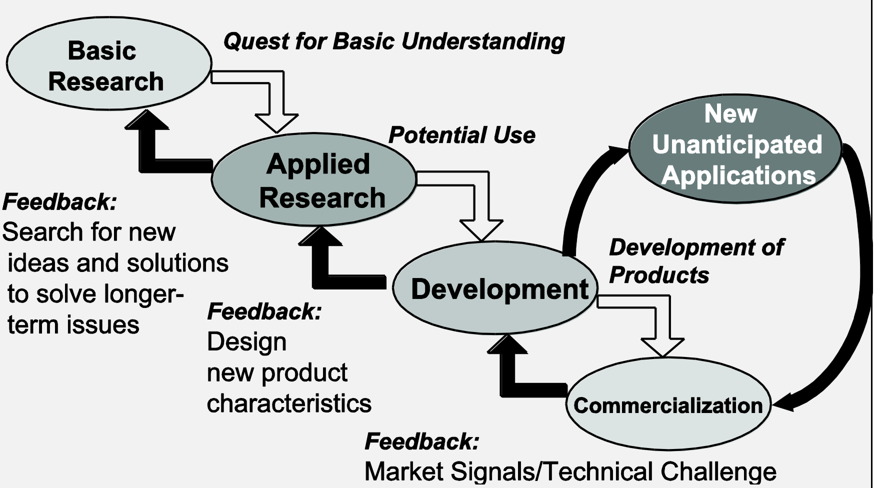

FIGURE 1-1 Schematic of the non-linearity of innovation.

Impact of Arizona State University on Metropolitan Phoenix," in *Growing Innovation Clusters for American Prosperity: Summary of a Symposium,* op. cit., p. 40.

[25]Adapted from Table 1-1 in National Research Council, *Rising to the Challenge: U.S. Innovation Policies for the Global Economy,* op. cit.

Ideas that result from the formalized exploration of knowledge do lead, in the long run, to innovations, but to expect this to be the case in the short run is misguided for both firms and governments. While innovation is not a direct consequence of R&D, it is also clear that continuous public investment has been critical in training a large number of people over many years and in creating the necessary environment to foster new technology-based businesses.

This complexity of the innovation process also highlights the role that a variety of intermediating institutions play in fostering collaboration among the many participants—including individual researchers, universities, banks, angel investors, venture capitalists, small and large companies, and local, state and national governments—across the innovation ecosystem.

What sets the United States apart from most other industrial nations is that there is no overarching national innovation strategy to support, much less coordinate, disparate initiatives to build commercially oriented industries. Paradoxically, this complexity with its many opportunities for entrepreneurship may be a major strength of the U.S. innovation system. Indeed, Nobel laureate economist Elinor Ostrom has extensively documented the adaptive advantages of open, institutionally diverse systems over linearly designed systems.[26]

a number of basic realities, institutional practices, policy measures, and trends have emerged with implications beyond their immediate local context in particular cases.

- ***U.S. research universities often play a key role in innovation-based regional economic development and are a cornerstone of U.S. international competitiveness.***

The university-driven character of the U.S. innovation system is a significant differentiator between this country and most other technologically-advanced countries, where the role of the academic research institution has been subordinated to other institutional arrangements. The United States enjoys the best university system in the world, and U.S. research universities have played a central role in driving the country's industrialization in the Nineteenth and early Twentieth Centuries and in making the transition to the knowledge-intensive economy of the late Twentieth and early Twenty-first centuries. University research programs and facilities supporting cooperative R&D programs with local industries, and specialized training programs are key to all of the recently-emerging clusters examined in this study.[27] For this reason, it is a serious matter

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[26]Elinor Ostrom, *Understanding Institutional Diversity*, Ewing, NJ: Princeton University Press, 2005.

[27]See for example, remarks by M.R.C. Greenwood, "Presentation of the Hawaii Innovation Council Report," in National Research Council, *Building Hawaii's Innovation Economy: Summary of a*

of concern that U.S. public universities now confront a steep decline in their traditional sources of funding (primarily state budgets) which threatens their ability to play their traditional role as innovation drivers.[28]

- ***Cooperative research arrangements involving universities and companies play an important role in fostering innovation.[29]***

In the past three decades, a veritable explosion in cooperative research centers has occurred in the United States. These entities, known variously as joint laboratories, centers of excellence, engineering research centers and industry-university research centers, break down barriers between academic disciplines and between scientific research, engineering applications, and commercialization of products and processes. Government organizations funding R&D are shifting their emphasis from support of individual researchers to funding these research centers, effectively creating public-private partnerships.[30] Companies taking part in such endeavors are changing their own approach to research, investing in facilities and projects that represent industrial commons," to be shared by other companies in a given industry.[31]

- ***Faculty recruitment, including the creation of endowed chairs, has emerged as an important tool in innovation-based economic development.[32]***

By attracting and holding prominent scientists and engineers as faculty members, universities not only improve the quality of their curricula and

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Symposium, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2012. See also remarks by John Ahlen, Michael Gealt and William Harris in the panel on "Universities and Regional Growth" in National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2012.

[28]NSB, *Diminishing Funding and Rising Expectations,* pp. 9-12, 19, 2012. For further discussion of the decline of funding of public universities, see Chapter 3.

[29]See for example, remarks by Luis Proenza, "Relevance, Connectivity, and Productivity: The Akron Model," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2013. See also remarks by Timothy Killeen, "The New York Innovation Economy and the Nanotechnology Cluster: The Role of SUNY" at the National Academies April 2013 symposium on New York's Nanotechnology Model: Building the Innovation Economy, held in Troy, NY.

[30]Craig Boardman and Denis Gray, "The New Science and Engineering Management: Cooperative Research Centers as Government Policies, Industry Strategies, and Organizations," *Journal of Technology Transfer,* February 2010, p. 447. For more discussion on cooperative research centers, see Chapter 3

[31]"Timken, UA Launch Venture—'Open Innovation' Partnership Allows University Students to Develop New Applications of Core Technology," *Akron Beacon Journal,* October 20, 2012. For more discussion of the role that companies play, see Chapter 6.

[32]This reflects a change from an earlier focus on a negative-sum pursuit for relocating established businesses to a competition for scientific and business talents.

enhance their reputation, but also stimulate local economic development and attract federal and foundation research grants. Entrepreneurial faculty are particularly prized and sought after. The state of Georgia was among the first ten states to adopt an "Eminent Scholars" program in 1992.[33] This program created endowed chairs at the state's universities to attract faculty from out of state, in particular individuals who had already founded companies or who had developed ideas they were seeking to commercialize.[34] More states have since followed in recent years. The University of Hawaii is reportedly implementing a plan to recruit top scientists and engineers in areas where the university has a decisive strategic advantage due to its location—the disciplines of volcanology, oceanography, and astronomy.[35] In 2002, South Carolina's legislature funded the Endowed Chairs Act to attract first-rate academic researchers to the state's universities.[36] Pursuant to a similar program in Ohio between 2005 and 2007, Case Western Reserve University attracted five academic-entrepreneurs to its biomedical program who secured $60 million in research grants during this period and started multiple companies to commercialize results. These prominent academics brought teams of experts with them to Case Western and helped the university recruit new staff.[37]

- ***Innovation intermediary organizations often make significant contributions to innovation-based economic development.***

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[33]Virginia was the first to adopt this program in the 1960s, with Ohio serving as the second adopter in 1983. They were followed by Tennessee, North Carolina, Louisiana, Georgia, and Arizona. See Maryann P. Feldman, Lauren Lanahan and Iryna Lendel, Experiments in the Laboratories of Democracy: State Scientific Capacity Building, *Economic Development Quarterly*, forthcoming.
[34]"Georgia's Technology Scholars Get a Tip of the Hat from Miller", *The Atlanta Journal-Constitution,* April 15, 1998; "Research Group Supportive of UGA Scientists," *Atlanta Banner-Herald* September 26, 2010. A 2013 audit of the Eminent Scholars Program by the state of Georgia found that the Eminent Scholars and their research teams had attracted about $270 million in non-state funding, supporting about 14,000 jobs at the state's universities in 2012. Georgia Department of Audits and Accounts, Performance Audit Division, *Georgia Research Alliance: Requested information on State-Funded Activities,* January 2013, p. 1. This program is similar in concept to the Canada Research Chairs program, which has established 2000 research professorships—in eligible degree-granting institutions across that country. According to their website, "The Canada Research Chairs program invests $300 million per year to attract and retain some of the world's most accomplished and promising minds." Accessed on May 10, 2013 at <*http://www.chairs-chaires.gc.ca/about_us-a_notre_sujet/index-eng.aspx*>.
[35]*University of Hawaii Innovation Recommendations,* University of Hawaii. 2011. See also remarks by M.R.C. Greenwood, "Presentation of the Hawaii Innovation Council Report," in National Research Council, *Building Hawaii's Innovation Economy: Summary of a Symposium*, op. cit.
[36]Presentation of David McNamara, South Carolina Research Authority, "Building the South Carolina Innovation Ecosystem," National Research Council, *Growing Innovation Clusters for American Prosperity: Summary of a Symposium*, op. cit, p. 15.
[37]Dan Simon, for example brought 15 doctors and scientist with him from the Brigham and Women's Hospital in Boston, and had built up a division of 59 professionals at CWRU's University Hospitals Heart & Vascular Institute in mid-2008. "The Fab Five," Cleveland *The Plain Dealer* July 20, 2008; "Influx of Researchers boosts NE Ohio Economy: Researchers Pump Millions into NE Ohio Economy," Cleveland *The Plain Dealer* July 20, 2008. For other examples, see Chapter 5.

Often possessing a deep knowledge of local research and workforce competencies, innovation-based economic development organizations can align local institutions, assets, skills, and resources to advance the innovation potential of states and regions.[38] One example is the Oklahoma Center for the Advancement of Science and Technology, whose mission is to diversify and grow Oklahoma's economy through strategic investment in developing, transferring and commercializing technologies.

- ***Successful innovation-based economic development is often fostered by a small number of key individuals bridging the space between science and commercialization.***

Susan Crawford, formerly of the National Economic Council, has pointed out that in fostering innovation, "it is so important to find that local leader who makes things go, the person who is tightly networked and who understands how community works."[39] The successful innovation clusters examined in this report reflect, to a very substantial degree, the efforts of a few individual actors capable of bridging the gap between academic science and commercialization of new technologies.[40] These innovation professionals are found in various intermediary organizations working to translate scientific knowledge into commercial products and processes. They have been active at different points in time during the past half century, have come from different backgrounds and have held diverse positions in their role as innovation enablers. It is important to note, indeed emphasize, that these individuals did not act alone, and were not solely responsible for the progress described. Despite their diverse backgrounds, what these individuals share in common is an ability to appreciate the commercial potential for scientific discoveries and to mobilize the disparate talents and resources that combine to make successful commercialization possible. By definition, they have not acted alone. They have functioned as individual innovation intermediaries, coordinating their

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[38]See, for example, Rebecca Bagley, "The Role of NorTech: Promoting Innovation and Economic Development," in National Research Council, *Building the Ohio Innovation Economy, Summary of a Symposium*, op. cit. For a review of the role of the Michigan Economic Development Corporation, see Eric Shreffler, "Michigan Investments in Batteries and Electric Vehicles," in National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities, Summary of a Symposium*, op. cit.
[39]Presentation by Susan Crawford, National Economic Council, in National Research Council, *Growing Innovation Clusters for American Prosperity: Summary of a Symposium,* op. cit., p. 37.
[40]For a review of the key role played by Alain Kaloyeros of the College of Nanoscale Science and Engineering in developing the Albany nano cluster, see the remarks by Michael Fancher at the National Academies April 2013 symposium on "New York's Nanotechnology Model: Building the Innovation Economy," held in Troy, NY.

jurisdictions' efforts to align locally developed knowledge with local resource to advance innovation.[41]

- ***State-of-the-art equipment has played a key role in the development of successful innovation clusters.***

A number of recent state initiatives to develop innovation clusters have demonstrated the powerful gravitational pull that can be exerted by state-of-the art scientific research infrastructure, particularly equipment and facilities that are costly and difficult for individual firms to acquire and operate.[42] New York State's Albany Nanotechnology initiative featured the establishment of the world's only university-based 300-millimeter semiconductor wafer fabrication facilities and clean room—a joint investment by the state and IBM—which was cited as a decisive locational advantage by other major microelectronics firms that subsequently established operations in Albany.[43] Youngstown, Ohio, invested in an incubator built out with a sophisticated software-testing lab and high-speed fiber optic connections and has succeeded in drawing a group of successful software companies—including a firm relocating from Silicon Valley and another which in 2007 had become the fastest-growing software company in the United States.[44]

- ***Non-profit organizations, philanthropies and foundations, and university affiliated research foundations can play a critically important role in regional innovation initiatives.***

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[41]National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium*, op. cit., March 8, 2011.

[42]Chad Mirkin, professor of chemistry at Northwestern University and director of the International Institute for Nanotechnology, observes that in forming innovation hubs a region needs a "state-of-the-art infrastructure, which is required to do the initial basic research and requires funding that is "seldom available locally." He indicates that "This is where the role of government is essential, applied in the form of federal and sometimes state grants to provide the physical innovation environment. … Such investments are beyond the reach or interest of the private sector, including the capital community, and depend on close partnerships with public agencies to lay the groundwork for innovation." See Chad Mirkin, "Welcome and Introduction," National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2013.

[43]Presentation by Gary Patton, "IBM's Strategic Alliance Partnerships," at the National Academies April 2013 symposium on "New York's Nanotechnology Model: Building the Innovation Economy," held in Troy, NY. See also, "U Albany Lands R&D Center," *The Times Union* November 21, 2002. For more discussion of the role that Albany's locational advantages played, see Chapter 7.

[44]"Youngstown Ohio: A Young Town Again," *The Economist* October 8, 2009; "Research Company to Open Office in Downtown Tech Block," Youngstown *Vindicator* January 12, 2010. For more discussion of Youngstown, see Chapter 6.

Private foundations and philanthropies have played an extraordinarily important role in the development of some innovation clusters and their actual and potential value warrants increased recognition. Foundations are typically less burdened with bureaucratic structures than government agencies. In some cases, foundations benefit from being managed by private sector entrepreneurs and others with experience in the business world. As a result, some foundations are willing to take risks, and are able to act quickly. They are sometimes able to bring substantial resources to bear on new initiatives or institutions.[45] From an economic development perspective, many foundations concentrate their investments in limited geographic areas.[46] North Carolina's Research Triangle Park arguably owes its existence to an extraordinary outpouring of giving by North Carolinians for the good of the state, administered through a foundation, in the 1950s.[47] In Ohio both philanthropic and university-based research foundations have played a central role in the conversion of the state's industrial base from traditional manufacturing to a more innovation-based economy—most importantly, during the past decade, local foundations pooled their resources and supported a small number of non-profit, professionally-staffed economic development organizations that have functioned as catalysts for knowledge-based industrial revitalization.[48]

- ***Entrepreneurs need early-stage financing to bring new ideas to the marketplace.***

At most of the symposia convened for this study, local economic development officials and entrepreneurs have lamented the difficulty encountered by would-be innovative startups in attracting sufficient early stage

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[45] George W. Bo-Linn, Gordon and Betty Moore Foundation, "Building the Workforce and the Universities," National Research Council, *Growing Innovation Clusters for American Prosperity: Summary of a Symposium*, Washington, DC: The National Academies Press, 2011, pp. 108-113.
[46] Heinz Endowments concentrates its investments in Southwestern Pennsylvania, which includes Pittsburg. The Cleveland Foundation Focuses on Northeast Ohio. The Moore Foundation makes over half of its awards to recipients in California, Christina Gabriel, Bomani Howze, The Heinz Endowments, "How Innovation Clusters are Reviving the Economies that 'Urban Renewal' Destroyed," National Research Council, *Growing Innovation Clusters for American Prosperity: Summary of a Symposium*, op. cit., pp. 105-108; George W. Bo-Linn, Gordon and Betty Moore Foundation, 'Building the Work Force and the Universities," *Growing Innovation Clusters for American Prosperity: Summary of a Symposium*, op. cit., pp. 108-113.
[47] Albert N. Link, A *Generosity of Spirit: The Early History of Research Triangle Park, Research* Triangle Park: Research Foundation of North Carolina, 2005. For more discussion about the history of Research Triangle Park, see Annex B.
[48] For a review of initiatives by the Cleveland Foundation, see Ronn Richard, "Economic Development in Ohio: The Role of Community Foundations," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium,* op. cit. See also *The Plain Dealer* "Philanthropy is Our Way of Life of Greater Clevelanders," December 26, 2010. For more discussion of the role of foundations in Ohio's successful initiatives, see Chapter 6.

financing.[49] Studies commissioned by state economic development authorities to address their prospects for innovation-based development commonly deplore the dearth of early-stage financing as a serious problem.[50] Even in California, long viewed as a Mecca for startups seeking venture capital, the availability of early stage financing has declined substantially since the onset of the financial crisis in 2008.[51] In Illinois the Chemistry of Life Processes Institute—a pioneering interdisciplinary biomedical research institution at Northwestern University—fostered two promising start-up companies but could not find local sources of early stage financing so both companies left the state to begin operations in the areas in which they secured venture capital.[52]

- ***Policy continuity and sustained funding are essential for the development of innovation clusters.***

Michigan's battery initiative, featuring lithium-ion technology for application in electric vehicles, and Toledo's emerging photovoltaic cluster, have fostered start-up companies that currently face highly uncertain demand for their products over the short run.[53] Some firms have failed or retrenched and the risk exists that foreign industrial groups with greater financial stamina and government support will eclipse promising U.S. industries in their infancy. In the past, nascent U.S. sectors in emerging technologies have benefitted from federal procurement in the early stages, which has enabled them to generate revenues and achieve cost competitiveness.

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[49]See, for example, comments by Barry Weinman, "Converting University Research into Start-up Companies," in National Research Council, *Building Hawaii's Innovation Economy: Summary of a Symposium*, op. cit. As used here, the term "early stage financing" refers to capital made available to an innovator in the initial phases of the start-up of a company to commercialize a new technology. It includes "seed" stage financing (comparatively small sums used for proof of concept and lining up startup capital); start up financing (pre-commercial funding of product development and early marketing efforts); and the first round of financing after start-up, usually involving a venture capital company of fund. The seed and start-up phase are often funded from the innovator's own resources and/or angel investor. See generally, Illinois Venture Capital Association, "Definitions," *<http://www.illnoisvc.org/pages/definitions/61.php>*.

[50]Arkansas' Task Force for the Creation of Knowledge-Based Jobs concluded in a 2002 Report that "a key element that has been missing from the entrepreneurial equation in Arkansas is the lack of venture capital to keep new, knowledge-based businesses in the state." *Report of the Task Force for the Creation of Knowledge-Based Jobs,* September 2002.

[51]In the first three quarters of 2012, biomedical firms in California obtained nearly $2 billion in venture capital investment—a substantial figure, but well below the nearly $4.5 billion raised in 2007, and quite possibly short of the annual total of $3.5 billion raised in 2011. "California Biomedical Industry Still the Biggest, Despite Tight Financing," *Alameda Times-Star* January 8, 2013.

[52]O' Halloran, Thomas, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit. For more discussion of the Chemistry of Life Process Institute, see Chapter 6.

[53]See National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium*, op. cit., which highlighted the need for adequate demand to sustain the emerging advanced battery industry in Michigan.

- ***Political leadership and stability play an important role in successful state and regional innovation-based developments.***

Some of the most successful innovation clusters reflect, in substantial part, the existence of longstanding bipartisan support from local political leaders, which has provided a stable environment for long range investments in innovation. In North Carolina, the Research Triangle Park was supported for decades by successive Democratic and Republican governors. In New York, the Albany nanotechnology initiative enjoyed bipartisan support. It was launched by Governor George Pataki, but has subsequently been supported strongly and effectively by Governors Eliot Spitzer, David Paterson, and Andrew Cuomo.[54] Ohio's Third Frontier program, one of the most ambitious and successful state innovations-promotion schemes, has enjoyed bipartisan support and is embedded in the state constitution.[55]

The Path Forward

The examples of successful practices cited above should not be taken as an ironclad formula for success. They are intended to identify needs and illustrate arrangements that have proven to be a promising path forward. As noted above, the development of regional clusters is not formulaic and much depends on continuity and the commitment of the political leadership that makes available a critical mass of funding and involves institutional partners, both private and public, that are committed to broad goals as well as specific outcomes. The observations above do identify key elements of successful cluster development, reflected in the examples reviewed by this report. There are no doubt many other examples and many nuances on those identified here. The material presented in the body of the report provides concrete illustrations of these principles.

OVERVIEW OF THE REPORT

This volume draws together our findings from a series of conferences and workshops on state and regional initiatives to foster growth and employment through innovation, supplemented by research on the global competitiveness challenge and federal, state, and regional policies and programs. The report is organized as follows: Chapter 2 discusses the role of clusters in state and local economic development efforts. Chapter 3 describes the opportunities and challenges facing universities as drivers of innovation and regional growth.

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[54]Darren Suarez, "Challenges and Opportunities for the New York Innovation Economy," at the National Academies April 2013 symposium on "New York's Nanotechnology Model: Building the Innovation Economy," held in Troy, NY.
[55]James Leftwich, "Investing in Ohio," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium,* op. cit.

Chapter 4 reviews the evolution of state strategies in economic development, from a short-term focus on industrial recruitment to longer-term investments in education and knowledge-based growth. In complement to the state role, Chapter 5 highlights the federal role fostering regional development, not only through funding for scientific research but also via support for innovation clusters, protection of intellectual property, trade policy, and procurement. Chapters 6 and 7 provide detailed case studies of major initiatives underway in Ohio and New York to develop and sustain new economic drivers. Chapter 8 reviews recent initiatives in Arkansas and Illinois to develop their innovation economies.

Chapter 2

State and Regional Development and Clustering

In the United States, the proper role of the federal government in economic development has been controversial since the days of Hamilton and Jefferson.[1] There is a general consensus that the federal government should conduct monetary, trade, and regulatory policy and support basic infrastructure such as highways and airports.[2] Industrial policy is something of an American tradition as well, perhaps most sustained in agriculture[3] but also with longstanding support for sectors associated with national security and public health.[4] However, the idea of supporting new industries, and especially particular firms, is a source of perennial controversy in the U.S. Congress and within U.S. economic policy circles, a fact that is manifested in the frequently erratic pattern of federal support for particular industries.

At the state level, however, the perspective toward economic development is much different, with policy actors relatively unconstrained by

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[1]See Nikolaos Karagiannis and Zagros Madjd-Sadjadi, "A New Economic Strategy for the USA: A Framework of Alternative Development Notions," *Forum for Social Economics* 41(2-3), 2012.
[2]This is a long held perspective. See, for example the review by Otto Eckstein, "Federal expenditure policy for economic growth," *The Journal of Finance* 17, 1962.
[3]U.S. agricultural interests, succeeded in securing the establishment of a cabinet-level department to promote their industry in 1889 and succeeded in establishing the proposition that the farm sector was a special industry requiring a special public policy, At various points in the past century U.S. farmers have benefitted from price supports, research and development assistance, import protection, low interest financing, and export subsidies. Paradoxically, this massive federal support has been paralleled by enthusiastic support for laissez-fair principles and free trade by industry spokesmen. Robert H. Wiebe, *The Search for Order, 1877-1920,* New York: Hill and Wang, 1967, pp. 126-127; Richard Hofstadter, *The Age of Reform,* New York: Vintage Books, 1955, pp. 122-129.
[4]In the post-World War II era, within the framework of national defense and the imperatives of the Cold War, the Department of Defense and other national security organizations, such as the National Aeronautics and Space Administration and the Atomic Energy Commission, supported the development of technologies and industries associated with national security, including titanium computers, aviation, microelectronics, nuclear power, and lasers. The National Institutes of Health supported research that included fostering U.S. capabilities in pharmaceuticals and biotechnology.

the ideological considerations that have occasionally inhibited implementation of federal policy. In 1988, an academic observer noted an "intensive preoccupation with economic development at the state and local level" that had emerged in the late 1970s and commented as follows:

> *The 50 states and many of their communities are in the process of fashioning, with varying degrees of vigor and coherence, separate little industrial policies, self-conscious attempts to foster selected industries judged to provide comparative local advantage or to be critical to the local economic future.*[5]

The states responded more aggressively to the structural changes besetting the American economy than did the federal government which became mired in Congress-Executive Branch debates about the rectitude and effectiveness of 'industrial policy' measures."[6]

In the years since these observations were made, state and local industrial development efforts have continued unabated while undergoing a qualitative evolution that increasingly emphasizes knowledge-based development. In the 1970s and 1980s, science and research initiatives were implemented by state governments, but these were generally ancillary to larger-scale efforts to shore up established industrial sectors and to recruit out-of-state companies with the objective of preserving and expanding employment.[7] In recent decades, however, innovation-related initiatives have moved to the center of state and local development efforts, featuring initiatives such as the upgrading of university research infrastructure, faculty recruiting, the promotion of systematic and professionalized university-industry technology transfer, the fostering of start-ups, and the development of research and innovation-based industrial clusters.

NATURAL DEVELOPMENTAL ADVANTAGES ENJOYED BY STATES AND REGIONS

State leadership in innovation enjoys a rationale that extends beyond the parochial concerns of local leaders. While federal spending on R&D is

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[5]Peter K. Eisinger, *The Rise of the Entrepreneurial State: State and Local Economic Development Policy in the United States,* Madison: The University of Wisconsin Press, 1988, p. 6.

[6]Irwin Feller, "Federal and State Government Roles in Science and Technology", *Economic Development Quarterly* 1997, p. 285.

[7]By 1985, about 35 U.S. states had some type of advanced technology programs involving initiatives such as technical and vocational education, promotion of start-ups through incubators or the provision of venture capital and support for university-industry R&D projects. The U.S. Office of Technology Assessment observed in 1983 with respect to these initiatives that "few of them have been in existence long enough to produce measurable results, and in most cases there has been no systematic evaluation of their effectiveness." Irwin Feller, "Evaluating State Advanced Technology Programs," *Evaluation Review* June 1998, p. 233.

massive, the greatest proportion of this expenditure is devoted to defense and national-security-related technology development projects sponsored by the Departments of Defense, Energy, and Homeland Security.[8] While much of the defense related research spending benefits private companies conducting contract R&D, the research results frequently cannot be applied in the commercial realm and indeed, federal policy priorities often divert funds and the efforts of private contractors away from consumer and industrial markets.[9] Accordingly, "state governments justify their involvement as brokers and patrons of the technology-transfer process on the grounds that their priorities lie in the development of innovations to be sold in the open market, transactions that will ultimately enhance the local economy."[10]

"Sub-national governments have a greater capacity to tailor programs to local conditions." In the United States, a number of academic studies have concluded that in the development of technology pioneering firms, state support has played a key role in pooling multiple external public and private funding sources, including federal funds and venture capital, and directing them to private firms.[11] At one of the symposia convened for this project, a Commerce Department official commented that with respect to economic development, "state and local leaders tend to be ahead of the curve." Regional innovation clusters cannot be legislated—"they are organic. You have to have champions at the local, private sector and state levels. What we can do is work with those

[8]For a review of the division of federal R&D spending, see AAAS Report XXXVII, Research and Development, FY 2013.

[9]For a classic review of the potential and limitations of military R&D, see John Alic et al., *Beyond Spinoff*, Boston: Harvard Business School Press, 1992. In 2004, a study was prepared for the U.S. Air Force under Commerce Department auspices, with respect to the attitudes of 447 high tech companies toward collaboration with DoD in R&D and technology sharing, of which 35 percent of the surveyed firms were classified as defense contractors. About 45 percent of the firms surveyed indicated a reluctance to discuss R&D with DoD, citing factors such as non-applicability of technology to non-DoD uses, difficulty or working with federal agencies, inadequacy of financial rewards, and inadequacy of development funding. Nearly 53 percent of the defense contractors surveyed complained about the inadequacy of financial rewards. U.S. Department of Commerce Bureau of Industry and Security, Office of Strategic Industries and Economic Security, *Assessment of Industry Attitudes on Collaborating with the U.S. Department of Defense in Research and development and Technology Sharing,* January 2004, pp. ii, 25. In 2012, acting in response to a Presidential Memorandum, "Accelerating Technology Transfer and Commercialization of Federal Research in Support of High Growth Business," October 28, 2011, DoD promulgated a "Strategy and Action Plan" to encourage an increase in DoD technology transfer. The plan features a series of improvements in DoD's technology commercialization processes and new performance metrics which include the commercial impact of DoD technology transfer. DoD, "Strategy Action Plan for Accelerating Technology Transfer [T2] and Commercialization of Federal research in Support of High Growth Business," October 4, 2012.

[10]Eisinger, *Rise of the Entrepreneurial State* op. cit. p. 275.

[11]Andrea Fernandez-Ribas, "Public Support to Private Innovation in Multi-Level Governance Systems: An Empirical Investigation," *Science and Public Policy* July 2009, p. 459.

folks as true partners and customize the deployment of federal resources to amplify and accelerate that particular cluster."[12]

The states and municipalities can often use policy levers with greater precision and effectiveness than the federal government. They control factors of production such as land use and availability, infrastructure, power and water, and waste disposal. Every state supports a system of public universities, institutions that along with their private counterparts have been at the forefront of innovation-driven economic development for well over a century. While federal government research grants and contracts influence the activities of the public and private universities, the largest substantial proportion of the operating budgets (non-targeted funds) of public universities are still derived from state governments, which remain in a position to encourage educational institutions to align their priorities with local economic development.[13] The states likewise control the provision of public K-12 education, which depending on its quality, can foster the development of an adult work force with the skill levels necessary to support an innovation-driven economy.

U.S. advantages in universities may be eroding. State funding for students at public universities has fallen on a per capita basis by 20 percent over the last ten years.[14] This has been followed in recent times by additional cuts to federal support for university R&D. [15] And the proportion of state university budgets derived directly from the state has declined sharply, even if the leading U.S. research universities continue to produce more highly cited articles than research universities in other countries.[16]

Moreover, most states lack a framework for considering R&D activities, or for integrating R&D at the state level with programs at the federal level. Notably, a 1995 report of The State-Federal Technology Partnership Task Force chaired by the Governors of Ohio and Pennsylvania (the Celeste-

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[12]Comments of U.S. Assistant Secretary of Commerce for Economic Development John Fernandez, National Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2012.
[13]National Science Board, *Science and Engineering Indicators 2012*, Arlington, VA: National Science Foundation, Chapter 6.
[14]According to the National Science Board, "State per-student funding for the nation's 101 major public research universities declined by an average of 20 percent in inflation-adjusted dollars between 2002 and 2010, with 10 states experiencing declines ranging from 30 to as high as 48 percent." NSF, Press Release 12-176, "Science Board Concerned About Declines in Public Research University Funding."
[15]*Washington Post*, "Sequester cuts university research funds," March 16, 2013. The article notes that "the federal budget sequester that took effect this month—requiring cuts of about 5 percent in nondefense programs and more than 7 percent in defense—is likely to shrink research spending by more than $1 billion. Advocates warn that the cuts could hamper exploration in biomedical science, among other disciplines, and undercut efforts to ensure U.S. leadership in science and engineering."
[16]National Science Board, *Science and Engineering Indicators 2012*, op. cit., Chapter 6.

Thornburg Report,) called attention to this disjunction and offered policy recommendations to remedy it.[17]

In contrast, for countries such as Singapore, Taiwan, and Korea, the health of the innovation economy is a central focus for policymakers, as is the acquisition and development of new technologies for commercialization and export.[18]

Where the federal authorities in the U.S. sometimes hesitate to support promising sectors, especially in a sustained fashion, countries in East Asia, as well as in Europe, provide sustained policy attention and substantial public investment.[19] They provide continued high level policy attention and substantial investment, backed by education and development policies.

Even so, the notion that individual U.S. states are overmatched in competition with other more mercantilist and more advanced countries may well be misplaced. While state levels of population and GDP are not always comparable to those of technology-intensive foreign countries, they are not altogether dwarfed by them. More significantly, U.S. states appear to enjoy an edge with respect to a key element in technology competition, the presence of first-rate universities.

THE INNOVATION CLUSTER PHENOMENON

The states have been the primary movers in the widespread and growing practice of fostering innovation clusters as an economic development tool. In his seminal 1990 book *The Competitive Advantage of Nations,* Michael Porter argued that in advanced economies, regional "clusters" of related industries—not individual companies or sectors—are the primary source of competitiveness, export growth and rising employment and income levels.[20] Clusters are geographically localized concentrations of firms in related sectors that do business with each other and have common needs for trained workers, infrastructure and technology. Although the cluster concept predates Porter by nearly a century, and the cluster phenomenon itself is as old as history, Porter popularized it so effectively that since his book appeared the cluster concept has

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[17]The State-Federal Technology Partnership Task Force—Final Report, September 5, 1995. Report Developed by 20-member State-Federal Technology Partnership Task Force assigned by Governors Celeste and Thornburgh.

[18]National Research Council, *Rising to the Challenge: U.S. Innovation Policy for the Global Economy*, C. Wessner and A. Wm. Wolff, eds., Washington, DC: The National Academies Press.

[19]Ibid. This is not to say that all foreign interventions in new technologies and new firms succeed. Many do not, just as U.S. investments in new technologies and new weapon systems do not always succeed. Yet, continued pursuit of these goals, and continued investment, is the global norm, and seen to be in the national interest.

[20]See Also Michael Porter, "Clusters and the New Economics of Competition," *Harvard Business Review* 1998.

Box 2-1
Examples of Leading National Programs for Applied Research

In a world where U.S. states and regions compete not only with their neighbors but with other innovative regions around a "spikey" world, it is worth noting the significant levels of policy attention and resources being devoted elsewhere to fostering innovation-led growth. Germany, Singapore and Finland illustrate how these nations see their future prosperity and security closely tied to their positions as global leaders in knowledge and innovation.

Germany's Fraunhofer-Gesellschaft

Fraunhofer-Gesellschaft is widely seen as a major factor behind Germany's continued export success in advanced industries. Established in 1949 as part of the effort to rebuild Germany's research infrastructure,[21] the non-profit organization is one of the world's largest and most successful applied technology agencies. Fraunhofer's 80 research institutes and centers in Germany and around the world employ some 17,000 people—4,000 of them with Ph.D.s and master's students—and has a $2.3 billion (€1.62 billion) annual budget. Fraunhofer engineers develop intellectual property on a contract basis, hone product prototypes and industrial processes, and work with manufacturers on the factory floor to help implement new production methods.

One-third of Fraunhofer's funding consists of core money provided by the German federal and state governments, roughly another third comes from research contracts with government entities, and a final third is provided through research contracts with the private sector—which are frequently supported by government grants and other financial assistance. In all, well over 80 percent of funding comes from taxpayers.[22]

Singapore's A*STAR

A city-state in south-east Asia, Singapore has a population of 4.5 million. With a budget of US$4.3 billion allocated in the 2010 S&T Plan, Singapore's technology agency mission is to conduct research and strengthen the base of scientific talent to support the development of the key industry clusters, including those in the biomedical sciences, chemicals, electronics, information and communications technologies, and engineering. A*STAR

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[21]For a history of the organization, see, 60 Years of Fraunhofer-Gesellschaft, Munich: Fraunhofer-Gesellschaft, 2009. The publication can be accessed at *<http://www.germaninnovation.org/shared/content/documents/60YearsofFraunhoferGesellschaft.pdf>*.
[22]House of Commons Science and Technology Committee, *Technology and Innovation Centres. Second Report of Session 2010-11*, Vol. I, Report, p. 27.

oversees 14 biomedical sciences and physical sciences and engineering research institutes, and six consortia and research centers. Its Biopolis and Fusionopolis facilities bring together over 2,500 scientists in close proximity to multi-national companies and small and medium enterprises who have established their R&D labs in these purpose-built, state-of-the-art infrastructures.[23]

Finland's TEKES

Finland's technology agency Tekes serves this European nation of 5.4 million. Tekes works with the top innovative companies and research units in Finland. "Every year, Tekes finances some 1,500 business research and development projects, and almost 600 public research projects at universities, research institutes and polytechnics." Tekes facilitates collaboration and networking between small and large businesses, industry and academia, and public and private sector and non-governmental organizations. In 2012, Tekes provided 570 million Euros in funding for Finnish companies and research organizations, and 350 million Euros for company projects, of which 135 million Euros were directed to young growth companies. With a view to promoting international R&D cooperation, Tekes can also finance R&D projects that are undertaken by foreign-owned companies that are registered in Finland.[24]

come to dominate the economic development thinking in advanced countries, including the United States.[25]

At present, most state and regional development efforts in technology-intensive industries are based on cluster formation.[26] A 2010 report by the Brookings Institution observed that "with little or no past federal support,

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[23]A*STAR, "Singapore Science, Technology, and Enterprise Plan 2015," Singapore: A*STAR, 2011.

[24]Tekes website at <*http://www.tekes.fi/en*>.

[25]Prior to industrialization, clustering was often essential because of the limitations of transportation and communications. However, the phenomenon persists at present notwithstanding the relative ease of global transport and communication. Prior to industrialization, clustering was often essential because of the limitations of transportation and communications. However, the phenomenon persists at present notwithstanding the relative ease of global transport and communication. Of course, clusters were identified a long time ago by Marshall and others. Until the 1960s, clusters were the only way that most industries could develop because of the limitations of communications and transportation. Over 100 years ago, the Census Bureau created enormous volumes setting out and analyzing in detail U.S. manufacturing clusters (see section XXXIX of <*http://www2.census.gov/prod2/decennial/documents/05457254v7ch02.pdf*>). Interest in clusters has revived since the 1990s as a reaction to the downsides of dispersion.

[26]Mary J. Waits, "The Added Value of the Industry Cluster Approach to Economic Analysis, Strategy Development and Service Delivery", *Economic Development Quarterly* 14(1):35-50, February 2000.

numerous U.S. regions and states today operate several hundred distinct cluster initiatives—formally organized efforts to facilitate cluster growth."[27]

Clusters attract the attention of state, regional, and local policymakers "because of the economic vibrancy that a successful cluster can give an area."[28] NorTech, a highly regarded non-profit technology-oriented development organization serving Northeast Ohio, recently summarized the local benefit clusters can deliver: "(1) transition from unemployment to high-skill employment; (2) create new higher-wage job opportunities; (3) develop local businesses less susceptible to offshoring; (4) stabilize communities by re-purposing idle assets and people; and (5) manufacture products in the region for export, restoring value to the region."[29]

Geographic concentrations of specialized artisanal and industrial activities can be traced back to the beginnings of recorded history, and a rich literature on the subject has developed since the writings of the great English economic historian Alfred Marshall in the late Nineteenth and early Twentieth Centuries. Marshall and his contemporaries identified a number of "agglomeration" forces underlying such concentrations, including reduced transportation costs with respect to inputs, availability of a skilled labor pool, the desire to capture "secrets of the trade," through local presence, enhanced likelihood of innovation, and sharing resources that entail substantial fixed costs.[30] More recently, Michael Porter has emphasized the manner in which local clusters ease the management of modern value chains, in which companies outsource various elements of design production, assembly, testing, and system management.[31]

As dramatic advances in transportation and communications unfolded, such as the railroad, the telegraph, and mass printing, many observers—including Marshall himself—believed that the advantages of localized industrial concentrations would diminish. On the basis of this logic, the advent of the

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[27]Mark Muro and Bruce Katz, *The New 'Cluster Moment': How Regional Innovation Clusters Can Foster the Next Economy*, Washington, DC: The Brookings Institution, September 2010, p. 20.
[28]Eugene Seeley, "A New View on Management Decisions that Lead to Locating facilities in Innovation Clusters", *Journal of Business Inquiry,* Vol. 10. 2011.
[29]NorTech, "Why Clusters Matter." Access at <*http://www.nortech.org/clusters/why-clusters-matter*>.
[30]See generally Nancy Dorfman, "Route 128: The Development of a Regional High Tech Economy," *Research Policy,* 1983. Dorfman credits the development of high technology in the Boston area in the 1970s to agglomeration effects, meaning that the local growth in the size and number of firms operating in a specific industry (as well as related support industries) make an area alternative for a firm. Dorfman indicated that there are "important advantages in locating near to complementary and competitive enterprises." Ibid.
[31]Michael E. Porter and Mark R. Kramer, "Creating Shared Value," *Harvard Business Review* January 2011. While it is quite evident that innovative activity is spatially distributed in an uneven manner, the reason(s) why this is so has given rise to numerous hypotheses. For a survey of these theories and the complex issues surrounding the "geography of innovation," see Ian R. Gordon and Phillip McCann, "Clusters, Innovation and Regional Development," Centre for Economic Policy Research, 2003.

Internet and other forms of instantaneous communication today should further undermine the advantages associated with specialized geographic industrial concentrations. In fact, that has not happened, particularly with respect to innovation-intensive forms of industrial activity, reflecting the fact that key aspects of knowledge formation and transmission favor location in specific places.

The persistence of clusters in the global era is closely associated with so-called "tacit knowledge", which confers a competitive edge on geographic localities where knowledge creation and transmission are occurring. Contrasted with codified or formal knowledge which is written down on paper or stored or transmitted through electronic media, tacit knowledge—e.g. "know-how"—is attained through actual operating experience, observation of results, and hands-on experimentation, and is typically conveyed to others on a face-to-face basis through repeated demonstration and coaching, as for example, traditionally occurred in an industrial apprenticeship or laboratory practicum.[32] Codified knowledge can be transmitted anywhere in the world instantaneously; transmission of tacit knowledge generally requires close geographic proximity[33]. Michael Polanyi, a Twentieth-Century scientist who developed understanding of tacit knowledge, summarized it in 1958:

> *An art which cannot be specified in detail cannot be transmitted by prescription, since no prescription for it exists. It can be passed on only by example from master to apprentice. This restricts the range of diffusion to that of personal contacts. We find accordingly that craftsmanship tends to survive in closely circumscribed local traditions.*[34]

The demands of tacit knowledge creation and transmittal usually require not only close personal interaction, but also localized facilities and infrastructure that permit practical, hands-on application and testing of theoretical concepts. For example, protracted aircraft propeller wind tunnel testing conducted at Stanford University by professors W.F. Durand and E.P. Lesley between 1916 and 1926 was necessary because "there was no way in which the body of scientific knowledge would permit a more direct determination of the optimal design of a propeller given the fact that 'the

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[32]Jan Youtie and Philip Shapira. "Building an Innovation Hub: A Core Study of the Transformation of University Roles in Regional Technological and Economic Development," *Research Policy.* 37:1190-1191, 2008.

[33]"Know-how is practical knowledge about how to get something done, as opposed to 'know-what' (facts), 'know-why' (science), or know-who (networking). Know-how is often tacit knowledge that means it is difficult to transfer from one person to another by means of writing it down or verbalizing it. "Intellectual Property (IP) and Know-How: Defined," *Charlotte Examiner* June 20, 2011.

[34]Michael Polanyi, *Personal Knowledge: Toward a Post-Critical Philosophy,* Chicago: University of Chicago Press, 1958, p. 52.

propeller operated in combination with both the engine and airframe…and it must be compatible with the power-output characteristics of the former and the flight requirements of the latter."[35] Similarly, optimal scale for a plant cannot necessarily be determined by reference to codified knowledge or even by simply scaling-up from a small-scale model. "The key experimental tool of the…engineer is therefore the pilot plant, and inferences drawn from experimental data provided by such plants. Such optimal size will be found to differ from one…product line to another."[36] The late Eugene S. Ferguson, an engineer and historian of technology, made the following pertinent observation two decades ago:

> *I was fortunate to learn early that an engineer's intelligent first response to a problem that a worker brings in from the field is "Let's go see." It is not enough to sit at one's desk and listen to an explanation of a difficulty. Nor should the engineer refer immediately to drawings or specifications to see what the authorities say. The engineer and the worker must go together to the site of the difficulty if they expect to see the problem in the same light. There and only there can the complexities of the real world, the stuff that drawings and formulas ignore, be appreciated.*[37]

The need and desire to capture tacit knowledge has long been recognized as a key factor underlying the location of research and development activity.[38] That fact favors locations with existing manufacturing, testing, and research and development operations that are all potential sources of tacit knowledge. A 2009 survey of U.S. semiconductor producers by the Semiconductor Industry Association found that these firms physically located their process R&D activities wherever their manufacturing operations were,

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[35]Nathan Rosenberg, and W. Edward Steinmueller, "Engineering Knowledge." SIEPR Discussion Paper No. 11-022, p.11, The authors note W. Vincenti's observation that "what the Stanford [wind tunnel] experiments eventually accomplished was something more than just data collection and, at the same time, something other than science. It represented, rather, the development of a specialized methodology that could not be directly deduced from scientific principles, although it was obviously not inconsistent with those principles… [T]he strength of experimental parameter variation is precisely its ability to provide solid results where no useful quantitative theory exists. Ibid pp. 13-14.
[36]Ibid. p. 21.
[37]Eugene S. Ferguson, *Engineering and the Mind's Eye,* Cambridge, MA: The MIT Press, 1992, p. 56.
[38]"[O]ne distinguishes between information on the one hand, and knowledge or know-how on the other. For this purpose, the distinction is in the tacit character of knowledge, not the formal conception of an innovation, but the skill and experience associated with effectively implementing it. Although advances in information technology may have caused the cost of transmitting the formal conception to become invariant to distance, effectively transmitting tacit knowledge requires proximity, and hence creates the potential for agglomeration." Gilson, "Legal Infrastructure of High Technology Industrial Districts," op. cit. p. 582. 1999. Citing Maryann Feldman, *The Geography of Innovation,* 1994, p. 53.

reflecting the fact that the best process R&D requires close interaction with actual manufacturing operations.[39] Tesla Motors chose Michigan as the site of a 2007 technical center, in part, on the basis of Michigan's existing infrastructure—"we felt it was smart to use the existing test tracks, validation equipment, wind tunnels and more, rather than duplicating these costly investments."[40]

Notwithstanding the intrinsic advantages arising out of co-location of innovative enterprises and research institutions in clusters, the fact remains that key innovative technologies originated in various regions of the United States have migrated to other countries for commercialization. The reasons for this vary from case to case but commonly involve the existence of superior and/or lower cost manufacturing competencies and infrastructure in other countries, work force issues, the availability of financing, and incentives deployed by foreign governments.[41] The President's Council of Advisors on Science and technology commented in a 2011 report that:

> *Foreign firms now manufacture many products invented here. For example, the United States no longer has the knowledge, skilled people, and supplier infrastructure required to produce light-emitting diodes for energy-efficient illumination, components for consumer electronic products like the Kindle e-reader, or advanced displays for TVs, computers, and handheld devices such as mobile phones.*[42]

"HISTORY MATTERS"— PATH DEPENDENCY AND PATH CREATION

While an appreciation of the role of tacit knowledge aids in the understanding of why clusters exist and convey advantages to firms that locate in them, a more basic question confronting localities is how and why clusters come to exist in the first place and what can be done to encourage their growth. One perspective is that clusters require the right combination of resources and other factor advantages exist in a given location, and that these need to be

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[39]Semiconductor Industry Association. *Maintaining America's Competitive Edge: Government Policies Affecting Semiconductor Industry R&D and Manufacturing Activity.* 2009. A recent example of this phenomenon is the decision announced in 2013 by GlobalFoundries that it would locate its global R&D facility adjacent to its most advanced wafer fabrication facility in Malta, NY. "GlobalFoundries to Invest $2 Billion in New Malta Research and Development Facility," *The Saratogian* January 8, 2013.

[40]"Tesla Motors Opens Michigan Technical Center to Focus on company's future products," Press Release, January 26, 2007.

[41]For a case study of the latter phenomenon, see Semiconductor Industry Association, *China's Emerging Semiconductor Industry: The Impact of China's Preferential Value-Added Tax on Current Investment Trends,* October 2003.

[42]PCAST, *Report to the President in Ensuring American Leadership in Advanced Manufacturing,* June 2011, p. 4.

present at a sufficient scale.[43] Another is that scientists, engineers, and other highly educated and creative people seek to live in an environment that emphasizes learning, culture, and a good physical environment.[44] However, most individuals who have addressed the question—including many who have been involved in attempts to form clusters—have concluded that there is "no magic formula" for doing so and that the task itself is daunting.

Professor Maryann Feldman has observed that cluster formation "is a process predicated on the actions of entrepreneurs and their symbiotic relationships with their local environments. The cluster and its characteristics therefore emerge over time from the individual activities of the entrepreneurs and the organizations and institutions that evolve to support them."[45] This perspective is widely shared. It follows that because clusters are rooted in the language and culture of a particular time and place, "replicating a successful cluster model elsewhere can be highly elusive."[46] A considerable amount of academic literature has applied the term "path dependency" to the factors underlying the emergence of clusters in a given geographic district, meaning the evolution is shaped not by the rules of economics but by "the details of the seemingly transient and adventitious circumstance" associated with their beginnings.[47] Put another way, "history matters."[48] The roots of success of districts such as Silicon Valley and the achievements of Research Triangle are more likely to be found in the historical idiosyncrasies and traditions, culture, and actions of individual movers in California and North Carolina, respectively, than in economics textbooks.[49] It follows that attempts to replicate some or all of the best features of these regions elsewhere requires an understanding of their individual history, innovation culture, and key individual movers.

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[43]See, for example, Nancy S. Dorfman, "Route 128: The development of a regional high technology economy," *Research Policy* 12, 1983.

[44]See for example, Richard Florida, *The Rise of the Creative Class, Revisited*, New York: Basic Books, 2012.

[45]Maryann Feldman and Johanna Francis, "Homegrown Solutions: fostering Cluster Formation," *Economic Development Quarterly* May 2004.

[46]National Research Council, *Growing Innovation Clusters for American Prosperity: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2011, p. 8.

[47]Ronald J. Gilson, "Legal Infrastructure of High Technology Industrial Districts: Silicon Valley, Route 128, and Covenants Not to Compete," *New York University Law Review, 1999* 74(3):577, citing Paul A. David and Joshua L. Rosenbloom, "Marshallian Factor Market Externalities and the Dynamics of Industrial Localization," *Journal of Urban Economics* 28:349, 368, 1990. A concrete example of path dependency is the fact that the United States has not fully adopted the metric system despite numerous major advantages associated with doing so. As a result of the short-run dislocations and costs associated with any transition from the English to metric system of measures, the U.S. remains locked-in to a system of measures that was determined centuries ago.

[48]Gilson, "Legal Infrastructure of High Technology Industrial Districts," op. cit. p. 577.

[49]See Martin Kenney and Urs Von Burg, "Paths and Regions: The Creation and Growth of Silicon Valley" in Raghu Garud and Peter Karnoe, *Path Dependence and Creation,* New York: Psychology Press, 2012, pp. 127-148.

The Local Industrial Legacy

Studies of successful innovation clusters reveal that they emerged from an existing local industrial context that favored the emergence of new high technology industries. Boston's high technology cluster known as Route 128 emerged from an industrial milieu characterized by thriving electrical manufacturing companies that had benefitted from federal military research expenditures during World War II organized around Harvard and MIT.[50] The San Francisco Peninsula was the home of numerous radio and electronic companies in the decades prior to the War, one of the factors credited with fostering the postwar emergence of an information technology industry in the region[51]. At present, Ohio's historical competencies derived from production of glass, polymers, and machinery are facilitating the emergence of clusters concentrating on photovoltaics, flexible electronics, and medical instruments, respectively.

Innovation Culture

In an extensively cited 1994 work, Annalee Saxenian makes the case that the culture of a region can be a decisive factor in its emergence and survival as an innovation center. She noted that Silicon Valley had not only survived a series of severe economic shocks but continued to flourish as a result of its network-based industrial system that fosters collective learning and knowledge sharing among producers of complex technologies:

> *The region's dense social networks and open labor markets encourage experimentation and entrepreneurship. Companies compete intensely while at the same time learning from one another about changing markets and technologies through informal communication and collaborative practices; and loosely linked team structures encourage horizontal communication among firm divisions and with outside suppliers and customers. The functional boundaries within firms are porous in a network system, as are the boundaries between firms themselves and between firms and local institutions such as trade associations and universities.*[52]

Although the current hallmark of Silicon Valley is the individualistic entrepreneur, the region has a long cultural tradition of informal cooperation and

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[50] See David R. Lumpe, *Route 128: Lessons from Boston's High Tech Community,* New York: Basic Books, 1992.

[51]See generally Timothy J, Sturgeon, "How Silicon Valley Came to Be," in Martin Kenney, *Understanding Silicon Valley,* Stanford CA: Stanford University Press, 2000.

[52]Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* Cambridge MA: Harvard University Press, 1994, pp. 2-3.

mutual assistance, even by direct competitors, which predates the existence of Silicon Valley itself and may help account for its genesis. William Hewlett and David Packard of the Valley's founding generation encouraged other entrepreneurs, shared technical knowledge, and worked to persuade companies to work together on common problems. Similarly although very different from the culture of the San Francisco peninsula, that of mid-Twentieth Century North Carolina was characterized by a longstanding tradition of generous philanthropy, civic-mindedness, collective spirit, and openness to institutional experimentation that transformed the state from a low-tech agrarian and light manufacturing economy into the more prosperous economy of the Research Triangle Park. Without the long-ago contributions of many ordinary North Carolinians, including hundreds of anonymous donors who provided the initial capital, the Research Triangle Park, today one of the country's leading high technology clusters, would not exist.[53]

Annalee Saxenian observes that in Silicon Valley labor is highly mobile and adaptable, characterized by "decentralization [which] encourages the pursuit of multiple technical opportunities through spontaneous regroupings of skill technology and capital."[54] She cites research by two academics that show that production in Silicon Valley grows from "a set of individuals with a strong sense of entrepreneurship, joined around a project mission, associated with a technology-driven change, who remain in contact frequently and informally with multiple levels and functions within the company through intense informal communications."[55] These core teams are supported by larger groups of employees, often temporary or contract workers with a variety of specialized skill sets; while the "possibility for meaningful participation and upward mobility" may be less for this group, their availability in large numbers on a flexible basis is an important aspect of the Valley's success.[56] As noted above, in 2007, Tesla Motors, a Silicon Valley based start-up entering the high-performance electric vehicle market, chose Michigan as the site for its new technical center, in part because of the availability of a deep pool of local talent with engineering expertise in the auto industry.[57]

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[53]See generally, Albert N. Link, *A Generosity of Spirit: The Early History of Research Triangle Park,* Research Triangle Park: Research Foundation of North Carolina, 2005.

[54]Annalee. Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* op. cit. pp. 9.

[55]Ibid. p. 55.

[56]Bryan C. Taylor and David Carlane, "Silicon Communication: A Reply and Case Study." *Management Communication Quarterly,* 2001, p. 295. Saxenian quotes a local computer executive who comments that the Valley has a "huge supply of contract labor that want to design your own chips, there are a whole lot of people around who just do contract chip layout and design. You want mechanical design. It's here too. There's just about anything you want in this infrastructure. Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, op. cit., pp. xi.

[57]"There are thousands of highly experienced automotive experts in this area. Growing Tesla Motors and creating higher-volume models requires more talented automotive engineers with experience in developing, manufacturing and assembling high-volume cars. We can hire the best, most

Although very different from that of Silicon Valley or Michigan, during the past generation, the workforce culture of Arkansas has helped the state attract investment by innovative companies. Nucor Steel, arguably the most innovative U.S. steel company to emerge in the past century, has located a number of major facilities in Arkansas, where local hires were typically "farmers or machinery workers who have been ingrained with a strong work ethic since childhood." Dan DiMico, an executive at the company, which emphasizes employee responsibility and merit-based compensation, commented that "we hire good people, put them in a culture that encourages them to do well, give them the tools, and the opportunity to excel and then we get the heck out of their way."[58] Similarly, Mitsubishi Power Systems Americas Inc. cited Arkansans' "extraordinary work ethic" as a factor underlying its decision to locate a $100 million manufacturing facility for wind turbines in Fort Smith, Arkansas. A Mitsubishi executive said that "we looked for a part of the country where manufacturing is not some lost art."[59]

A region's innovation culture can also exert negative influence on the development of innovative industries. Saxenian documents how the hierarchical, secretive big-company culture of the Route 128 innovation cluster led to its eclipse by Silicon Valley in computer technology.[60] Workforce culture in some of the Rust Belt states has suffered from the legacy of the Twentieth Century "American system of manufactures" based on the theories of Frederick Winslow Taylor and the industrial methods of Henry Ford, which emphasized the segmenting of manufacturing operations into extremely narrow, comparatively unskilled tasks performed repeatedly by individual workers under close supervision of low level managers, with fluctuations in demand addressed through layoffs.[61] This system placed a low emphasis on employee skills and perpetuated an adversarial relationship between labor and management. In the 1980s and 1990s, when international competition forced a punishing series of contractions on the old industries of the upper Midwest and Northeast, hundreds of thousands of relatively unskilled production line workers were cast adrift, lacking adaptability or skills relevant to anything other than jobs that no longer existed. In some U.S. regions, the lingering legacy of the "Ford/Taylorist"

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experienced automotive talent here in Michigan." "Tesla Motors Opens Michigan Technical Center to Focus on company's future products," Press Release, January 26, 2007.

[58]"Nucor Makes Blytheville Steel Capital of the South," *Arkansas Business* December 16, 1996.

[59]"Mitsubishi Breaks Ground on Nacelle Facility in Arkansas," *North American Windpower* October 8, 2010.

[60]Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* op. cit., pp. 9.

[61]David C. Mowery, and Nathan Rosenberg, "The U.S. National Innovation System" in Richard R. Nelson, ed., *National Innovation Systems: A Comparative Analysis*, Oxford: Oxford University Press, 1993, pp. 35-36.

system arguably still stands in the way of industrial adaption through innovation.[62]

Innovation by its very nature entails substantial risks, and in the United States most start-ups seeking to pioneer new technologies end as failures. A region's cultural attitudes toward failure directly influence would-be entrepreneurs' appetite for risk and willingness to break new technological ground. Annalee Saxenian observes with respect to Silicon Valley that "not only was risk-taking glorified, but failure was socially acceptable … [T]here was little embarrassment or shame associated with business failure. In fact, the list of individuals who failed, even repeatedly, only to succeed later, was well known within the region."[63] By contrast, as the former Mayor of Bloomington, Indiana, pointed out in 2012, in explaining the relative slow rate of start-ups in the region, "[F]ailure is not okay" in the Midwest. "You are ostracized, and you have huge problems with your next funding."[64]

Finally, the environment of a region plays an important role in its success in fostering innovation. In the past decade, factors such as the high quality of schools have worked in favor of upstate New York's initiative to foster knowledge-based industries centered on nanotechnology. In the cases of Akron and Youngstown, Ohio, part of the effort to stimulate local innovation-based economic development involved demolition of old industrial areas and creation of new green spaces, parks, and attractive urban neighborhoods.

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[62]Taylor was a mechanical engineer who is regarding as the "father of scientific management." He commented on labor-management relations that "only through enforced standardization of methods, enforced adoption of the best implements and working conditions, and enforced cooperation that this faster work can be assured. And the duty of enforcing the adoption of this cooperation rests with management alone." On the value he placed on worker skills, he stated, "I can say, without the slightest hesitation, that the science of handling pig-iron is so great that the man who is…physically able to handle pig-iron is sufficiently phlegmatic and stupid to choose this for his occupation is rarely able to comprehend the science of handling pig-iron." David Montgomery, *The Fall of the House of Labor: The Workplace, the State and American Labor Activism 1865-1925,* Cambridge: Cambridge University Press, 1989, pp. 229, 251.

[63]Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* op. cit., pp. 38-39.

[64]John Fernandez, "An Overview of Federal Cluster Policy," in National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2013. Robert Wolcott, a professor at Northwestern University's Kellogg School of Management, recalls his experience at a party in Chicago, where he found "the usual conversation about sports real estate and banking. When asked what he was doing, he replied that he was an entrepreneur. Asked how big his company was, he said he had just started it and times were difficult. At that point the questions stopped and the conversation returned to real estate. He recalls "I knew what was in their minds. He's between jobs." Robert Wolcott, "Driving Entrepreneurship in Illinois," National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit.

THE IMPORTANCE OF ENTREPRENEURSHIP

A recent academic work has noted the contradiction between the deterministic aspects inherent in the concept of "path dependency" and the theory of entrepreneurship itself. Proponents of path dependency "relegate human agency to choosing to go with the flow of events" determined by "historical accidents" that "actors have little power to influence in real time." The authors argue instead for the term "path creation" which integrates the acknowledgement of historical context with recognition of the importance of the individual:

> *Entrepreneurs meaningfully navigate a flow of events even as they constitute them. Rather than exist as passive observers within a stream of events we see entrepreneurs as knowledgeable agents with a capacity to reflect and act in ways other than those prescribed by existing social rules and taken-for-granted technological artifacts*[65]

Indeed, small businesses are a major driver of high-technology innovation and economic growth in the United States, generating significant employment, new markets, and high growth industries.[66] American innovation has long been driven by creative and often eccentric individuals with a powerful sense of the potential for practical application of their new ideas. Optimizing the ability of innovative small businesses to develop and commercialize new products is essential for U.S. competitiveness, economic growth, and employment. Developing better incentives to spur innovative ideas, technologies, and products, and ultimately bring them to market, is a central policy challenge for state governments, as it is for the national government.

Challenges Facing Innovative Small Businesses

Despite their value to the U.S. economy, small business entrepreneurs with new ideas for innovative products often face a variety of challenges in bringing their ideas to market. Because new ideas are by definition unproven, the knowledge that an entrepreneur has about his or her innovation and its commercial potential may not be appreciated by prospective investors. [67] For

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[65]Raphu Garud and Peter Karnoe, "Path Creation as a Process of Mindful Deviation" in Garud, Raghu and Peter Karnoe, *Path Dependence and Creation,* New York: Psychology Press, 2012, pp. 2.
[66]See Zoltan Acs and David Audretsch, "Innovation in Large and Small Firms: An Empirical Analysis," *American Economic Review* 78(4):678-690, September 1988. See also Zoltan Acs and David Audretsch, *Innovation and Small Firms,* Cambridge, MA: The MIT Press, 1990.
[67]Joshua Lerner, "Public Venture Capital," in National Research Council, *The Small Business Innovation Program: Challenges and Opportunities,* C. Wessner, ed., Washington, DC: National Academy Press, 1999. For a seminal paper on information asymmetry, see Michael Spence, *Market Signaling: Informational Transfer in Hiring and Related Processes*, Cambridge, MA: Harvard University Press, 1974.

Box 2-2
The Role of Leading U.S. Innovators

Innovators like Eli Whitney, Robert Fulton, Alexander Graham Bell, Thomas Edison, the Wright Brothers, and Jonas Salk are rightfully legends in this regard. In a similar vein, the emergence of innovation centers in the Twentieth and Twenty-First Centuries is associated with key individuals who, by their actions, created a path forward for innovation in the thematic areas and geographic regions where they operated. These individuals include Stanford's Frederick Terman, the "Father of Silicon Valley" and Toledo's Harold McMaster, whose pioneering work in photovoltaics provided the foundation for that city's emerging photovoltaic cluster.

example, few investors in the 1980s understood Bill Gates' vision for Microsoft or, more recently, Bill Page and Sergey Brin's vision for Google.

The challenge of incomplete and insufficient information for investors and the problem for entrepreneurs seeking seed capital. Because the difficulty of attracting investors to support an imperfectly understood, as yet-to-be-developed innovation is especially daunting, the term *"Valley of Death"* has come to describe the period of transition when a developing technology is deemed promising, but too new to validate its commercial potential and thereby attract the capital necessary for its continued development.[68] This reality belies a widespread myth that U.S. venture capital markets are so broad and deep that they are invariably able to identify promising entrepreneurial ideas and finance their transition to market. In reality, angel investors and venture capitalists often have quite limited information on new firms

Given their obligations to their investors, venture capital firms tend not to invest upstream in the higher-risk, early-stages of technology commercialization, and they have been moving further downstream in recent years. In 2012, venture capitalists in the United States invested $26.5 billion over the course of 3,698 deals. However, only 3 percent of these venture capital funds were directed to firms in the seed stage of development.[69]

Recognizing their importance for regional economic growth and employment, many states are seeking to encourage entrepreneurship through a variety of means including the use of innovation prizes, efforts to attract SBIR grants though Phase Zero funding, encouragement of Angel funding, through tax

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[68]For an academic analysis of the Valley of Death phenomenon, see Lewis Branscomb and Philip Auerswald, "Valleys of Death and Darwinian Seas: Financing the Invention to Innovation Transition in the United States," *The Journal of Technology Transfer* 28(3-4), August 2003.
[69]PriceWaterhouse 2013 MoneyTree Report.

incentives, and state-backed early stage and venture funding, such as Ohio's Jumpstart program.

LESSONS LEARNED

- State, regional, and local governments are in a strong position to lead local innovation-based economic development, reflecting their control over local factors of production and influence over the education and research infrastructure, and knowledge of local innovation culture.
- State and regional governments are pursuing the establishment of innovation clusters as their major development policy tool.
- Most of the state and regional developmental efforts that the Committee has considered seek to build on existing local advantages arising out of their geography, industrial legacy, and culture, rather than seek to establish entirely new competencies.
- Regional culture and attitudes toward innovation, collaboration, and entrepreneurialism are a key determinant of success as failure in innovation-based development.

II

THE CATALYTIC ROLE
OF PUBLIC PURPOSE ORGANIZATIONS

Chapter 3

Universities as Innovation Drivers

A key factor in the rise of the United States as a technological power has been a long tradition of close ties and frequent collaboration between companies and a network of first-rate universities[1]. Underlying the success of innovation clusters such as Silicon Valley, Route 128, and the Research Triangle of North Carolina are local universities with a longstanding mission of spurring economic development by developing technology with and transferring technology to local industry and stimulating the creation of new businesses in university-centered incubators and science parks. Technology-intensive companies commonly locate their operations near the best universities in particular fields of science and engineering in order to enable their internal research departments to work with "star" scientists and to recruit promising students.

Start-up companies spinning off from universities most commonly establish operations near those institutions.[2] "[T]he presence of research universities is now widely viewed as a necessary (if insufficient) condition to bring about innovation-based economic development of regions."[3] Illustrating the impact a single research university can have on a region, in 2004 alone MIT produced 133 patents, launched 20 startup companies, and spent $1.2 billion in

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[1]"Premier universities are at the heart of just about every high-tech success story: Stanford University and UC Berkeley in the Silicon Valley; Boston-area institutions such as Harvard and the Massachusetts Institute of Technology that helped draw researchers to the Route 128 Corridor; the University of Texas and its support of Austin's booming computer industry." "Universities Need to Court Top-Tier Researchers, *The Plain Dealer* March 21, 2002.

[2]The Association of University Technology Managers reported in 2002 that in the fiscal year 2000, at least 368 new companies were formed based on university research and that most of them settled "near the institution where the technology was born. "Universities Need to Court Top-Tier Researchers," *The Plain Dealer* March 31, 2002.

[3]Hegde. "Public and Private Universities," op. cit., p. 7, 2005. Citing Feldman "The New Economics of Innovation, Spillovers and Agglomeration: A Review of Empirical Studies," *New Technology* 8:5-25, 1999.

sponsored research. Data from 1994 showed that, at that time, MIT graduates had founded over 4,000 companies employing 1.1 million people generating $232 billion in sales worldwide.[4] In the Boston area, MIT is flanked by other great research universities, including Harvard, Tufts, the University of Massachusetts, Boston University and others. Since the early 1970s, spinoffs from these institutions have created a thriving pharmaceutical industry where virtually none had previously existed.[5]

The state of Maryland offers an extreme example of university-driven economic development. According to Aris Melissaratos of Johns Hopkins University, the state at one point invested nearly 90 percent of its economic development budget into local universities and research programs to take advantage of complementary federal investments in the state by the National Institutes of Health, the U.S. military, and the Food and Drug Administration. As a result, he observed, Maryland receives more research dollars per capita than any other state. The economic result in the state has been the creation of a diversified base of industries including information technology, biotechnology and biomedicine, and aerospace and defense.[6]

Compared with universities in most developed countries, U.S. universities are highly decentralized and independent of central authority. The U.S. has never had an Education Ministry allocating resources and giving central direction to the nation's institutions of higher learning. Other than the military academies, there are no "federal universities." Universities enjoy a high degree of freedom in developing curricula, introducing novel courses of study and defining their relationship with the private sector. In addition, in contrast to a number of European and Asian countries, the United States has not made systematic investments in a system of public industrial laboratories such as Germany's Fraunhofer-Gesellschaft. The U.S. supports a system of national laboratories through the Department of Energy, but most of these concentrate on national defense and energy themes. The national laboratories are encouraged to engage the private sector and transfer technology, but their primary mission is not private industrial development.[7] Most public R&D support for industry

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[4]Presentation of David Daniel, University of Texas at Dallas, "Making the State bigger: Current Texas University Initiatives," National Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2011. This figure models MIT graduates who went on to other institutions for graduate studies and who founded companies in clusters distant from MIT itself.

[5]Presentation by Ashley J. Stevens, Boston University and Association of University Technology Management, "Current Trends and Challenges in University Commercialization," National Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium,* op. cit.

[6]Aris Melissaratos, "Improving the University Model," National Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium,* op. cit.

[7]The Stevenson-Wydler Technology Innovation Act of 1980 provided a legal foundation for technology transfer at the national laboratories and established a technology transfer office, the Office of Research and Technology Application. The Federal Technology Transfer Act of 1986 requires federal laboratories to actively seek opportunities to transfer technology to industries, universities, and state and local government. The National Competitiveness Technology Transfer

including federal support occurs via collaborations between universities and companies.[8]

U.S. research universities, both private and public, produce most of the country's science and engineering graduates, perform more than half of the U.S. basic science and engineering research, and are often major drivers of economic development in the areas in which they are located.[9] The strengths of the U.S. research university system include its heterogeneity, its diversity, its decentralized character, and the joining of research with graduate education. Engineering and applied science are incorporated in the curricula of most U.S. research universities, a fact which reinforces "the long-standing predisposition of U.S. universities toward problem-solving, working with industry, and training people for industry."[10] According to Robert Berdahl, "Research universities also provide the scientific, technical, and professional foundations for those who will go on to found and lead the new industries made possible by innovative research."[11]

Many of the nation's foremost research universities have been private institutions—albeit recipients of extensive public funding. MIT and Stanford have been central to the emergence of dense concentrations of knowledge-based industries in Boston and the San Francisco Peninsula, respectively. At the same time, the contribution of U.S. public research universities, which receive a proportion of their funding from state and local budget appropriations, to regional development of innovation-based industries should not be overlooked. These institutions educate a large percentage of undergraduate and graduate students in science, mathematics, and engineering and perform over half of U.S. academic R&D.[12]

Public universities have played a key role in local economic development since the early days of the United States. A tradition of state

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Act of 1989 made the transfer of technology a mission of government-owned, contractor operated (GOCO) laboratories and enabled GOCOs to enter into cooperative research and development agreements (CRADAs).

[8]Denis Gray, "Cross Sector Research Collaboration in the USA: A National Innovation System Perspective," *Science and Public Policy* 38(2):123, 132, March 2011.

[9]See National Research Council, *Research Universities and the Future of America: Ten Breakthrough Actions Vital to Our Nation's Prosperity and Security,* Washington, DC: The National Academies Press, 2012. The report "focuses on strengthening and expanding the partnership among universities and government, business, and philanthropy that has been central to American prosperity and security." See also, PCAST, "Transformation and Opportunity, the Future of the U.S. Research Enterprise," Washington, DC: The White House, November 2012. This report addresses the challenges of "enhancing long-range U.S. investment in basic and early-stage applied research and reducing the barriers to the transformation of the results of that research into new products, industries, and jobs."

[10]Ibid, p. 323.

[11]Robert Berdhal, "Research Universities: Their Value to Society Extends Well Beyond Research," April 2009.

[12]National Science Board, "Diminishing Funds and Rising Expectations: Trends and Challenges for Public Research Universities," Arlington, VA: National Science Foundation, 2012, pp. 1-2.

funded colleges began in the South in the late Eighteenth Century and spread to the rest of the country in the Nineteenth.[13] The federal Morrill Land Grant Act of 1862 provided for the donation of public lands to states and territories to facilitate the establishment of institutions of higher learning.[14] The purpose of these land-grant institutions, as stated in the Act, was

> *without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life.*[15]

A number of public universities were established pursuant to the Morrill Land Grant Act with an explicit mandate to perform research with local application in agriculture and the "mechanic arts."[16] Eventually, every U.S. state had at least one public state-funded university. The enactment of the Morrill Act and its follow-on legislation was "probably one of the most significant things Congress has ever done."[17]

Political considerations associated with state funding ensured that the research topics and curricula of the state schools addressed topics of relevance to local economies. "Especially within emerging subfields of engineering and, to a lesser extent, within mining and metallurgy, state university systems often introduced new programs as soon as the requirements of the local economy became clear," a tradition that has continued down to the present day.[18] The federal Hatch Act of 1887 provided for permanent annual appropriations to each state to establish and operate agricultural experimental stations, "thus marking

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[13]In the Southern states, the impacts of the Civil War retarded the development of private educational systems compared to their Northern counterparts. State educational institutions were launched in Georgia (1785), North Carolina (1789), South Carolina (1801), and Virginia (1819). Diana R. Rhoten, and Walter W. Power, "Public Research Universities: From Land Grant to Federal Grant to Patent Grant," in Diana Rhoten and Craig Calhoun, eds., *Knowledge Matters: The Public Mission of the Research University*, New York: Columbia University Press, 2011, p. 321.

[14]The Second Morrill Act (1890) provided for cash grants to land-grant colleges that did not discriminate in their admissions policies on the basis of race.

[15]Morrill Act of 1862, Section 4. A faculty member of North Dakota State University in Fargo responsible for university extension services said in 2007 with respect to this language, "You read that today and it seems so second nature to us, but it was revolutionary in the history of the world." "Evolution of Extension," *Grand Forks Herald* October 14, 2007.

[16]Deepak Hegde, "Public and Private Universities: Unequal Sources of Regional Innovation?" Georgia Tech Ivan Allen College Working Paper Series 2005, Working Paper #5, p. 4.

[17]Joseph T. Walsh, *Building the Illinois Innovation Economy: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2013.

[18]David C. Mowery, and Nathan Rosenberg. 1993. "The U.S. National Innovation System" in Richard R. Nelson, ed., *National Innovation Systems: A Comparative Analysis* Oxford: Oxford University Press. pp. 35-36.

the advent of public universities' responsibilities to help generate research that both enhanced agricultural productivity and supported agricultural communities."[19] In the late Nineteenth century, the land grant schools loaded their faculty onto trains, and the professors went barnstorming through their states, with "extension trains" making whistle-stops in small towns, enabling farmers to board them and learn of the latest agricultural research findings.[20] The creation of a federally-funded technology-transfer system in agriculture

> *also strengthened and institutionalized the tradition of a practical and utilitarian university (e.g. one that worked closely with industry) that began with the early state universities. Over time, the viability and success of the land grant universities probably created a precedent for more traditional state universities and private universities to move closer to the land grants in their mission, values and operations.*[21]

Such traditional state universities have since then created new and relevant missions that further broaden the framework set forth by pioneering private and public land grant universities. Many such universities have provided deeper access to first generation students, pertinent expertise to industry, technology commercialization and spin out of companies.

A recent model of an innovative university-industry model can be found in the collaboration between The University of Akron and The Timken Company wherein the University reached out to a company and took over a key technology and made it accessible to the broader global markets.[22] This broadens the traditional university technology commercialization model to not

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[19]Rhoten and Power, op. cit., 2011, p. 321. The enactment of the Smith-Lever Act of 1914 made federal funding available for the diffusion of agricultural research results. Each state is required to match the amount of funds it receives from the federal government. Ibid.

[20]"Evolution of Extension," *Grand Forks Herald* October 14, 2007.

[21]Denis Gray, "Cross Sector Research Collaboration in the USA: A National Innovation System Perspective," *Science and Public Policy* 38(2). March 2011, p. 125. Citing R. Stankewicz, *University-Industry Relations,* Lund, Sweden: Research Policy Institute, 1984. Texas A&M, a land grant school that currently enrolls 50,000 students, has an annual research budget of over $700 million. Texas A&M's College of Agriculture and Life Sciences is one of the country's largest academic units educating students for careers in agribusiness. It has numerous highly-regarded service organizations, including Texas AgriLife Research, Texas AgriLife Extension Service, Texas Forest Service, and Texas Veterinary Diagnostic Laboratory. Texas A&M's Dwight Look College of Engineering works through services organizations that include Texas Transportation Institute, Texas Engineering Experiment Station, and Texas Engineering Extension Service. Finally, Texas A&M operates a College of Medicine and a college of Veterinary Medicine and Biomedical Sciences. "Texas A&M is a Premier Land-Grant School," *The Eagle* August 19, 2012.

[22]See Chapter 6, Box 6-2, "The Akron Model of Industry-University Partnership." See Industry Week, "Innovation: MIT -- To Sustain Innovation, Manufacture," March 8, 2013. <*http://www.industryweek.com/innovation/innovation-mit-sustain-innovation-manufacture?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+IWNews+%28IndustryWeek+Most+Recent+News%29*>.

only include its own internal technologies, but to move technologies from industry to more entrepreneurial environments.

Such endeavors further enhance the regional ecosystems as they create two-way pipelines of intellectual property, wherein in the past they have usually been one-way, i.e. from a university to a company. As this model progresses, and more spin-out companies are launched, this cooperation is giving rise to multi-way pathways of innovation, according to Luis Proenza.[23]

UNIVERSITIES AND INDUSTRIALIZATION

In the years after the Civil War, the U.S. economy grew explosively as railroads and the telegraph revolutionized transportation and communications and new, mechanized methods of production were adopted—"a wave of industrial innovation…far more wide-ranging than that which occurred in Britain at the end of the eighteenth century" which "has been quite properly termed by historians the Second Industrial Revolution." [24] By 1913, the United States accounted for 36 percent of the world's industrial output compared with Germany's 16 percent and Britain's 14 percent.[25] Private and public U.S. universities responded to the rapid advances in technology with remarkable speed and flexibility, establishing curricula in emerging practical disciplines to train large numbers of engineers, scientists, and managers to lead the new industries.

The foremost U.S. university driving U.S. industrialization in the late Nineteenth and early Twentieth century was the Massachusetts Institute of Technology. From its inception in 1861 as a chartered private corporation, MIT emphasized the need to combine scientific theory with engineering practice through hands-on experience in laboratory teaching and experimentation. One of MIT's early presidents, John D. Rankle, arranged for advanced students to work in the machine shop of the Boston Navy Yard and take field trips to local manufacturing facilities.[26] Following a protracted internal controversy among leading faculty members about MIT's proper relationship with industry MIT, after 1920, became deeply engaged with local industry—over a third of its teaching staff was actively engaged in research, testing, and commercial analysis for industry and most engineering department chairs ran consulting firms in downtown Boston.[27] The General Electric Company recruited key researchers

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[23]Luis Proenza, "Relevance, Connectivity, and Productivity: The Akron Model,: in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, Washington, DC: The National Academies Press, 2013.

[24]Alfred D. Chandler, *Scale and Scope: The Dynamics of Industrial Capitalism,* Cambridge, MA, and London: Belknap Press of Harvard University, 1990, p. 62.

[25]Ibid. p. 47.

[26]Merritt R. Smith, "God Speed the Institute: The Foundational Years, 1861-1864," in David Kaiser, ed., *Becoming MIT: Moments of Decision,* Cambridge, MA, and London: The MIT Press, 2010, pp. 23-24.

[27]Alfred D Chandler, *Scale and Scope: The Dynamics of Industrial Capitalism,* op. cit., p. 62.

from MIT's faculty and "continued to rely heavily on MIT's engineering department" which was "reputed to be the best in the world for both technical expertise and the training of potential managers." Similarly DuPont drew some of its key corporate leaders from the ranks of MIT graduates and relied on MIT's chemical engineering department for technical support.[28]

The industrial development efforts of elite private universities were paralleled by those of the public research universities. The University of Akron not only trained skilled personnel for the local rubber industry, but also acquired a strong reputation for its research capability in rubber processing and, subsequently, polymer chemistry.[29] In 1890, the University of Wisconsin developed and introduced the Babcock test, an inexpensive method for measuring the butterfat content and assessing the adulteration of milk, a capability of obvious value to the state's extensive dairy industry.[30] State universities, in particular, offered a broad curriculum linked to the local economy. In the years after World War I, the University of Illinois offered courses in architectural engineering, municipal and sanitary engineering, railway engineering, civil and mechanical engineering, and ceramic engineering. "Nearly every industry and government agency in Illinois has its own department at the state university in Urbana-Champaign."[31] The University of Minnesota operated a sustained program from the end of World War I through the early 1960s to develop a technological response to the depletion of the state's high-yield iron ores in the Mesabi Range and the need to develop its vast reserves of ores with lower iron content.[32]

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[28]Christophe Lecuyer, "Patrons and a Plan," in David Kaiser, ed., *Becoming MIT: Moments of Decision,* op. cit., pp. 69. In the early years of the twentieth century, a number of young faculty members began to challenge MIT's prioritization of teaching undergraduates and the nature of its approach to engineering education. A number of these individuals had performed graduate work in Germany, where they witnessed sophisticated collaborations between academic research laboratories and major industrial firms. Arthur A. Noyes sought to turn MIT into a research university focused on the sciences, which would forge close ties with industry, particularly technology-intensive companies. He founded the Research Laboratory of Physical Chemistry, which graduated MIT's first Ph.D.s in 1907 and sent many alumni onto research careers in industry. William H. Walker, a rival of Noyes, founded the Research Laboratory of Applied Chemistry, saw engineers as corporate leaders and emphasized the management dimension of engineering, with an emphasis on serving small and medium companies. Dugald Jackson, the chairman of the department of Electrical Engineering, saw the main mission of technical institutes like MIT as serving large firms as utilities and major makers of electrical equipment. Ibid, pp. 62-63.

[29]See the University of Akron website at *<http://www.uakron.edu/cpspe/about-us/college-history.dot>*.

[30]N. Rosenberg and R. R. Nelson, "American Universities and Technical Advance in Industry," *Research Policy* 23:326.

[31]Ibid, p. 52.

[32]The university's Mines Experiment Station focused on the processing and engineering challenges associated with extracting iron from taconite ores in which impurity levels reached 50 to 70 percent, but which existed in Minnesota in enormous quantity. This effort required "decades of tedious experimentation." The project was launched before World War I and success was not achieved until the early 1960s. The principal financing came from the state of Minnesota through the university to

"One of the major accomplishments of the American universities during the first half of the Twentieth Century was to effect the institutionalization of the new engineering and applied science disciplines."[33] In contrast to Europe, where engineering was taught at separate schools, in the U.S. engineering subjects were introduced at elite universities like Yale (1863) and Columbia (1864). In 1894, MIT President Francis Amasa Walker observed that "there is now not a State in the Union without an institution in which more or less of a course in Engineering is laid out. Some of these are classical institutions of long standing and high repute, which are rapidly as possible transforming to meet the wants of the age."[34] The reaction of U.S. universities to the advent of new electricity-based industries was "virtually instantaneous," with MIT launching courses of instruction in electrical engineering in 1882, the same year Edison's Pearl Street Station became operational in New York City, followed by Cornell in 1883. In the Twentieth Century, U.S. engineering schools and their faculty routinely developed electrical generating and transmission equipment in their labs.[35]

These traditions have been carried forward down to the present day. In perhaps the most famous example of University-led economic development, Stanford University played a central role in the emergence and flourishing of Silicon Valley, a dynamic which is examined in the Annex of this report. Universities also played a key role in the success of research Triangle Park in North Carolina, also described in the Annex. "In terms of commercial success, American dominance of the computer software industry was overwhelmingly due to the remarkable speed with which university faculties were able to develop and introduce an entirely new academic curriculum in computer science" between 1959 and 1965. The activities of U.S. universities, backed by federal funding, "led directly into the creation of today's Internet."[36]

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the experiment station, which operated its own blast furnace. N. Rosenberg and R. R. Nelson, "American Universities and Technical Advance in Industry," *Research Policy* op. cit.

[33]N. Rosenberg and R. R. Nelson, "American Universities and Technical Advance in Industry," *Research Policy* op. cit.

[34]Merrit Roe Smith, "God Speed the Institute: The Foundational Years, 1861-1864," in *Becoming MIT: Moments of Decision,* op. cit., p. 30.

[35]N. Rosenberg and R. R. Nelson, "American Universities and Technical Advance in Industry." *Research Policy* 23:320.

[36]Research performed at the Advanced Research Projects Agency (ARPA) was led by academics on leave from their institutions. The World Wide Web began as an ARPANET effort to link four research universities, MIT, Stanford, Cal-Berkeley, and Carnegie-Mellon, all of which were doing contract research for the Department of Defense. David Hart, *The Emergence of Entrepreneurship Policy: Governance, start-Ups, and Growth in the U.S. Knowledge Economy,* Cambridge: Cambridge University Press, 2003.

THE EMERGENCE OF COOPERATIVE RESEARCH CENTERS

Since 1980, the U.S. innovation landscape has seen a veritable explosion in the number of cooperative research centers (CRCs) including university-government-industry collaborations. These centers seek to provide organizational solutions to the challenge of cooperation in science. CRCs are known by a variety of labels including centers of excellence, joint laboratories, industry-university research centers (UIRCs) and engineering research centers, but they all are characterized by triadic public-private-university collaboration. CRCs function as intermediary organizations between the research base and private industry, and appear to "compensate for the lack of a system of government-funded industrial labs [such as Germany's Fraunhofer-Gesellschaft] for what must be a fraction of the cost." "To a large extent, research centers are the organizational solution to the problems team science poses for disciplinary and bureaucratically structured institutions like universities."[37]

According to *Research Centers and Services Directory* (2010), nearly 16,000 university-based and non-profit research centers are operating in the U.S. and Canada, a significant percentage of which can fairly be characterized as CRCs.[38] The vast preponderance of individual research and innovation projects and initiatives addressed in this study can fairly be characterized as CRCs. Support for CRCs, rather than traditional funding of grants to individual researchers, are how government organizations are funding strategies to promote research that is variously termed "translational," "transformative," "paradigm-shifting," "high-risk, high-yield," and so on.[39] CRCs are increasingly becoming public-private partnerships with funding derived from government and private sources.

CHALLENGES FACING PUBLIC RESEARCH UNIVERSITIES

U.S. public research universities have traditionally received the biggest share of their funding from state and local governments. A 2012 study by the

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[37]Craig Boardman and Denis Gray, "The New Science and Engineering Management: Cooperative Research Centers as Government Policies, Industry Strategies, and Organizations," *Journal of Technology Transfer,* February 2010, p. 447.

[38]Denis Gray, "Cross Sector Research Collaboration in the USA: A National Innovation System Perspective," *Science and Public Policy* 38(2):129, March 2011. Gray used the following definition of a CRC; "an organization or unit within a larger organization that performs research and also has an explicit mission (and related activities) to promote, directly or indirectly, cross-sector collaboration, knowledge and knowledge transfer, and ultimately innovation." He indicated that "it is difficult to obtain an accurate estimate on how many exist" but that a 1994 survey had estimated a total of 1,100 "industry-university centers existed at about 200 universities" and that of the 16,000 university-based non-profit research centers in the USA and Canada, "I suspect a large percentage now meet the definition of a CRC." Ibid.

[39]Craig Boardman and Denis Gray, "The New Science and Engineering Management: Cooperative Research Centers as Government Policies, Industry Strategies, and Organizations," *Journal of Technology Transfer* February 2010, p. 447.

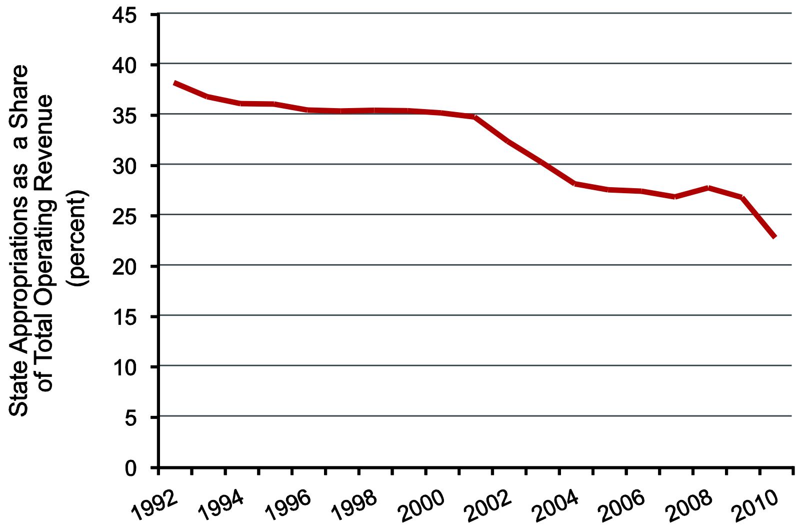

FIGURE 3-1 State appropriations as a percentage of public research universities total operating revenue, 1992 to 2010.
SOURCE: National Science Board, *Diminishing Funding and Rising Expectations: Trends and Challenges for Public Research Universities*, Arlington, VA: National Science Foundation, 2012.
NOTE: The NSB notes that these NCSES tabulations exclude Pennsylvania State University and Rutgers University because data for total revenues were unavailable.

National Science Board (NSB) found that during the period from 1992 to 2010, the proportion of state outlays as a percentage of public universities' total revenue fell from 38 percent to 23 percent, with the steepest decline occurring in the 2002 to 2010 time frame. States have confronted a variety of pressures that have contributed to this decline, including economic recession, rising costs, and the demands of non-higher education related mandated requirements. State appropriations per educated student hit a 25-year low in 2011.

These trends led the NSB to warn that

> *reductions in revenue of public research universities and gaps in salary between public and private research universities have the potential to lead to an outflow of talent at public research universities and reduced research capacity, These could result in greater concentration of talent and R&D in fewer geographical locations and at fewer universities, with smaller and less diverse student bodies. This could have a*

> *substantial impact on economic and workforce development at the local, state, and national levels.*[40]

A 2013 study documented the reductions in state funding for higher education that have occurred since the onset of the financial crisis in 2008.[41] The study found that every U.S. state except North Dakota and Wyoming were spending less per student on higher education in fiscal 2013 than they did prior to the financial crisis in 2008. On average, states are spending $2,353 or 28 percent less per student in fiscal 2013 than they did in 2008.[42] These cuts translate into higher tuition and a decline in the quality of higher education which risks jeopardizing states "ability to compete for the jobs of the future."[43] In January, Moody's Investors Services indicated it had a negative outlook for the entire higher education sector, citing "mounting fiscal pressure on all key university revenue sources."[44]

HARNESSING THE UNIVERSITY OF HAWAII AS AN ENGINE OF GROWTH

Hawaii faces a number of challenges in fostering innovation that arise out of its geographic location and economic history. Hawaii's location in the middle of the Pacific Ocean provides unique challenges as well as important opportunities. On one hand, the Hawaiian Islands are remote from the U.S. mainland, small geographically, with a population of nearly a million people. On the other hand, as Senators Inouye and Akaka pointed out in their conference keynotes at the National Academies symposium on Building the Hawaii Innovation Economy, the islands are strategically located as America's 'front door' to the vibrant economies of East Asia and are home to unique geographical features and land and marine life, as well as a rich cultural heritage.[45]

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[40]National Science Board, *Diminishing Funding and Rising* Expectations, op. cit., pp. 9-12, 19.

[41]Phil Oliff, Vincent Palacios, Ingrid Johnson, and Michael Leachman, *Recent Deep State Higher Education Cuts May Harm Students and the Economy for Years to Come,* Washington, DC: Center on Budget and Policy Priorities, March 19, 2013.

[42]Ibid. p.1. The costs reflect a number of pressures on state budgets. The recession of 2007-09 precipitated a steep decline in tax revenues at the state level. At the same time, school enrollments are up both at the K-12 and college level, partially reflecting the "baby boom echo.." 535,000 more K-12 students were enrolled in the 2013 school year than in 2008 and enrollment at the college even increased by about 1.3 million full-time students between 2008 and the 2011-12 school year. States have relied heavily on budget cuts, rather than revenue increases, to address budget deficits. Finally, the federal government has allowed emergency funds available to the states for education and Medicaid to expire. Ibid., p. 6.

[43]Ibid., p. 2.

[44]"State Budget Officers Seek Overhaul of University Funding," *Reuters* March 22, 2013.

[45]See the summary of the keynote addresses by Senators Daniel K. Inouye and Daniel K. Akaka in National Research Council, *Building Hawaii's Innovation Economy: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2012.

Hawaii's economy has been over dependent on a succession of single products, beginning with sandalwood and continuing through whaling, sugar, pineapples, military bases, and currently, tourism. The contribution of these traditional industries to the state's economy is unlikely to grow significantly, and Hawaii is currently looking to develop multi-sector interdisciplinary competencies to support science and technology-based innovation and spur economic growth.[46]

Recognizing the need for innovation-based growth, the state of Hawaii is actively seeking to diversify its economy by drawing on the University of Hawaii system and other research and educational organizations as engines of sustainable, innovation-led growth. To this end, the University of Hawaii under the leadership of its President, Dr. M.R.C. Greenwood, convened an Innovation Council made up of nationally recognized experts to develop recommendations to grow the state's knowledge-based economy.[47] The Innovation Council drew up four recommendations in 2011 to implement this vision:[48]

- Identify research as an industry in Hawaii, undertake a strong recruiting effort to attract the top academics in areas which UH has a strategic advantage, such as volcanology, astronomy and oceanography; and formalize relationships to encourage collaborations similar to consortia.
- Establish HiTE (Hawaii Innovation Technology Exchange Institute) staffed with technology transfer professionals, to promote public/private collaboration on translational research and offer assistance to start-ups from proof-of-concept centers and innovation centers.
- Designate key areas for commercialization opportunities—energy and food sustainability and security; data analytics, and Asia-Pacific health.
- Integrate entrepreneurship into the UH curriculum, including the creation of cross-disciplinary entrepreneurial courses.

At a symposium convened for this study, University of Hawaii (UH) President Greenwood augmented the Committee's areas for opportunity for UH, noting that in data analytics, "There's an insatiable need to accumulate and analyze data, and we have some of the largest data sets in the world here in Hawaii. If we were able to master this new and emerging field, we would be a

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[46]See the summary of remarks by Neil Abercrombie, Governor of Hawaii as well as the summary of the presentation by Dr. Carl Bonham, University of Hawaii Economy Research Organization, "State and Regional Economic Context," National Research Council, *Building Hawaii's Innovation Economy: Summary of a Symposium*, January 13-14, 2011.

[47]Presentation of University of Hawaii President M.R.C. Greenwood, National Research Council, *Building Hawaii's Innovative Economy*, 2011, op. cit.; "Creating an Innovation Economy for Hawaii," *Civil Beat* March 1, 2011.

[48]The Council is comprised of a wide range of experts from academia, industry and government from Hawaii and other states.

leader, not a follower." She also pointed out that a new UH Cancer Center placed the university in a position to build expertise in cancers that are prevalent in Hawaii and the Pacific Rim region. She also indicated that in its curriculum, UH would eventually require entrepreneurial experience for every student.[49]

The University of Hawaii Innovations and Technology Transfers Program (UHITT) has established a pilot program to provide $25,000 to $100,000 in early stage funding to UH faculty members for proof-of-concept for commercialization of their research. The program is being funded by Hawaii Technology Development Venture (HTDV) a non-profit specializing in the commercialization of defense and homeland security technologies, and by UH.[50]

Fostering Start-ups

A medical researcher at the University of Hawaii observed in 2010 that "intellectual property developed by UH faculty is an inadequately tapped resource with enormous potential for economic benefit." The UH Upside fund, the University's venture capital fund, is seeking to address that problem through support for start-ups commercializing technologies developed at the University. Fund manager Barry Weinman commented that "UH has a lot of research dollars that go in and then don't come out for commercialization. What we're trying to do with the Upside Fund is change that economics."[51]

Recently the University of Hawai'i has spun off a number of innovative and successful companies.[52]

- ***Protekai*** ("Proteins from the Sea") was launched with the help of UH's venture capital fund, the Upside Fund (supported by the UH Foundation) to commercialize the biomedical technology research of UH faculty member Angel Yanagihara, who discovered and patented physalia florescent proteins, which have major biomedical and diagnostic applications.[53] The market for these proteins is $2.5 billion annually and growing at double-digit rates.

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[49]"Recommendations from the Innovation Council," National Research Council, *Building Hawaii's Innovation Economy: Summary of a Symposium*, op. cit.

[50]Hawaii Technology Development Venture is funded by the Office of Naval Research (ONR) and seeks to create a Pacific regional center for commercializing defense/homeland security technologies.

[51]"Venture Capital Fund Shines Light on UH," *Honolulu Star-Advertiser* December 7, 2010.

[52]Presentation of Barry Weinman, Allegis Capital LLC, "converting University Research into Start-Up Companies," National Research Council, "Building Hawaii's Innovation Economy," 2011, op. cit.

[53]Yanagihara is a researcher in the UH Department of Tropical Medicine, Medical Microbiology and Pharmacology, UH John A. Burns School of Medicine. When the Upside Fund invested $100,000 in Protekai's startup in 2010, Yanagihara commented that "It's really a very exciting discovery that's been sitting on a shelf at UH. The full patent was issued, but we didn't have the money for the next step to sequence the protein. This gives us the funds to go after the full sequence of genes, which is

- ***KinetiCor:*** KinetiCor is a start-up commercializing technology developed at UH and the Queens Medical Center, which compensates for patient movement during an MRI, increases MRI efficiency, and ultimately reduces health care costs. KinetiCor licensed technology developed at UH and received early stage financing from the UH Upside Fund.[54]
- ***Hoana*** was formed in 2001 and operates as a privately-held medical device company that aspires to be the world's leader in intelligent medical sensing. Its proprietary LifeBed patient-monitoring systems utilize non-contact sensors embedded in a hospital mattress coverlet to monitor patients' vital signs. Originally funded by grants from the U.S. military, this technology is being used to track patient conditions throughout the U.S.
- ***Kuehnle Agro Systems*** was founded by UH professor Adelheid Kuehale to commercialize technology for producing biofuels from algae, and "it employs numerous graduates from the University of Hawaii." The company has proven adept at securing federal support, and has received numerous SBIR awards from NSF, the Department of Agriculture, and DoD, as well as contracts with ONR and DARPA.[55]
- ***Renewable Water Technologies:*** Renewable Water Technologies is a start-up by UH engineering professor Weilin Qu, his former UH student Riley McGivern and former head of Hawaii Strategic Development Corp. John Chock to commercialize UH-developed technology using solar thermal heat collectors to desalinize sea water. The business model for RWT envisions supply of small-scale desalinization systems for local military installations and hotels. Start-up funding was provided by HTDV and Sopogy Inc., a renewable energy company based in Hawaii.[56]

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necessary to get to a point where we can use it as a diagnostic tool in medicine." "Venture Capital Fund Shines Light on UH," *Honolulu Star-Advertiser* December 7, 2010.

[54]Upside Fund Director Barry Weinman commented that "The UH Foundation was intrigued by KinetiCor, not only for its extraordinary technology, but because of the huge financial upside that could be achieved by commercializing UH's intellectual property. More than $2 billion globally a year is wasted by having to re-do MRI scans because the patient moves and blurs the images." "High Tech Company Based on UH Research Launches Amid High Interest," <*http://www.hawaii.edu/news/article.php?ald=5622*>, March 10, 2013.

[55]"Featured Scientist: Author/Entrepreneur/Biofuel Innovator Adeheid Kuehale," *TechHui* (March 2, 2009); "Invest in New Ideas for Isles—Bio-tech Firms Here Will Change the Face of Our Local Economy," *Honolulu Star-Advertiser*.

[56]"Desalinization Pilot Project Harnesses Solar Power," *Honolulu Star-Advertiser* (June 25, 2012.

Box 3-1
Technology Induction Fosters Local Start-Ups

Skai Ventures, founded by Hank Wuh, a graduate of the UH medical school, searches worldwide to identify technologies that can be commercialized in Hawaii, typically from universities and national laboratories, and which represent transformational rather than incremental innovation. ***Eyegenix***, one of Skai's portfolio companies, arose out of an Asian cultural aversion to organ/tissue transplants, including corneal transplants. Wuh found a technology at the University of Ottawa which could be used for an artificial cornea, and at Sweden's Karolinska, found the surgeon who had done the first pre-clinical trials with the technology. Initial tests have been promising—resulting in complete restoration of vision—approvals are being pursued, and a manufacturing plant is being constructed on the site of an old Dole cannery in Hawaii which will be capable of supplying enough artificial corneas to meet the entire world's demand. ***CBI Polymers*** leverages the artificial cornea technology to meet a U.S. Air Force request for a polymer that binds radioactive particles. A series of products were developed to remove toxic materials, including radioactive particles, to restore building surfacts, and to perform other tasks. As of early 2012, CBI Polymers had 50 customers worldwide.[57]

UH Space Flight Program

In 2007, the UH School of Ocean and Earth Sciences and Technology (SOEST) collaborated with the UH College of Engineering to create the Hawaii Space Flight Laboratory (HSFL). The mission of the HSFL is to conduct research and engineering for terrestrial and planetary space missions; develop, launch and operate spacecraft from the Hawaiian Islands; provide relevant workforce experience, and collaborate with other interested institutions. The HSFL is designed, in part, to address the erosion of the U.S. space industry, largely attributable to the cost of getting into space from the U.S. "while other countries innovate cheaper ways."[58] UH plans to be the first university in the world with dedicated rocket launch capability for satellites built and operated by its faculty and students.[59] Kauai Community College collaborates with HSFL in

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[57]Presentation by Hank Wuh, National Research Council, *Building Hawaii's Innovation Economy: Summary of a Symposium*, op. cit.

[58]Brian Taylor, University of Hawaii at Manoa, "Hawaii's Satellite Launch Program," National Research Council, *Building Hawaii's Innovation Economy: Summary of a Symposium*, op. cit. One partner of the HSFL is Sandia National Laboratory, which has performed a large number of launches from the Pacific Missile Range Facility (PMRF) on the island of Kauai. Ibid.

[59]"Research as an Industry: The Economic Contribution of HI?" *<http://www.universityofhawaiiinnovation.com>*.

providing the primary communication links, and Honolulu Community College designs satellite payloads and is planning to operate receiving stations.[60]

HSFL intends to develop the capability to provide complete satellite systems and to spin off niche companies. UH will provide key support infrastructure, including a clean room, a thermo-vacuum chamber, and a vibration chamber for satellite testing and spin balance, facilities that will be available to students and local businesses. HSFL's first operational mission is LEONIDAS (Low Earth-Orbiting Nanosatellite Integrated Defense Autonomous System), which will feature two launches.[61]

- The first launch will seek to advance readiness of a semiconductor device to be used in future launches for data compression, and is being built by UH students.
- The second launch, being built by UH faculty and graduate students, will conduct a thermal and visible image study of the Earth.

Ultimately the UH satellite launch program is expected to yield innovations in the areas of cost reduction, risk reduction and capability of rapid response—"the involvement of the University in the program promises not only a new economic driver for Hawaii but also a focus for developing the high-tech workforce."[62]

UH Astronomy Activities

While Hawaii's geography presents challenges, it also gives rise to opportunities in areas where the state enjoys natural advantages, which have given rise to actual and prospective innovation clusters. For example, the top of the mountain of Mauna Kea is one of the best sites for astronomy in the world. The state and federal governments have undertaken substantial investments in infrastructure and the creation of an 11,000 acre science reserve. At present 13 telescope facilities exist on Mauna Kea representing a capital investment of over $1 billion. UH has established sophisticated infrastructure on the mountain, including the largest capacity camera in existence, a charge-coupled device with 1.4 billion pixels. The cluster has generated commercial activity, including the sale of astronomy equipment by local companies and spinoffs like GL Scientific, founded by a former UH faculty member, which makes precision scientific instruments.[63]

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[60]"UH Plays a Vital Role in Hawaii's First Space Launch," <*http://www.hawaii.du/news/article.php?ald=56917*>, April 10, 2013).

[61]HSFL partners in this effort include Vanenburg Air Force Base; Aerojet Corp, a maker of rocket parts; Sandia; NASA/Ames Research Center; and the Pacific Missile Range Facility. Taylor, "Hawaii's Satellite Launch Program," op. cit.

[62]Taylor, "Hawaii's Satellite Launch Program." op. cit.

[63]Robert McLaren, Institute for Astronomy, University of Hawaii, "Astronomy in Hawaii," National Research Council, *Building Hawaii's Innovation Economy*, 2011, op. cit.

It is too early to determine whether UH's innovation initiatives will move the state substantially further toward a knowledge-based economy. However, UH has developed its initiatives on the basis of expert advice and appears to be making progress in addressing its principal challenge, which is to increase the flow of its research results into commercial application. The establishment of the UH Upside Fund and the apparent success of a succession of UH-spawned start-ups is encouraging. UH is capitalizing on Hawaii's unique geographic factors to develop competencies and companies which have the potential to attain world-class status and conceivable to dominate niche areas such as astronomy and low-cost satellites.

THE GROWING ROLE OF COMMUNITY COLLEGES

President Obama has placed a priority on expanding the role of the nation's 2-year community colleges in improving U.S. workforce skills, fostering innovation, and enhancing U.S. manufacturing competitiveness. Community colleges currently enroll over 7 million students and award 790,000 associate degrees annually, as well as certificates in specialties directly relevant to work opportunities, such as manufacturing, computer, and scientific skills. These institutions also form a bridge to higher education for students requiring improved competencies in academic fields including STEM. Enrollment in Community Colleges has been growing dramatically, having increased by 75 percent between 1979 and 2009, and by 12 percent between December 2007 and June 2009.[64] Calling these institutions "the unsung heroes of America's education system," he has called for 5 million new community college graduates by 2020 and in 2012, visited 10 community colleges[65]. The President has been seeking $8 billion in his budget for training community college students in the fields of health care, high tech manufacturing and transportation[66].

One of the 2-year institutions the President visited in 2012 was Lorain County Community College (LCCC) in Elyria, Ohio, which has attracted growing attention for its successful training programs and support for start-ups. In 1980, Lorain County had 43 percent of its work force engaged in manufacturing, the highest percentage of any county in northern Ohio, but by

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[64]Figures from National Center for Education Statistics 2010, Tables 196 and 198, cited in Department of Commerce, *The Competitiveness and Innovative Capacity of the United States,* January 2012, pp. 6-13.

[65]"Community Colleges' Cash Crunch Threatens Obama's Retraining Plan," *Reuters* March 5, 2013; "We already Knew the Value of 2-Year Schools," *Canandaigua Daily Messenger* October 12, 2010.

[66]Among other things, the Community College to Career fund would require 2-year colleges to partner with employers in a community to teach workforce skills. "President Obama Announces Community Colleges Partnership Program," *Lexington Examiner* February 22, 2012. In 2009, the President sought $10 billion for a job-training program to produce more community college graduates, but only got $2 billion from the Congress, "Must Match Education to Jobs," *The Philadelphia Enquirer* February 21, 2012.

2012, that figure had fallen to 14 percent.[67] Between 2001 and 2012, the county lost 11,500 jobs overall, 10,500 of them in manufacturing.[68] LCCC "worked to steer the county's work force toward technology, business, and the sciences, as those who have lost their jobs in manufacturing look to make themselves competitive again."[69] In 2009, the Cleveland *Plain Dealer* characterized LCCC as "an economic engine that is refocusing the work force in an area of high unemployment."[70] In 2011, the *Plain Dealer* commented that LCCC "has emerged as a major driver of efforts to transform Lorain County's economy. It trains prospective business owners—as well as their future employees."[71]

LCCC has struggled with limited resources to progressively improve workforce training programs. Local businesses complained in the late 1990s about the shortage of certified welders, and in 2007, the college secured a $4.9 million grant from the National Science Foundation to establish a center for welding education.[72] For many years, LCCC pursued the funding necessary to open a testing center for sensors, a goal which was achieved with a $5.5 million award from the state of Ohio in 2010.[73] LCCC partnered with other institutions to cut costs and enhance its curriculum.[74] In 2012, LCCC's "Transformations" program for computerized Numerically Controlled Machining reported a placement rate of over 90 percent of its participants within 3 months of graduation.[75]

The GLIDE Incubator

In 2001, LCCC collaborated with the local Chamber of Commerce and the Lorain County commissioners to form the Great Lakes Innovation and Development Enterprise ("GLIDE"), a business incubator intended to "try to wrap good business processes around entrepreneurs who had good product or business ideas." In the decade that followed 2001, GLIDE worked with over 1,900 entrepreneurs and incubated 65 companies, 62 of which were still in

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[67] Roy Church, "Stimulating Entrepreneurship: The Lorain County Model," *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.
[68] "Federal Job Training Funding Helps Unemployed Find Work in High-Growth Areas," *Long Island Examiner* April 19, 2012.
[69] Lorain City Councilman Craig Snodgrass in "County Fears LCCC Fire Will Affect Economy," *The Plain Dealer* February 21, 2009.
[70] "County Fears LCCC Fire Will Affect Economy" *The Plain Dealer* February 21, 2009.
[71] "Seed Funds See Fertile Ground Here," *The Plain Dealer* October 20, 2011.
[72] "LCC to Use Science Grant for Welding Program Study Center," *The Plain Dealer* June 30, 2007; "LCCC Looks to Offset Cost of Welding Course," *Wyoming Tribune-Eagle* August 28, 1998.
[73] "CSU Amends Plan to Salvage Grant LCCC Would House Engineering Center," *The Plain Dealer* February 19, 2009; "Server Projects Get Funding from Ohio's Third Frontier," *The Plain Dealer* September 1, 2010.
[74] "Federal Job Training Funding Helps Unemployed Find Work in High-Growth Areas," *Long Island Examiner* April 19, 2012.
[75] Roy Church, "Lorain County Model," op. cit.

business in 2013.[76] GLIDE began receiving financial support from Ohio's Third Frontier program, a state-level economic development initiative in 2006.[77]

Roy Church, LCCC's President, recalls that most of the new companies being launched entered the Valley of Death when they had exhausted friends, family, second mortgages, and credit cards. "We knew we had to figure out a way to bring in some pre-seed capital that would enable them to move their ideas to market." The GLIDE development team considered use of LCCC's foundation to provide funding, but encountered a legal barrier in the form of a rule that required the IRS to agree that a donation to a fund which invested in a private business was deductible. After an effort of over three years, GLIDE secured an IRS ruling that a foundation investment in a private company gave rise to a deductible "public good" if the entrepreneur receiving the funding provided one or more students with a work-based learning experience. This was a "triple win"—enabling the college to build educational value, the community to gain a new business, and the entrepreneur to receive financial support.[78]

In addition to financial support, GLIDE provides other forms of assistance to entrepreneurs. Companies located at the LCCC incubator (the Entrepreneurship Innovation Center) enjoy access to the LCCC infrastructure, faculty and students, co-located start-ups, and GLIDE advisors. The advisors are individuals with extensive business experience in both entrepreneurial ventures and corporate management, and competencies in engineering, materials, technology, business generation, distribution, quality control, marketing and sales, and strategic development.[79]

In 2007, the LCCC Foundation was renamed the Ohio Innovation Fund, extending its investments to a 21-country region in northeast Ohio. By 2013, it had made 71 awards to 60 companies launched by professors, students, and local citizens. Based on metrics developed by the Ohio Third Frontier Program, the 3.8 million invested in the Fund through September 2010 yielded a "return on investment" of $42 million in follow-on investments.[80]

The Financial Challenge

While the President and the business community are calling for an expanded role for community colleges, steep cuts in the level of state funding for 2-year institutions is forcing many of them to raise tuition and cut faculty

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[76]GLIDE invests at two levels: $25,000 for the "imagining" stage and completion of research, and $100,000 to mature the business, which must be matched 1:1 by the entrepreneur and repaid after 5 years. Roy Church, "Lorain County Model," op. cit.

[77]Roy Church, "Lorain County Model," op. cit. "Entrepreneurial Efforts Get Grants," *The Plain Dealer,* November 17, 2006.

[78]Roy Church, "Lorain County Model," op cit.

[79]LCCC, "Great Lakes Innovation and Development Enterprise" <*http://www.lorainccc.edu/business+and+industry/entrepreneurial+support/glide*>.

[80]Calculation of ROI from an economic development perspective considers factors such as follow-on investments, earning, and other types of investments. Roy Church, "Lorain County Model," op. cit.

and course offerings.[81] Because community colleges are far more dependent on state funding than four year institutions, the cuts in state funding are particularly challenging.[82] Between 2000 and 2010, the average annual community college tuition increased by 41 percent, to $3,269.[83] The President's proposals for federal assistance to the community colleges have run into stiff resistance in the Congress. The fiscal crisis facing community colleges is causing concern in the manufacturing community that depends on the 2-year institutions as "an essential source of skilled workers."[84]

LESSONS LEARNED

- A distinguishing feature of the American innovation ecosystem is that it is driven by a network of superb research universities.
- This innovation ecosystem is dominated by triadic collaborations involving universities, industry, and government, with institutional arrangements that promote silo-breaking and multidisciplinary research.
- The decentralization of the U.S. university system lends itself to differentiated state and regional innovation strategies that leverage local geographic, industrial legacies and cultural advantages.
- U.S. community colleges are an important resource base for creating the high-skills work force needed to sustain an innovation-based economy.
- The decline in state funding for public research universities and community colleges represents a fundamental threat to the nation's capacity to create and capture the fruits of innovation.

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[81] A 2013 report by the nonprofit Public Policy Institute of California indicated that in the wake of $1.5 billion in state budget cuts, between 2007 and 2012 the state's 112 2-year colleges experienced a decline in enrollment of 500,000 students (from 2.9 million to 2.4 million). Across the system, course offerings dropped by 21 percent. "Budget Cuts Hobble Calif. Community Colleges," *Associated Press* March 26, 2013. The same phenomenon is occurring in many other states. "Texas Community Colleges Face Shortfall," *Corpus Christi Caller-Times* January 25, 2013; "Community Colleges' Cash Crunch Threatens Obama's Retraining Plan," *Reuters* March 5, 2013.

[82] In the 2008-2009 school years, 47 percent of the revenues were derived from state appropriations, compared with 24 percent for public 4 year institutions. U.S. Department of Commerce, *The Competitiveness and Innovative Capacity of the United States,* January 2012, citing figures from the National Center for Education Statistics, IPEDS, 2010, Table 198.

[83] "Community Colleges' Cash Crunch Threatens Obama's Retraining Plan," *Reuters* March 5, 2013.

[84] Ibid.

Chapter 4

State Strategies for Innovation

While U.S. universities have played an important role as drivers of local innovation for well over a century, state governments have emerged as major promoters of innovation much more recently. While some modern state economic development efforts can be traced back to the early Twentieth Century, the focus on strategies for innovation-based development has grown in recent years.[1] First-generation industrial promotion programs frequently included a science or research dimension, but in most cases, placed primary emphasis on buttressing and retaining existing industrial sectors and recruiting major companies from other states.[2] Today, there is a growing emphasis on the growth of local innovation ecosystems and the role they can play in revitalizing older manufacturing sectors, helping new industries arise out of the established

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[1]State-driven economic development efforts are traceable back to the early federal period. In 1791, the New Jersey Legislature authorized the incorporation of Alexander Hamilton's Society for Establishing Useful Manufactures as an institution for industrial development, extending to it a state tax exemption, the power to condemn property for its own use and legal control over much of the water supply of Northern New Jersey. Peter K. Eisinger, *The Rise of the Entrepreneurial State: State and Local Economic Development Policy in the United States,* Madison: The University of Wisconsin Press, 1988, p. 15. The Erie Canal was built largely as a result of the efforts of New York Governor, DeWitt Clinton who persuaded the New York legislature to approve and support the project. Evan Cornug, *The Birth of Empire: DeWitt Clinton and the American Experience, 1769-1828*, Oxford: Oxford University Press, 2000, p. 8. Enactment of Right to Work Laws prohibiting the closed union shop began in the South in the 1940s, spreading to Great Plains and Mountain states, reducing labor costs as an inducement to attract manufacturing firms from states with a high percentage of unionized workers. Eisinger, *The Rise of the Entrepreneurial State: State and Local Economic Development Policy in the United States,* op. cit., pp. 165-167.

[2]For a review of the relevant policy landscape up to the mid 1990s, see Kevin T. Leicht and J. Craig Jenkins, "Three Strategies of State Economic Development: Entrepreneurial, Industrial Recruitment, and Deregulation Policies in the American States," *Economic Development Quarterly* 8(3):256-269, August 1994. The authors find "evidence of three general approaches: (1) an entrepreneurial approach focusing on new firm and technology development; (2) an industrial recruitment strategy emphasizing financial incentives for the relocation or expansion of existing enterprises; and (3) a deregulation approach that minimizes governmental control over private enterprise."

TABLE 4-1 Large Recruitment Incentives

Company	Year	Site	State	Incentive (Millions of Dollars)
Boeing	2003	Everett	WA	1, 984
AMD	2006	Malta	NY	1,118
ThyssenKrupp	2007	Mt. Vernon	AL	734
Scripps	2003	Palm Beach	FL	567
IBM	2000	East Fishkill	NY	533
Volkswagen	2008	Chattanooga	TN	450
Kia	2006	West Point	GA	353
Toyota	2006	Blue Springs	MS	292
Nissan	2000	Canton	MS	290
Sematech	2007	Albany	NY	269
Dell	2004	Winston-Salem	NC	242
Hyundai	2002	Montgomery	AL	234
Ford	2006	Detroit	MI	220
Toyota	2003	San Antonio	TX	218

manufacturing base, and in recruiting out-of-state firms with knowledge-based incentives rather than (or in addition to) traditional fiscal and infrastructure incentives.[3]

FROM INDUSTRIAL RECRUITMENT TO SCIENCE-BASED DEVELOPMENT

Industrial Recruitment

The modern practice of systematic promotion of local industry began in the first decades of the Twentieth Century, when southern states sought to attract companies by offering tax incentives, capital, and subsidized plant and industrial sites[4]. The practice of industrial recruitment eventually spread to the rest of the country and evolved from "smaller deals with manageable incentive amounts in the 1950s and 1960s to fiercely competitive megadeals involving hundreds of

[3]For a review of the growth and scope of contemporary innovation-based economic development policies by U.S. cities, regions and states, see David B. Audretsch and Mary L. Walshok, *Creating Competitiveness, Entrepreneurship and Innovation Policies for Growth,* Northampton, MA: Edward Elgar, 2013.

[4]In 1971, the New Jersey legislature incorporated Alexander Hamilton's private firm, the Society for Establishing Useful Manufactures, to promote industrial development. The society received a state tax exemption, control over much of the water supply of northern New Jersey and the power to condemn property for its own use. Eisinger, *The Rise of the Entrepreneurial State: State and Local Economic Development Policy in the United States,* op. cit., p. 15.

millions in corporate tax breaks and cash giveaways from the 1980s onward."[5] A recent survey of the biggest incentive deals in the United States between 1999 and 2011 revealed thirteen transactions in which states paid companies incentives in excess of $200 million and in one case, nearly $2 billion.[6]

The so-called recruitment incentives aimed at attracting businesses led contemporary media to characterize them as "blind smokestack chasing" or "buffalo hunts" and a zero-sum "economic war between the states."[7] Companies have found that they can force states into bidding wars over locational decisions to extract the maximum concessions with respect to incentives.[8] In 2004, Dell agreed to build a factory in North Carolina's Piedmont Triad, after the state—that prided itself on the lack of corporate incentives on its books—agreed to a $242 million package of tax incentives over a 15 year period. A local observer commented that

> *Dell has turned the art of negotiating economic development into a science by taking the same approach to incentives that it does to the rest of its business, steadily ratcheting up the stakes. More than a decade ago, Round Rock, Texas offered Dell a 60-year package of tax refunds that eventually drew the company's headquarters out of Austin... six years after its deal with Round Rock, Dell wrangled a 40-year, $166 million package of grants and tax breaks from Nashville, Tenn…* few *communities or their elected officials are willing to call a company's bluff when jobs are at stake.*[9]

While academic criticism of competition between states to attract companies through incentives is not altogether misplaced, it overlooks the fact that some state recruitment efforts have attracted innovative companies that have put down local roots, undertaken extensive local investments (including training programs and major contributions to local universities) and which have had very positive long-term local economic impacts.[10] Perhaps the most salient example

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[5]Nichola Lowe, "Southern Industrialization Revisited: Industrial Recruitment as a Strategic Tool for Local Economic Development," in *The Way Forward: Building a Globally Competitive South,* Chapel Hill: Global Research Institute, 2011.

[6]Kenneth P. Thomas, *Investment Incentives and the Global Competition for Capital,* Basingstoke: Palgrave MacMillan, 2011, p. 99.

[7]Walter H. Plosila, "State Science and Technology-Based Economic Development Policy: History, Trends and Developments and Future Directions," *Economic Development Quarterly* 18(2):114, 2004.

[8]"As Companies Seek Tax Deals, Governments Pay High Price," *New York Times* December 1, 2012; "State Should Stay Out of Investing In Plants," *The Times Union* June 9, 2012.

[9]"Some Believe Incentives are Wasted on Big Business—More Bang for the Buck Might Come from Helping Smaller Businesses, Which Could Create More Jobs," *Greensboro News & Record,* November 30, 2004.

[10]For a balanced examination of the debate over the value and effectiveness of incentives as a development tool, see Jonathan Q. Morgan, "Using Economic Development Incentives: for Better or for Worse," *Popular Government* Winter 2009.

of a successful recruitment initiative involving knowledge-based industries is the creation of North Carolina's Research Triangle Park, described in the Annex to this report. Another example is Texas' victory in the 1987-88 competition between states to secure the SEMATECH consortium, in which Texas prevailed because of the presence of the University of Texas at Austin and the state's commitment to enhance the university's microelectronics infrastructure.[11] More recently, New York has successfully implemented a university-based recruitment strategy that has led to the creation of a semiconductor manufacturing cluster in the region around Albany, including, ironically, the transfer of SEMATECH headquarters from Texas to New York.[12]

The Emergence of State Science Economic Development Policies

During the 1960s, formal state advisory bodies were set up with the support of the Commerce Department's State Technical Services Program (STS), which was cancelled by the Nixon Administration. In 1977, Congress authorized the National Science foundation to set up the State Science, Engineering, and Technology (SSET) program to support the development of science and technology strategic plans by the states. As a result of these programs, by the end of the 1970s, most U.S. states had some form of science and technology advisory organization associated with their government. These entities offered planning and advice to governors, but in general did not engage industry or state economic development bureaucracies.[13]

During the 1970s, the U.S. was buffeted by rising energy costs, inflation, and intensifying international competition. A severe economic slowdown in the early 1980s hit traditional manufacturing industries particularly hard, and the term "rust belt" came into popular use in reference to large areas of the industrialized Midwest, Northeast, and Upper South. The erosion of U.S. manufacturing is observable in high technology industries as well as traditional sectors. The U.S. trade balance has shifted from surplus to deficit since 2001, with an $81 billion deficit in 2010. With this decline, the U.S. has lost research and development activity associated with manufacturing to other countries. Job losses in the advanced manufacturing sector are of particular concern because

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[11]"The university was cited by SEMATECH as a main reason they chose Texas over 11 states that competed for the high tech prize." "UT Officials Elated at SEMATECH Decision," *The Dallas Morning News,* January 11, 1988; "SEMATECH Research Contract Approved by UT Regents—University to Study Semiconductor Manufacturing," *Austin American-Statesman* February 10, 1989; "State Board OKs $38 Million in Bonds for Project by UT," *Houston Chronicle* February 17, 1988.

[12]See Chapter 7.

[13]Walter H. Plosila, "State Science and Technology-Based Economic Development Policy: History, Trends and Developments and Future Directions," *Economic Development Quarterly* 18(2):115, 2004.

high technology workers earn 50 to 100 percent more than the average of workers in all other fields.[14]

With the decline of manufacturing during and after the 1970s, U.S. states began to rethink their development strategies and the focus on the entrepreneurial dynamism evident in areas such as Silicon Valley, Route 128, and North Carolina's Research Triangle. Texas revolutionized incentives competition in the early 1980s by recruiting the research consortia Microelectronics and Computer Technology Corporation (MCC) and SEMATECH using not only traditional lures like tax abatements and infrastructure improvements but also endowed university chairs and access to talent pools. In a major reappraisal a number of states,

> *realized they had not been engaging their universities in economic development; even fewer had thought of talent not as a mere commodity but as a discriminating vehicle for the future growth of state and regional economies …unlike the many previous chases for auto, steel, brewery, and other durable manufacturing branch facilities, this competition began a change in direction for state economic development to one involving talent, technology, and capital, not one just focused on traditional real estate issues of financing bricks and mortar.*[15]

The 1980s saw a profusion of advanced technology programs at the state level, which featured aspects such as university-industry government R&D projects, promotion of start-ups using policy tools such as incubators and venture capital pools, and the provision of vocational and technical education and training. Cooperative research centers or "centers of excellence" were established pursuant to new state initiatives, including Ohio's Thomas Edison Program and New York's Centers for Advanced Technology programs.[16] At present, all fifty U.S. states incorporate science and technology programs in their economic development strategies.[17]

The recession of 2008-09 hit state budgets hard, and by 2010, 44 states had budget deficits.[18] However, a number of states that had committed to long-

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[14]President's Council of Advisors on Science and Technology, *Report to the President on Ensuring American Leadership in Advanced Manufacturing,* June 2011, pp. i, 9.

[15]Walter H. Plosila, "State Science and Technology-Based Economic Development Policy: History, Trends and Developments and Future Directions," *Economic Development Quarterly,* 18(2)115-116, 2004.

[16]Irwin Feller, "Evaluating State Advanced Technology Programs," *Evaluation Review* 12(3):233, 1988.

[17]Susan E. Cozzens, et al, "Distributional Effects of Science and Technology-Based Economic Development Strategies at State Level in United States," *Science and Public Policy* February 2005, p. 32.

National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2012, p. 59.

term efforts to promoting innovation have sustained funding through the period 2008-13. Ohio voters approved an additional $700 million for the state's Third Frontier innovation institute in 2010.[19] New York has sustained financial support for its nanotechnology initiative in the years since the 2008 financial crisis, including a $400 million contribution to SUNY Albany's College of Nanoscale Science and Engineering in 2011.[20] A recent study of Arkansas' innovation initiative reported in 2012 that the state's knowledge-based economy initiatives focused on research have received $61.2 million in state funding from 2008 through 2011 and leveraged on additional $191.8 million in non-state support."[21]

Academic Recruitment

Traditional state industrial recruitment methods, such as the offer of tax abatements, infrastructure concessions, and financial assistance to companies, are increasingly being augmented—if not displaced altogether—by knowledge-based measures, including training programs, upgrading of university research infrastructure, buildout of broadband networks, and establishment of medical research centers. Perhaps most significantly, an intensive competition has developed between universities for science and engineering faculty members conducting cutting-edge research. The most sought-after faculty members are often holders of "endowed chairs," positions backed by donor funds that generate an income stream that compensates the faculty member and provides for research support. The offer of an endowed chair position can be a compelling inducement to attract sought after researchers as well as their post-doctoral fellows, who are young people in their most productive years. "What is generally agreed upon is that endowed chairs represent an important tool in building a research hub capable of attracting big federal grants, commercializing technology, and spawning start-up companies."[22]

Following the lead of Virginia and Ohio, the state of Georgia launched a formal program in 1992 to attract top flight research faculty to the state with the creation of the Georgia Research Alliance, a consortium of six universities, business leaders, and government officials.[23] The Alliance implemented the Eminent Scholars program, creating endowed chairs at universities in the state funded initially at about $750,000 a piece, to be matched by the host institution. The Eminent Scholars program targeted entrepreneurial faculty, in particular many of whom had already founded companies or who were looking to commercialize ideas they had already developed. By 2010, not quite two

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[19]"Third Frontier Win was Big, Not Easy," *Dayton Daily News* May 6, 2010.
[20]Presentation by Pradeep Haldar, CNSE, Vice President, Troy, New York, April 3, 2013.
[21]Battelle Technology Partnership Practice, *Arkansas's Knowledge Economy Initiatives: Analysis of Progress and Recommendations for the Future,* November 2012, p. ES-2.
[22]"Universities Need to Court Top-Tier Researchers," *The Plain Dealer* March 31, 2002.
[23]See Maryann P. Feldman, Lauren Lanahan and Iryna Lendel, Experiments in the Laboratories of Democracy: State Scientific Capacity Building, *Economic Development Quarterly*, forthcoming.

decades after the launch of this program, the Georgia Research Alliance had attracted 60 of the country's eminent researchers who had secured $2.6 billion in federal and state research grants, created at least 150 start-up companies, 5,000 high tech jobs, and generated discoveries with potential applications benefitting 100 local companies.[24] In one dramatic episode, the Medical College of Georgia in Augusta "raided" Yale "pretty heavily," attracting nine scientists specializing in molecular biology, including Dr. Howard Rasmussen, an extremely highly-regarded cell-signaling scholar.[25] A 2013 state audit of the Eminent Scholars Program concluded that in 2012, Eminent Scholars and their research teams attracted about $270 million to non-state funding for research, supporting around 1,400 jobs at the state's universities.[26]

The Eminent Scholars concept is being replicated in other states.[27] In 2002, the legislature of South Carolina passed the Endowed Chairs Act, funding an initiative to attract top-quality academic researchers.[28] Ohio has used a similar program authorizing the state Board of Regents to endow faculty chairs, and additional funds have been made available from revenue land issues to fund endowed chairs.[29]

THE MICHIGAN BATTERY INITIATIVE

Michigan's efforts to diversify its economy through the establishment of industrial clusters have been led by the Michigan Economic Development Corporation (MEDC), a state economic development corporation. At the onset of the global financial crisis in 2008, Michigan Governor Jennifer Granholm tasked MEDC with devising a strategy to diversify the state's economy beyond the auto industry.[30] MEDC devoted a substantial effort to the study of industrial

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[24]Georgia's Technology Scholars Get a Tip of the Hat from Miller," *The Atlanta Journal-Constitution* April 15, 1998; "Research Group Supportive of UGA Scientists," *Atlanta Banner-Herald* September 26, 2010.

[25]"Augusta College Builds Program by Raiding Yale," *The Atlanta Journal-Constitution,* May 6, 1993.

[26]Of the total reported, about $108 million was attributable to the scholars themselves and the other $162 million a result of the work of the scholar's research teams and centers. Of the $108 million associated with the scholars themselves, $46.3 million, or 43 percent, was associated with the work of 6 scholars out of the total 64. Georgia Department of Audits and Accounts, Performance Audit Division, *Georgia Research Alliance: Requested Information on State-Funded Activities,* January 2013, p. 17.

[27]"Initiative Seeks Top Researchers: $143 Million Goes to Universities for Cutting Edge Solutions," *The Plain Dealer* May 21, 2008.

[28]Presentation of David McNamara, South Carolina Research Authority, "Building the South Carolina Innovation Ecosystem," National Research Council, *Growing Innovation Clusters for American Prosperity: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, D.C.: The National Academies Press, 2011, p. 15.

[29]"Universities Need to Court top-Tier Researchers," Cleveland *The Plain Dealer* March 31, 2002.

[30]At that time, Michigan had the nation's highest unemployment rate, losing nearly 1 million manufacturing jobs as the crisis unfolded. Doug Parks, "Battery Initiative in Michigan," in National

acceleration and clustering models around the world, and was particularly impressed with Sweden's application of the so-called "triple-helix" model.[31] MEDC developed a cluster strategy based on Michigan's intrinsic strengths, which included a highly developed manufacturing sector, natural resources such as the Great Lakes. The state targeted six thematic areas for cluster development, which were advanced energy storage, solar power, wind turbine manufacturing, bio-energy, defense, and advanced materials and manufacturing.

Having identified thematic clusters MEDC set up cross-functional teams to develop roadmaps for each sector, with each team comprised of representatives from universities, industry, venture capital and other fields. The state deployed an array of incentives to support the clusters, including tax credits and the establishment of "Centers of Energy Excellence."[32] Michigan sustained aggressive investments in the cluster effort despite a budget deficit exceeding $1 billion.[33]

Advanced energy storage is closely associated with the future of Michigan's auto industry. Electric-powered and hybrid motor vehicles are

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Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2012.

[31]The triple helix model assigns an enhanced role to universities in government/industry/university innovation collaboration. "The common objective is to realize an innovative environment consisting of university spin-off firms, tri-lateral initiatives for knowledge-based economic development, and strategic alliances among firms (large and small, operating in different areas, and with different levels of technology), government laboratories, and academic research groups. These arrangements are often encouraged, but not controlled, by government, whether through new "rules of the game," direct or indirect financial assistance, or through the Bayh Dole Act in the U.S.A" or the creation of new policy actors. Etkowitz, Henry and Loet Leydesdorff, "The Dynamics of Innovation: From National Systems and 'Mode 2' to a Triple Helix of University-Industry-Government Relations," *Research Policy* pp. 109, 112, 2000.

[32]The Centers of Energy Excellence program awarded state grant funds to partnerships between companies, on the one hand, and universities or federal laboratories, on the other hand. The university is engaged either with supply chain issues or a specific technology. State funds are matched by the private sector, universities, and federal laboratories. The centers of excellence are modeled after those in Sweden, which feature an anchor company supported by universities and the Swedish government. MEDC was particularly impressed with a Swedish collaboration at a pulp and paper mill north of the Arctic Circle that developed technology to convert a chemical waste, "black liquor," into biofuels. A MEDC official commented that "what we thought was compelling was that they brought together federal agencies, end users, and the value chain. All of those resources were focused on solving the problem, which the Swedes thought could provide 10 to 15 percent of their biofuel requirements." Doug Parks, "Battery Initiative in Michigan," in National Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium*, op. cit.

[33]"Anchor Tax Credits" provided rebates based on personal income tax, paid by employees and investments, and were designed to encourage high technology supply chains in Michigan. "Advanced Battery Credits" of $1 billion refunded business taxes, paid by companies manufacturing battery cells and battery packs and engaged in advanced battery engineering. "Photovoltaic Tax Credits" gave companies investing in manufacturing plants for photovoltaic technology, systems or energy a credit equal to 25 percent of the investment. Technology Collaboration Tax Credits" encouraged strategic innovation collaborations involving small companies. Firms receive credits for investing in companies employing 50 or fewer people and under $10 million in revenue. Ibid. 104-105

widely viewed as a necessary response to the rising cost of fossil fuels, energy import dependency, and the need to reduce greenhouse gas emissions.[34] A major obstacle to the widespread adoption of electric and hybrid vehicles, however, is the cost of the battery packs, which account for one-third of the cost of the electric car.[35] A number of foreign countries regard the advanced-battery industry as strategic, and have committed substantial resources to the development of lower-cost, higher-performing batteries for electric vehicles.[36] Much of this effort has been directed toward development of lithium-ion battery technology, which is seen as the most promising alternative to the costly nickel-metal hydride batteries that power most current-generation electric vehicles.[37]

Lagging U.S. Competitive Position

At present, the U.S. produces only about 1 percent of the world's lithium batteries, and until recently, it faced the prospect of "entering the age of electrified vehicle transportation without a domestic advanced battery manufacturing industry."[38] The implications were particularly troubling for Michigan, whose economy is far more dependent on motor vehicle manufacturing than that of any other state.[39] Underscoring the vulnerabilities of

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[34]In 2011, the Boston Consulting Group forecast that electrified vehicles (hybrids, plug-in hybrids, and pure electric) would account for 9-12 percent of the U.S. vehicle market by 2020, up from 3 percent in 2010. Center for Michigan, *Special Report: Michigan Goes Big on Batteries,* 2011. Daniel Sperling of the University of California at Davis points out that state and local governments across the United States have implemented numerous policies to promote electric vehicles, subsides for manufacturers and government-sponsored R&D. California also requires a 10 percent reduction in the carbon-intensity of all fuels, providing an additional incentive for the adoption of electric drive vehicles. Daniel Sperling, "Incentives for the Electric Vehicle Market," in National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit.

[35]Ford CEO Alan Mulally said in 2012 that battery packs for his company's Focus electric car cost $12,000 to $15,000 apiece, raising the cost of a car that would normally sell for $22,000 to $39,200. *Wall Street Journal,* "Ford CEO: Battery is Third of Electric Car Cost," April 17, 2012.

[36]In 2010, the government of South Korea pledged to commit 15 trillion won (14 billion dollars) to develop the country's rechargeable battery industry in the next decade.. "Korean Firms Set to Lead Rechargeable Battery Market," Korea Herald Online. July 26, 2010; In 2010, China began construction of its first Lithium-New Energy High Tech Industry Base in Yichun, Jiangxi Province, with output value expected to exceed $14 billion by 2020. The 20 square km site will be an economic service zone for manufacturing and recycling lithium batteries and associated research and development. An industrial chain will be established on the site, and "the zone is expected to become a new energy automobile manufacturing base." Yichun has the world's largest lithium mine, accounting for 12 percent of the world's reserves. "East China to Get First Lithium High-Tech Zone," *Xinhua* April 10, 2010.

[37]A lithium-ion battery produces electrical charges by lithium ions that flow between an anode plate and a cathode plate. The liquid chemical mixture in the battery (electrolyte) contains lithium salts and an organic compound. National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit. p. 5.

[38]Ibid. p. 1.

[39]Michigan is seven times more dependent on the auto sector than any other state.

TABLE 4-2 Michigan Advanced Battery Tax Credits

Credit	Topic	Value (Millions of Dollars)	Beneficiaries
Pack Manufacturing	Manufacture of plug-in hybrid and traction battery packs	255	GM, Ford, JCS
Vehicle Engineering	Expenses for battery integration, prototyping, and launch	135	GM, Ford, Chrysler
Advanced Battery Technologies Engineering	Engineering activities	30	Ford
Cell Manufacturing	Capital investments in cell manufacturing facilities	600	JCS, Dow Kokam, A123 Systems, LG Chem, Xtreme Power, fortu Power

SOURCE: Michigan Economic Development Corporation.

import-dependency for a strategic technology, as of October 2012, a total of ten antitrust lawsuits were pending against Asian makers of lithium batteries by battery-consuming companies, alleging price-fixing.[40] Absent a domestic production base, U.S. industrial consumers of lithium batteries are exposed to the price manipulation of offshore syndicates.

Michigan's Promotional Efforts

Since 2008, Michigan has made the nation's most significant commitment to the development of electrified vehicles, offering over $1 billion in grants and tax credits to manufacturers of lithium-ion battery cells, packs, and components. Michigan also invested in research centers and worker training programs for electrified vehicles. The state's investment was substantially augmented by federal grants under the 2009 American Recovery and

[40] "Lithium Battery Manufacturers Accused of Price-Fixing," *Lithium Investing News* November 12, 2012.

Reinvestment Act to producers of lithium-ion cells, packs, and materials.[41] State tax credits have proven to be powerful tools, "literally cash to the companies" offsetting investment requirements, whether for plant equipment or processes. $1 billion in refundable tax credits for batteries was "completely bid out."[42]

Half of the federal stimulus money went to Michigan.[43] The federal government provides other support measures for advanced batteries and electrified vehicles:

- The government has made $25 billion in debt capital available to automakers to finance the development of more energy-efficient vehicles pursuant to the Advanced Technology Vehicles Manufacturing Program (ATVM).
- The Department of Energy has funded R&D in battery technology pursuant to its Vehicles Technology Program.
- DOE heads a government-industry partnership, the U.S. Advanced Battery Consortium, which funds projects for the commercialization of new battery technologies and the establishment of industry performance targets.
- The battery industry has benefitted from $4.5 billion in investments pursuant to the Recovery act in smart-grid technologies.
- DOE's Advanced Research Projects Agency-Energy (ARPA-E), a program that funds "transformational" energy technology has allocated $100 million to energy storage research.
- The federal government offers a variety of tax incentives, which benefit the advanced battery industry.[44]

The advent of state and federal incentives produced a flurry of investment in the advanced battery sector in the state of Michigan. In 2010, Governor Granholm noted that 16 advanced battery projects were under way and that "a whole advanced battery supply chain is taking root from the Detroit area to the shores of Lake Michigan," including companies making anodes, cathodes, separators, and electrolytes, as well as firms integrating them into

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[41]National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit., pp. 1-2.
[42]Doug Parks, Michigan Economic Development Corporation, "Building on Battery Initiative in Michigan," National Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2012.
[43]Sridhar Kota, White House Office of Science and Technology Policy, June 26, in National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit.
[44]The Advanced Energy Manufacturing Tax Credit program provides $2.3 million to companies to cover 30 percent of investments in new, expanded, or refurbished factories producing renewable-energy equipment. U.S. consumers purchasing electrified vehicles are eligible for tax deductions. National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit., pp. 7-8.

Box 4-1
Training an Electric Vehicle Work Force

Ann Marie Sastry of the University of Michigan, who has been directing battery research for more than a decade, pointed out at the symposium on the battery industry for electric drive vehicles that "the current graduation rate from U.S. university electric power engineering programs is not sufficient to meet our nation's current and future needs."[45] In an effort to address the skills shortfall, Wayne State University in Detroit is developing a comprehensive curriculum for degree programs for batteries and electric-drive vehicles. This effort, mounted n collaboration with Macomb County Community College and Next-Energy, a nonprofit, is funded by DOE and its advisory board includes representatives of GM, Ford, and TARDEC, the U.S. Army's organization for tank automotive research. The program offers a master's degree in electric-drive vehicle engineering, a bachelor's in electric transportation, and at Macomb, associate degrees in automotive and electronic engineering technology. The university is working closely with the electric drive vehicle industry to ensure that its coursework is relevant to industry needs, and students can use industry laboratories for practice and experiments. New laboratories are being developed for this program, including an energy-storage laboratory with three levels: (1) new materials, cell assembly and fabrication of cathodes and anodes; (2) vehicle integration; and (3) characterization of cells and relevant topics such as thermal management. A second new laboratory is dedicated to electric propulsion. Courses began in the fall of 2010.[46]

battery packs and electric vehicles. "The whole spectrum is right here in Michigan."[47]

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[45]Ann Marie Sastry, "The University/Startup Perspective," National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit. Work force needs of the advanced battery industry vary along the supply chain. For electrode manufacturing, skilled workers are needed for mizing, coating, calendaring and alip-punch processes. Competencies required for cell production include dry-room, electrode-stacking, assembly and formation processes. Other required skills include pack assembly and testing. Training and education requirements for manufacturing positions range "all the way from high-school degrees to Ph.Ds." Robert Kamischke, EnerDel, "Workforce Needs and Opportunities," National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit.
[46]Simon Ng, Wayne State University, "Technical Training and Workforce Development," National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit.
[47]Summary of remarks of Governor Jennifer Granholm, July 26, 2010, in National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit., p. 11.

The Foreign Competitive Challenge

Even with this promising beginning, Michigan's nascent electric vehicle cluster confronts daunting long run challenges. Even with government and industry investments in an advanced battery supply chain, an executive at Johnson Controls, whose joint venture, Johnson Controls-Saft makes lithium-ion batteries for hybrid vehicles, commented in 2010 that most of this company's key suppliers were still based overseas—"we really like to work with local suppliers," but the cells separators and cathode materials for lithium-ion batteries were "pretty much coming out of Europe, Japan, and Korea."[48] Forecast demand for electric vehicles has not materialized in the U.S., confronting Michigan's emerging battery industry with overcapacity—an executive at Ann Arbor's Center for Automotive Research commented in 2012 that "too much battery capacity has been built for the market to even remotely justify."[49] In October 2012, A123 Systems, a lithium-ion battery maker with several sites in Michigan, filed for bankruptcy and subsequently accepted a bailout offer from China's largest auto parts maker, Wangxiang Group Corp.[50] Korea-based LG Chem, with a lithium-ion battery plant in Holland, Michigan, furloughed the plant's 200 employees in 2012 and was reportedly supplying batteries for the Chevy Volt from its factories in Korea.[51]

Michigan's fledgling battery industry faces stiff foreign competition. Despite recent investments in U.S.-based battery production, "many newer electric car models, such as Renault's Zoe, are still getting their batteries from Asia, where the battery industry has had many years' head start."[52] U.S. battery makers have turned to Asian firms for the technology needed to enter the lithium-ion battery industry.[53] A number of the leading Asian battery makers are

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[48]Tom Watson, "A Battery Manufacturer's Perspective," in National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit., p. 58. Japanese manufacturers control 70 to 100 percent of the world market for some key components for lithium batteries. "Major Investment Needed to Pull Ahead in Electric Car Battery Market," Chosun Ilbo Online, July 13, 2010.

[49]"Here Comes Michigan's Battery Industry—But Where are the Electric Vehicle Buyers?" *Crain's Detroit Business* March 6, 2012. General Motors halted production of the Chevy Volt in March 2012, citing poor sales. Crain's Detroit Business commented that "the sales numbers couldn't be clearer: for now, people don't want electric cars. Or, more specifically, people don't need electric cars. Despite recent spikes, gas prices have remained relatively low since the downturn." Ibid.

[50]"Troubled Battery Maker A123 Fell Short on Job Creation and Defaulted on Some of its Debt," *Grand Rapids Press* October 17, 2012.

[51]"Why the New U.S. Battery Industry is Still Struggling," *Washington Post*. October 3, 2012.

[52]Ibid.

[53]Japan holds over two-thirds of all the patents for lithium-ion battery technology registered at the U.S. Patent Office. "Korea Leads in Battery Production but Lacks Innovation," *Chosun Ilbo Online* April 6, 2011. The head of automotive systems for A123 Systems, a U.S.-based maker of lithium batteries was asked in 2011 why his company had opened its first production sites in China and Korea. He said "that's where the supply base was. That's where the know-how was. It was non-existent in the U.S." To establish its plants in the U.S., "we call it 'copy exact'. We bought a company in Korea that had the technology around that type of battery and had developed the

Box 4-2
Consequences of Erratic Funding

At the Symposium on the *U.S. Battery Industry for Electric Drive Vehicles*, Mohamed Alamgir, the research director of lithium-ion battery maker Compact Power, spoke of the effects of erratic funding on the evolution of the U.S. industry. Acknowledging recent federal and state financial support, he said that if such help had been available 25 years ago, "I wouldn't have had to go through five companies during my career in lithium-ion batteries. If you do a study on what went wrong and right in lithium-ion, you can use me as a case example. This kind of funding was not there before. It was very spotty, which is why we were in trouble." Between 1985 and 1995, he worked at EIC Laboratories in Boston which "survived completely" on funding from the SBIR program. He noted that Duracell, which at one time "was the house to go to for research related to lithium batteries," dismantled its lithium-ion research operations "after a series of takeovers." Alamgir was part of three battery companies that disappeared and he listed failed lithium-ion companies including Energizer, Moltech, Polystor, Motorola ESG, Firefly, Imora, MoliCell, and ElectroEnergy. "Early battery companies couldn't get enough funding to survive against tough competition from Japanese and Korean companies." He concluded from this history that "the government does need to support research in the future, just as the Japanese government did in the 1990s with their "New Sunshine Program."[54]

incorporated in huge industrial conglomerates and have the financial resources necessary to withstand years of low sales levels as the electric vehicle market evolves.[55] Korea's battery makers, which include LG Chem Co., Samsung SDI Co. and SK Energy, "have been supplying batteries for their affiliate companies …, which has boosted their sales."[56]

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manufacturing process there. We basically brought that here, copied it exactly, and scaled it up." A123 also brought six Korean engineers to the U.S. and sent a team of Americans to Korea for training. "Does America Need Manufacturing?" *New York Times* August 24, 2011.

[54]Presentation by Mohamed Alamgir, National Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium*, op. cit.

[55]LG Chem, a major Korean producer of lithium-ion batteries, was nearly shut down twice, in 2001 and 2005, because of complaints from executives in other parts of the LG Group about poor battery sales. The group's Chairman, however, Koo Bon-moo resisted these calls, and the company eventually secured supply contracts with 10 automakers, including Ford, Renault, Volvo, and Hyundai. "Electric Vehicle Batteries Power Korea Ahead," *Joong Ang Daily Online,* April 19, 2011.

[56]"S. Korean Battery Makers Fast Catching Up with Japanese Rivals: Nomura," *Yonhap* June 24, 2010.

The conundrum confronting the U.S. battery industry is the technological reality that despite rapid technological progress, current-generation vehicle batteries still cost too much and deliver too little with respect to performance, resulting in stagnant consumer demand. This problem will at some point be resolved through innovation, although the time horizon over which this will occur remains unclear.[57]

Michigan's battery initiative underscores pitfalls confronting innovation-based economic development. The state has been effective in mobilizing its own and federal funds to stimulate the emergence of a battery production industry chain within the state, raising the prospect that the U.S. may be able to avoid foreign dependency on a key technology in the auto industry in the future. However, the demand side of the equation remains a critical unknown as the fledgling U.S. battery makers struggle with stagnant ales and foreign competition. The same type of challenge confronts Toledo's emerging photovoltaics cluster, and raises the question whether states, by themselves, have the resources and the stamina to support industries of the future through what may prove to be very long periods of gestation.

LESSONS LEARNED

- State government economic development efforts, traditionally centered on incentives-based industrial recruitment, are now also emphasizing knowledge-based initiatives and the creation of innovation clusters.
- Recruitment-based development efforts centered on research universities have proven effective (Research Triangle Park in North Carolina, Tech Valley in New York State)
- As the experience of Michigan's Battery Initiative demonstrates, even very well-endowed state innovation initiatives face daunting challenges, including demand uncertainties intrinsic to investments in industries of the future, formidable foreign competition, and gaps in U.S. industry chains.

[57]In November 2012, DOE announced that it was creating a new "Joint Center for Energy Storage Research" (JCESR) at the Argonne National Laboratory, a $120-million effort to develop batteries that are 5 times as powerful as and 5 times cheaper than current batteries within five years. "DOE wants 5x Battery Power Boost in 5 Years," *Computerworld,* November 30, 2012.

Chapter 5

The Federal Dimension

In much of the world outside the United States, national governments have implemented comprehensive regional development programs and have taken a central role in the formation of innovation clusters—26 of the 31 European Union countries have cluster development policies at the national level. By contrast, in the U.S., while the federal government has over 200 programs associated with regional development, there has until recently been "no federal policy on clusters."[1] In general, and with noteworthy exceptions in fields of national security and public health, the federal role in the states and regions has been to dispense a large number of relatively small packets of financial assistance for R&D and to support small business, and to set regulatory policies that define the competitive environment for innovation. Since 2009, however, the federal government has begun to establish and expand new programs explicitly for the purpose of fostering regional innovation clusters.

FEDERAL FUNDING OF SCIENTIFIC RESEARCH AND ECONOMIC DEVELOPMENT

Most of the United States' basic scientific research is funded by the federal government and conducted by U.S. research universities pursuant to grants and contracts.[2] Basic R&D is funded in both established and promising thematic areas are seen as providing the foundation for scientific advance over the long run. The federal government also funds R&D to meet the mission requirements of federal agencies and departments. Much of this spending

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[1]Presentation by Andrew Reamer, Brookings Institution, "Stimulating Regional Economies," in National Research Council, *Growing Innovation Clusters for American Prosperity: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2011. pp. 52-56.

[2]National Science Board, *Science and Engineering Indicators 2012*, Arlington, VA: National Science Foundation, 2012.

Box 5-1
The Federal Role in Economic Development and Innovation

The federal government has been active in promoting economic development and innovation since the early days of the nation, manifested in such initiatives as the creation of the Patent Office (1802), the Coast and Geodetic Survey (1807), and early initiatives to improve navigation. Between the 1860s and the 1930s U.S. manufacturers were protected by a high tariff wall intended, in part, to foster new industries. Since World War II, investments in research by DoD, NIH, NASA, DOE, NSF, and other government institutions have given rise to new technologies creating entire new industries and millions of U.S. jobs. Federal funding was critical to the development of the transistor by Bell Labs, the emergence of the semiconductor industry, the development of GPS, and the creation of the Internet, and if anything, the importance of federal support for innovation is increasing. A survey of U.S. innovation concluded

Whereas the lion's share of the R&D 100 Award-winning U.S. innovations in the 1970s came from corporations acting on their own, most of the R&D 100 Award-winning U.S. innovation in the last two decades have come from partnerships involving business and government, including federal labs and federally funded research… [T]he federal government is playing a much more supportive and important role in innovation.[3]

supports development of technologies relevant to defense and national security, which sometimes has little or no near term commercial applicability. The U.S. national laboratories support research related to national defense, energy security and public health; despite a long history of initiatives to foster increased commercial application of their research results, their impact in the commercial arena has been an ongoing subject of concern on the part of policymakers.[4]

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[3]Fred Black and Matthew R. Keller, "Where Do Innovations Come From? Transformations in the U.S. National Innovation System, 1920-2006," Information Technology and Innovation Foundation, July 2008, pp. 2-3

[4]A number of recent reports have concluded that the metrics available to assess the federal laboratories' performance in technology transfer to industry are inadequate, but that a number of factors inhibit such transfers, including the laboratories' management, supervision, culture, available resources, mission(s), and location. See National Institute of Standards and Technology, *Federal Laboratory Technology Transfer Fiscal Year* 2010, August 2012; Institute for Defense Analysis Science and Technology Policy Institute, *Technology Transfer and Commercialization Landscape of the Federal Laboratories,* June 2011. In 2009, the General Accountability Office conducted a review of technology transfer by the DOE laboratories. It found that "the completeness and accuracy of DOE's technology transfer data are questionable…One laboratory failed to report complete information on its federal work-for-others agreements for fiscal years 2004 through 2008…[M]ore could be done to ensure that promising technologies are being transferred…DOE's lack of

The activities of Sandia National Laboratory in New Mexico in engaging U.S. industry suggests the opportunities that exist in expanding the federal laboratories' role in commercially relevant innovation. Sandia has been involved in corporate research partnerships for over 15 years with companies such as Intel, Lockheed-Martin, Corning, Proctor & Gamble, IBM, and Hewlett-Packard.[5] Sandia has collaborated with the state of New Mexico and Los Alamos National Laboratory to create Sandia Science and Technology Park, a public-private partnership which had 30 tenants as of 2012 (some of them spinoffs from Sandia) and accounted for 2,000 jobs in Albuquerque.[6] The New Mexico Small Business Assistance program provides tax credits to Sandia and Los Alamos to provide technical support to local businesses, collaboration credited with creating and retraining 1,020 small business jobs in the state. Sandia's Entrepreneurial Separation to Transfer Technology program allows its scientists to apply for "entrepreneurial leave" to help expand or start-up a company, with a guarantee of re-employment upon return (for whatever reason) within two years. Between 1998 and 2012, 138 scientists and engineers left Sandia and Los Alamos to found companies, starting up 91.[7]

There is no central clearinghouse or coordinating mechanism with respect to federal R&D spending, which is administered by numerous government agencies in a manner that is sometimes contradictory or duplicative. At the same time, the disaggregation of federal research spending accords innovators with multiple possibilities for securing federal funding. The notion of a national industrial policy or innovation strategy has been debated for decades,

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overarching goals—including a consensus on what activities constitute technology transfer—and reliable performance data have left DOE's laboratories and program offices to chart their own course, most often with mixed results." GAO, *Technology Transfer: Clearer Priorities and Greater Use of Innovative Approaches Could Increase the Effectiveness of Technology Transfer at Department of Energy Laboratories,* June 2009, pp. 19-31. Dr. Eric Isaacs, Director of the Argonne National Laboratory in Illinois, recalls the case of a promising new material developed "very quickly" in the laboratory but which took 19 years to develop into practical applications in the automobile industry. Eric Isaacs, "The Federal Laboratory Contribution," National Research Council, "Building the Illinois Innovation Economy: Summary of a Symposium," June 28-29, 2012.

[5]Sandia initially collaborated with Goodyear on computational simulation technology that Goodyear needed to improve its tire design and production processes. The relationship flourished and Goodyear now uses Sandia simulation tools to design many types of tires. Goodyear fully funds the program and has invested over $40 million in it. J. Stephen Rottler, "Sandia National Laboratories as a Catalyst for Regional Growth," National Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2012.

[6]Jobs in the Science Park pay salaries that are twice as high as the Albuquerque average. Ibid.

[7]Ibid. Solar equipment maker Emcore acquired MODE, a company founded by Sandia scientists in 1996 to develop photovoltaic applications for satellites. Emcore moved its headquarters to Sandia's Science Park and continued to license technologies from Sandia. As of 2012, having grown substantially, it employed 350 people. Emcore receives assistance from Sandia's small business assistance program.

Box 5-2
A Groundbreaking National Laboratory-University Partnership

The University of Chicago and the Chicago-based Argonne National Laboratory have launched collaboration—the Institute for Molecular Engineering—intended to redefine the engineering discipline. The Institute is building a new engineering program "across the boundaries of two very large institutions," which "transcends disciplinary boundaries from the outset." The new institute will treat various engineering fields—electrical, mechanical, chemical—at the most basic (e.g. molecular) level. The program will bypass traditional departmental structures and draw on multiple competencies, including the synthesis of new materials, synthetic biology and biological engineering, computational modeling, molecular-scale imagining, and micro-mechanics. Many of the faculty members will also have appointments at the Argonne National Laboratory. Incentives will be provided to encourage collaborations with industry.[8]

and the government has actively fostered key sectors, but the idea of industrial policy remains controversial, reflecting a widespread aversion to government planning, free market beliefs, and a reluctance to "pick winners and losers" in industry or between states and regions.[9] Federal promotion of innovation in industry has been carried forward under the guise of assistance to small business and through mission-related programs by federal departments that support research and often directly impact actors in the commercial arena.[10] Federal regional economic development policies have "evolved in a wildly ad hoc,

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[8]Matthew Tirrell, "Building an Institute for Engineering Innovation at the University of Chicago and Argonne National Laboratory," in National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2013. The Argonne National Laboratory is also partnering with the University of Kentucky in the Kentucky-Argonne Battery Manufacturing Research and Development Center, where R&D is being undertaken with respect to the fabrication of state-of-the-art lithium-ion cells and new cell chemistries. The Center plans to develop manufacturing lines for batteries. A spokesman for the project said that his goal is "to re-establish the United States as a world leader, not only in materials and development but in manufacturing technology and capability [in batteries]." The project has received $10 million in funding from NIST and $4 million from the state of Kentucky to fund construction of a 36,000-square foot laboratory for advanced batteries. Ralph Brodd, "The Kentucky-Argonne Battery Manufacturing R&D Center," National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2012.

[9]See generally: Otis, Graham, Jr., Losing *Time: The Industrial Policy Debate,* Cambridge Ma: Harvard University Press, 1992.

[10]Wendy H. Schacht, "Industrial Competitiveness and Technological Advancement: Debate Over Government Policy", CRS Report to Congress, March 13, 2012, pp. 41-43.

idiosyncratic and uncoordinated fashion."[11] Ginger Lew of the National Economic Council recalled in 2011 that she had met with a group of community leaders from the Pacific Northwest who were pursuing federal energy grant money:

> *They showed a mind-boggling diagram of 23 program offices they had to apply to, coordinate with and manage. They talked about how there were in the second year of this particular journey to get access to federal dollars, all related to this particular topic and this same issue.*[12]

In 1993, in a departure from the traditional federal approach, the Clinton Administration called for a national commitment to technology development in the context of a broader national economic strategy emphasizing the development of new products, industrial processes and services by the U.S. private sector.[13] The Presidency of George W. Bush diverged from this approach, favoring more traditional promotional tools such as federal support for basic research and tax incentives. Federal support for private sector technological development was curtailed.[14] In early 2009, President Obama declared an intention to double the budget of the most important science agencies, as identified by former President Bush, over a 10-year period. The Obama stimulus package enacted in 2009 allocated an additional $7.6 billion to scientific research, and additional funds to directly support green technologies such as renewable power generation, bio-fuels, green buildings, and electric vehicles.[15] The government provided financial support to promising companies across a spectrum of technologies, without perhaps sufficient attention to the growth of demand for their products.[16] At the same time, the government actively intervened to support the banking sector and recapitalized the automobile industry.

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[11]Karen G, Mills, Elisabeth B Reynolds and Andrew Reamer, *Clusters and Competitiveness: A New Federal Role for Stimulating Regional Economies,* Washington, DC: Brookings Institution, April 2008, p. 24.
[12]Presentation of Ginger Lew, "Regional Innovation Clusters," National Research Council, *Clustering for 21st Century Prosperity*, op. cit.
[13]William J Clinton, and Albert Gore Jr, *Technology for America's Economic Growth, A New Direction to Build Economic Strength,* February 22, 1993.
[14]Wendy H. Schacht, "Industrial Competitiveness and Technological Advancement: Debate Over Government Policy", CRS Report to Congress, March 13, 2012, p. 4.
[15]The American Recovery and Reinvestment Act of 2009 is commonly referred to as the "stimulus" or the "stimulus package. See <*http://www.recovery.gov/About/Pages/The_Act.aspx*>.
[16]National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles, Progress, Challenges, and Opportunities*, op. cit.

The National Science Foundation (NSF)

NSF is a government agency that supports basic research and education in non-medical fields of science and engineering. It is a funding agency without its own laboratory network—"all of the [federal] money that comes in, goes out—primarily to universities—to support basic research in science and engineering, as well as educational activities."[17] Its annual budget is $7.5 billion. While its emphasis is on basic research, it supports teams of university-industry researchers who explore potential applications and funds numerous translational research programs, which affect state and local economic development. Leading NSF initiatives include:

Industry- University Cooperative Research Centers (I/UCRCs)

These centers are located at or near universities with strong research capabilities in engineering and information technology, and engage companies such as Corning, Kyocera, BASF, Ceradyne, and Kennametal.

Engineering Research Centers (ERCs)

These centers involve thematic industry-university R&D in a broad range of fields, including bioengineering, earthquake engineering, advanced manufacturing technologies, and power electronic systems.[18]

Materials Research Science and Engineering Centers (MRSECs)

These centers support research of a scope and complexity that would not be feasible under traditional funding of individual research projects. According to NSF, "MRSECs are university-based, and undertake an interactive, interdisciplinary approach to materials research and education while fostering active cooperation among university-based researchers and those concerned with the application of materials research in industry and elsewhere."[19]

The Science and Technology Centers (STCs)

"STCs conduct world-class research through partnerships among academic institutions, national laboratories, industrial organizations, and/or other public/private entities, and via international collaborations, as appropriate. They provide a means to undertake significant investigations at the interfaces of disciplines and/or fresh approaches within disciplines."[20]

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[17]NSF doesn't directly run any laboratories, but it funds a number of central facilities (NCAR, LIGO, etc.) through contractors.

[18]Thomas Peterson, "The NSF Role in the Innovation System", in National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2013.

[19]Access at <*http://www.mrsec.org/mrsec-program-overview*>.

[20]Access at <*http://www.nsf.gov/od/oia/programs/stc/*>.

The National Institutes of Health (NIH)

The National Institutes of Health, which is part of the U.S. Department of Health and Human Services, is by far the most important federal entity supporting research and development in the life sciences. NIH conducts research in its own substantial laboratories, but most of its funds are allocated through its Extramural Research Program in the form of roughly 50,000 competitive grants to over 300,000 researchers at Universities, medical schools and research organizations in the U.S. and other countries. NIH also awards grants to small businesses through the Small Business Innovation Research (SBIR) program.[21]

NIH grants have a very substantial impact on local economies. Organizations in California alone received $3.33 billion in biomedical-related financing from NIH in 2011.[22] In 2012 NIH awarded $392 million in grants in the state of Florida to 52 public and private organizations. NIH support has helped to foster Medical City, a partnership involving the University of Florida, the Sanford-Burnham Medial Institute and other organizations in a research collaboration at Lake Nona, Florida.[23] Sanford-Burnham has received $52 million from NIH since starting operations at Lake Nona in 2009. Medical City has become a "magnet for scientists and research groups and clinics across the region," enabling Medical City to become a "leading biosciences cluster in Florida."[24]

The National Institute of Standards and Technology (NIST)

Founded in 1901, the National Institute of Science and Technology (NIST), now a part of the Department of Commerce, is a non-regulatory federal agency tasked with promoting U.S. industrial competitiveness through measurement science, standards, and technology. In the words of NIST Director, Pat Gallagher, NIST has become "industry's national laboratory. With the decline of the corporate laboratories created over a century ago, NIST now performs many of those functions." NIST is currently organized into six mission-oriented operating units—national user facilities, the center for nanoscale science, the center for neutron research, and technology laboratories

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[21]National Research Council, *Venture Funding and the NIH SBIR Program,* C. Wessner, ed. Washington, D.C.: The National Academies Press, 2009.
[22]"California Biomedical Industry Still the Biggest, Despite Tight Financing, Report Says," *Alameda Times-Star* January 8, 2013.
[23]Access at <*http://learnlakenona.com/medical-city/*>.
[24]"Growth of Bioscience Research Depends on Continued Funding," *The Orlando Sentinel* March 5, 2013.

for engineering, information technology, and measurement sciences.[25] NIST offers a number of programs promoting innovation:

Manufacturing Extension Partnership (MEP)

MEP is a program to support small and medium-sized U.S. manufacturers through a network of manufacturing extension centers located in all 50 states and Puerto Rico. In all the MEP program has approximately 60 centers with about 370 field location and total of about 1,400 non-federal staff. The MEP centers are operated by independent organizations rather than MEP itself, and are co-funded at an annual level of about $300 million with one-third supplied by the federal government and the remainder by state and industry sources. The MEP centers provide services and expertise to small and medium sized enterprises (SME) to improve manufacturing processes, supply chain positioning, exploitation of new technologies, application of information and techniques, and manpower training. MEP is best known for promoting "lean manufacturing" and efficiency, but is currently implementing programs to promote new products and innovative processes.[26]

The Technology Innovation Program (TIP)

NIST's Technology Innovation Program (TIP) was derived from, but not identical to the Advanced Technology Program, which ended in 2007.[27]. Its mission was to support research and innovation in areas of critical national need. TIP grants, typically $3 to $5 million, supported precompetitive technology development by small and medium companies, with a focus on manufacturing technology. Thematic areas of critical national need included civil infrastructure, energy, healthcare, water, sustainability, complex systems and networks, and manufacturing (advanced robotics and intelligent automation).[28] The program never gained broad support in the Congress and was effectively ended in 2011.

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[25]Phillip Singerman, "Reviving Manufacturing: The Role of NIST," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2013.

[26]For a review of the program, see National Research Council, *Strengthening American Manufacturing: The Role of the Manufacturing Extension Partnership*, C. Wessner and P. Shapira, eds., Washington, DC: The National Academies Press, forthcoming.

[27]The Advanced Technology Program (ATP) was designed to foster early-stage technology development by companies that might otherwise not be funded. Kristina Johnson, the U.S. Undersecretary of Energy, was previously a co-founder of ColorLink, a company formed in 1995 and sold in 2007. She indicated that the only reason ColorLink survived for 12 years was that it received a $2 million, three-year grant from ATP to develop the process to make 3-D glasses worn in movie theaters. "Without that staying power, we would have died in the Valley of Death." Kristina Johnson, "Building a Clean Energy Economy through Accelerated Innovation," NRC, *Clustering for 21st Century Prosperity: Summary of a Symposium*, op. cit.

[28]For a review of the Advanced Technology Program, see National Research Council, *The Advanced Technology Program: Assessing Outcomes,* C., Wessner, ed., Washington, DC: National Academy Press, 2001.

Nanotechnology Research Initiative

The Nanotechnology Research Initiative, launched in 2007, involves research to identify successor technologies to CMOS, currently the dominant semiconductor technology. This effort involves 35 universities and four research centers around the United States. A NIST spokesman indicated in 2012 that his agency was contributing $2.75 million annually to finance the university-based research at each center, industry partners were contributing $5 million, and states $15 million to grants and tax incentives. Total funding was estimated to exceed $200 million.[29]

The Small Business Innovation Research Program

In 1982, Congress enacted the Small Business Innovation Development Act, creating the Small Business Innovation Research Program (SBIR), which requires government agencies that dispose of large research budgets, such as the Departments of Defense and Energy and the National Institutes of Health to utilize 2.5 percent of their extramural research budgets as grants or research contracts to small businesses.[30] SBIR Phase I awards of $150,000 can be augmented, where appropriate, by Phase II awards of up to $1 million. Phase III (commercialization) must be funded by private, state or other non-federal sources. Participating agencies periodically release Phase I solicitations, setting forth research themes that will be considered for grants. Small businesses are eligible to compete. A number of federal agencies operate "match" programs pursuant to which successful SBIR grantees are introduced to companies, venture capital funds, and other potential supporters.[31]

SBIR awards are valuable to recipient companies as a means of securing early stage funding for innovations, but entail other advantages as well. Many states have implemented programs that augment the federal grants with additional state funds.[32] A number of states have also introduced Phase Zero

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[29]Marc G Stanley, Acting Deputy Director, NIST, "Enhancing Competitiveness and Speeding Innovation: Design and Initial Results of the NIST Rapid Innovation and Competitiveness Initiative," NRC, *Clustering for 21st Century Prosperity: Summary of a Symposium*, op. cit. A second phase in this project was launched. "Nanoelectronics Boosted by NIST and SRC," *EE Times* May 8, 2013.

[30]The National Research Council, in its recent assessment of the SBIR program found it "sound in concept and effective in practice" and documents support for a variety of technologies that have addressed national missions and advanced U.S. competitiveness. See National Research Council, *An Assessment of the SBIR Program*," C. Wessner, ed., Washington, DC: The National Academies Press, 2008. At the same time, it called for a number of operational improvements to the program, including the need to shorten processing times. The NRC is currently reviewing the operations, challenges, and achievements of the SBIR program.

[31]"A Grant Program for Small Business," *Seattle Post-Intelligencer* November 9, 2007.

[32]Robert McMahon, "The Role of SBIR and State Awards" in National Research Council, *Understanding Research, Science, and Technology Parks: Global Best Practices—Summary of a Symposium,* C. Wessner, Editor, Washington, DC: The National Academies Press, pp. 116-117; "State Offers Research, Technology Grants to Businesses," *The Pilot* December 9, 2005. States

Box 5-3
Leveraging SBIR: The Role of State Phase Zero Programs

Phase Zero programs are explicitly designed to help state-based companies apply for and win Federal SBIR/STTR funding. They range in scale and scope, and there does not appear to have been a completed comparative assessment of either their operations or their impact. Approximately 21 states currently operate "Phase Zero" programs.[33]

Most programs are operated either directly or in partnership with state economic development agencies. However, they are often housed at a university. In some cases, a consulting group has been hired to run the program, but in most cases it is run out of a university tech transfer office or similar.

The core of most programs is a mini-grant designed to support potential Phase I applicants. Typically ranging from $3-5,000 the funding pays for a number of potentially useful supports, such as:

- Grant writing
- Professional application review
- Market studies
- Travel, especially to connect with Federal SBIR-granting agencies
- Other consulting costs, such as lawyers

A few states fund technology development and in particular testing to generate results showing the worth of future Federal funding. A few states have "00 Programs," aimed at supporting Phase II applications. Most programs have limitations on the uses and conditions of funding. These can include

- A requirement that the funding result in a valid SBIR/STTR application
- Exclusions for some expenses—several states will not pay company salaries

Some programs require a cash or in kind match from the company, usually 1:1.

SBIR funded research must usually be largely or completely executed in the state providing the Phase Zero funding.

Phase 0 programs are entirely state funded and have no direct connection to Federal programs (with the minor exception that in a few instances that funding

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matching SBIR awards include Texas, Kentucky, Connecticut, North Carolina, Montana and Michigan.

[33]Phase Zero programs have sometimes been cut in the face of budget problems at the state level, so the number in operation at a given time fluctuates somewhat. At least 20 have been in continuous operation.

from the Federal and State Technology Partnership (FAST)[34] is sometimes used by states to partly support Phase 0 programs).[35]

programs designed to help state-based companies apply for SBIR funding. (See Box 5-3)In addition, venture capital funds and other potential backers tend to view an SBIR award as a "technology validation."[36] SBIR awards allow proof of principle and prototype, which can considerably enhance the value of firms' intellectual property. Moreover, SBIR awards do not require grantees to surrender intellectual property, no royalties are paid, and they can obtain funding "without giving away the baby."[37]

The Economic Development Administration

The Economic Development Administration is an agency in the Department of Commerce with a mandate to provide assistance to economically distressed regions to stimulate economic growth, innovation and competitiveness, and to preserve and create jobs. The EDA differentiates its "bottom up" programs from other federal economic development programs in that its grants are not formulaic but can "fund a range of customized investments developed specifically to meet the strategic priorities of applicant communities."[38] The EDA offers a wide range of regional assistance. Every three years it awards grants to "University Centers" to support student mentoring with local industries and work force training.[39] It is currently funding university-based manufacturing programs, such as the Center for Energy and Advanced Manufacturing at South Carolina's Aiken Technical College.[40] Its current national strategic priorities are advanced manufacturing, information technology (broadband, smart grid) infrastructure, assistance to areas affected by

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[34]FAST provides about $2 million in funding annually (typically up to $100,000 per applicant) for outreach and technical assistance to science and technology driven small businesses, with particular emphasis on helping socially and economically disadvantaged firms compete for SBIR awards.

[35]A handful of programs—such as the Florida program and the Phase Zero operated by the Leonard Wood Institute in Missouri—appear to have funding from Federal agencies such as DoD or other business-based sources.

[36]Joshua Lerner, "Evaluating the Small Business Innovation Research Program: A Literature Review," in National Research Council, *SBIR: An Assessment of the DOD Fast Track Initiative*, C. Wessner, ed., Washington, DC: National Academy Press, 2000.

[37]*The Deseret News,* "A Champion Sought to Help Secure Federal Tech Grants," August 21, 2004.

[38]"For example, some communities identify strategy development as their top priority. In other cases, communities already have a well-defined strategy and now need implementation support. This flexibility enables EDA to target its competitive grants funding to support the development of robust regional innovation ecosystems based on the specific priorities of each community." EDA, *Congressional Budget Report* (FY 2012).

[39]"Economic Development Administration Selects SOSU as a University Center," *Durant Daily Democrat* November 25, 2007.

[40]"U.S. Economic Development Administration," *The State,* May 31, 2012.

TABLE 5-1 State Phase Zero Programs as of March 2013

State	Agency	Per Project Funding Max
Alaska	TREND/U. Alaska Anchorage	5,000
Delaware	Delaware ESPCOR	10,000
Florida	Enterprise Florida	3,000
Hawaii	Innovate Hawaii	3,000
Idaho	Department. Of Commerce	n/a
Kentucky	Kentucky Science and Engineering Foundation	4,000
Maine	Maine Technology Institute	5,000
Mississippi	MS-FAST	3,000
Missouri	U. Missouri	5,000
Missouri	Leonard Wood Institute	2,500-75,000
Nebraska	Nebraska Business Development Center/U. Nebraska	2,500
New York	Directed Energy	2,000
North Dakota	Center for Innovation/U. N. Dakota	1,500
Ohio	U. Toledo	8,000
Oregon	Business Oregon (State of Oregon)	4,000
Puerto Rico	Center for Innovation and Technology	n/a
South Carolina	U. South Carolina	6,000
Tennessee	Launch TN	n/a
Vermont	U. Vermont	15,000
Washington	Innovate Washington	n/a
Wyoming	U. Wyoming	5,000

SOURCE: Web research, March 2013.

automotive restructuring, urban water, natural disasters (mitigation and resiliency), access to capital for SMEs, ethnically diverse enterprises, and health care.[41]

The EDA's i6 program involves multi-agency grants to state and local government and non-profits to support commercialization of new technologies through the establishment of proof of concept centers and supporting networks

[41]EDA Website. <*http://www.eda.gov/investmentpriorities.htm*>.

Box 5-4
Proof of Concept Centers

In March 2011, President Obama announced that $12 million would be awarded to create or expand Proof of Concept Centers (PoCCs) to promote commercialization of green technologies, the "i6 Green Challenge."[42] PoCCs address the phase of innovation "between invention and product development, when commercial concepts are created and verified, appropriate markets are identified, and protectable Intellectual Property (IP) may have to be developed," a phase in which funding is often difficult to obtain.[43] Typical university-based PoCCs provide seed funding, incubator space, market research, and business advisory support, and the universities' technology transfer offices assist with networking, IP issues, and securing external funding. A 2013 survey identified 36 university-based PoCCs operating in the U.S. and concluded, based on limited data available, that "the number of new university start-ups increased in the years after the founding of the PoCCs." Many PoCCs receive financial support from state governments and/or foundations.[44]

of experts, facilitating start-ups, job creation, and economic growth in distressed regions. Federal grants are provided on a 50-50 matching basis.[45] An example of projects receiving i6 funding is the Global Center for Medical Innovation (GCMI) which opened in Atlanta near Georgia Tech in 2012. GCMI, the Southeast's first comprehensive medical device innovation center, involves collaboration between universities, research centers, clinicians, established device and drug companies, and investors and startups. The Center features a prototyping design and development facility to accelerate commercialization, clean room facilities, and other equipment. It provides a broad array of services

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[42]Presentation by Sridhar Kota, White House Office of Science and Technology Policy, in National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit. Federal agencies partnering in this effort include the U.S. Patent and Trademark Office, DoE, NSF, EPA, the Economic Development Administration, and the Department of Agriculture. Recipient organizations are the Iowa Innovation i6 Green Project in Ames; the Louisiana Tech Proof of Concept Center in Ruston; the Washington State Clean Energy Partnership Project; the iGreen New England Partnership; the Ignite Innovation (12) Cleantech Acceleration Network in Orlando, Florida; and the Proof of Concept Center for Green Chemistry Scale-up in Holland, Michigan. Samantha Bradley, Christopher Hayter, and Albert Link, "Proof of Concept Centers in the United States: An Exploratory Look," University of North Carolina at Greensboro Working Paper 13-4, March 2013, pp. 2-3.
[43]Catarina Maia and Joao Claro (forthcoming) "The Role of a Proof of Concept Center in a University Ecosystem: An Exploratory Study," *Journal of Technology Transfer*, cited in Bradley, et.al., "Proof of Concept Centers," op. cit., 2013, p. 4.
[44]Bradley, et. al. "Proof of Concept Centers," op. cit., 2013, p. 2, Table 2.
[45]Economic Development Administration, "i6 Challenge: Office of Innovation and Entrepreneurship," <*http://www.eda.gov/challenges/i6/*>.

to medical device innovators, including design, engineering, product development, prototyping and small-scale manufacturing, preclinical testing, clinical trials, market research, and regulatory and quality assurance.[46] The Center is providing seed funding to promising start-ups in the form of convertible notes.[47]

The Defense Advanced Research Projects Agency (DARPA)

DARPA is an agency within the Department of Defense which develops new technologies for use by the U.S. military, but which often also have commercial applications. It conducts research projects through contracts with companies, consortia, and universities. It has a long track record of fostering transformative technologies in computing, telecommunication microelectronics, the Internet and aerospace.

> *DARPA…adopts a model that emphasizes intense short-term forays into uncharted territory beyond the recognized scientific frontier. DARPA's combinations are revolutionary, either disciplinary or interdisciplinary, and project-based. These projects often fail, but when they succeed they can produce spectacular results.*[48]

The Office of Naval Research (ONR)

Established in 1946, the Office of Naval Research characterized itself as the "Navy-Marine Corps bank for funding research." Its budget of $2.25 billion is roughly divided between basic research (45 percent), naval prototypes (12 percent), future naval capabilities (12 percent), and quick reaction science and technology. Roughly two-thirds of its basic research funding is allocated to university-based R&D; with respect to applied research, 65 percent goes to companies, 30 percent to naval laboratories, and 23 percent to universities.[49]

THE FEDERAL ROLE IN REGIONAL DEVELOPMENT AND MANUFACTURING

While many federal policies and programs have indirectly helped foster the evolution of innovation clusters, until recently the federal government has not explicitly sought to promote the development of specific industries in particular regions. In recent years a number of policy organizations have begun

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[46]*<http://www.devices.net>*.

[47]"GCMI Provides Support to Two Medical Device Companies," *Market Wired* March 29, 2012.

[48]President's Council of Advisors on Science and Technology, *Transformation and Opportunity: The Future of the U.S. Research Enterprise,* November 2012, p. 69.

[49]Chris Fall, "The Office of Naval Research: A Unique Innovation Organization", In National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium*, op. cit.

to urge the federal government to make innovation clusters a fundamental aspect of its economic development policies.[50]

During the 2008 presidential campaign, President Obama indicated that he wanted to provide $200 million in grants to improve local infrastructure including the funding of "research parks." In 2010, the Obama administration formed the Taskforce for Advancing Regional Innovation Clusters, involving collaboration between agencies such as the Defense Department, the Economic Development Administration, the Department of Energy, and the Small Business Administration.[51] The America COMPETES Reauthorization Act of 2010 directs the Secretary of Commerce to establish a regional innovation program to encourage regional innovation strategies, "including regional innovation clusters, science and research parks." A number of specific cluster-promoting initiatives have been launched. The Obama administration initiatives in the area include:

Small Business Administration

In 2010, SBA initiated two regional innovation cluster funding programs. The first provides existing clusters with funding for business training, commercialization and transfer services, and other services to support small businesses. The second focuses on clusters specializing in defense-related technologies to provide training, matchmaking, and business advice.[52]

DOE Energy Hubs

The Department of energy has established regional innovation clusters ("energy-innovation hubs") in thematic areas such as batteries, solar power, nuclear energy, and energy-efficient buildings.[53] The purpose of the hubs is to serve as a magnet for other programs and initiatives, including start-up businesses. A DOE spokesperson commented in 2010 that "we are talking about job application here. In addition to investing in what it takes to build one job, we are investing in people who can create multiple jobs."[54] In 2010, DOE announced that in conjunction with the SBA, the National Institute of Standards and Technology and the EDA, it would award a grant of $129 million to a

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[50]Center for American Progress, "The Geography of Innovation: The Federal government and the Growth of Innovation Clusters, 2009; Bruce Katz and Mark Muro "The New 'Cluster Movement': How Regional Innovation Clusters Can Foster the New Economy," The Brookings Institution, September 21, 2010.
[51]*Tampa Bay Times,* "Cluster Spending Exceeds Obama's Goal," April 27, 2012.
[52]Karen Mills "Building Regional Innovation Clusters", in National Research Council, "Clustering for 21st Century Prosperity," 2012, op. cit.
[53]Kristina M. Johnson, "Building a Clean Energy Economy Through Accelerated Innovation," in National Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium*, op. cit.
[54]Ibid.

project team based at Penn State University to create the Greater Philadelphia Innovation Cluster for Energy Efficient Buildings.[55]

EDA Cluster Activities

The America Competes Act of 2007 (reauthorized in 2010) established a key role for the Economic Development Administration in supporting and funding regional clusters. [56] The EDA plays a key role in supporting the implementation of regional innovation clusters programs, providing planning support and grants to regional innovation initiatives.[57] The EDA received $50 million in 2010 to fund the creation of regional innovation clusters in the United States.[58] It is undertaking a "cluster mapping" initiative in conjunction with Harvard's Michael Porter to enhance understanding of how the cluster model can best be utilized, forming linkages with other clusters in the U.S. and abroad.[59] In 2011, the EDA launched the "Jobs and Innovation Accelerator Challenge" to foster innovation and job creation through public-private partnerships in at least 20 U.S. regions.[60]

In February 2013, Brookings scholar Mark Muro, whose previous work on innovation clusters has criticized the relative lack of federal involvement, commented on these new programs and drew the "inescapable conclusion:"

> *Proliferating under the radar, the Obama administration's "small bore" regional initiatives in economic development are beginning to add up to something meaningful. As of now some 74 cluster initiatives and region-focused innovation efforts are underway, helping to catalyze more linked effort and creative economic development in the nation's regional centers of innovation. Through these initiatives some $250 million is being used to raise matching money and catalyze*

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[55]"Penn State to Lead Energy Innovation Hub at Navy Yard," *The Philadelphia Inquirer* August 25, 2010.
[56]Presentation by Barry Johnson, EDA, "Infrastructure for the 21st Century Economy: the Role of EDA," National Research Council, *Building Hawaii's Innovation Economy: Summary of a Symposium,* op. cit.
[57]John Fernandez, "Regional Innovation Strategies Initiative," in National Research Council, *Clustering for 21st Century Prosperity: Summary of a Symposium*, op. cit.
[58]*Tampa Bay Times,* "Cluster Spending Exceeds Obama's Goal," April 27, 2012.
[59]Presentation by Barry Johnson, EDA, "Infrastructure for the 21st Century Economy: the Role of EDA," National Research Council, "Building Hawaii's Innovation Economy: Summary of a Symposium," January 13-14, 2011.
[60]The program features funding by EDA, the Department of Labor, and the Small Business Administration for technical assistance and workforce development. Applicants for funds are required to provide evidence of a high-growth cluster, the cluster's needs and opportunities, proposed project concept and scope of work, projected impact and measurable outcomes (including business formation, commercialization of federal and private research, and development of a skilled workforce). Economic Modeling Specialists International, "EDA's Jobs and Innovation Accelerator Challenge and EMSI" May 3, 2011.

regional efforts to strengthen the nation's regional innovation ecosystems.[61]

Recent Federal Manufacturing Initiatives

In 2011, the President's Council of Advisors on Science and Technology (PCAST) issued a report documenting the decline in the U.S. competitive position in manufacturing and warning that "the United States is lagging behind in innovation in its manufacturing sector relative to high-wage nations such as Germany and Japan, and has relinquished leadership in high-tech industries that employ highly-skilled workers."[62] In response, in December 2011, the President created the cabinet, level White House Office of Manufacturing Policy to coordinate manufacturing initiatives across the federal government.[63] In June 2011, the President launched the Advanced Manufacturing Partnership (AMP) to bring together industry, university, and government actors to coordinate investments in advanced manufacturing.[64] The National Digital Engineering and Manufacturing Consortium (NDEMC) convenes manufacturers, federal agencies and research organizations, and research universities to make modeling and simulation tools and skills available to SMEs.[65]

In March 2012, the Administration announced plans to create 15 research institutes around the country to help rebuild the nation's manufacturing base, the National Network for Manufacturing Innovation (NNMI). The centers will feature a collaboration between companies, universities, and state, local and federal government agencies. The first center, the National Additive Manufacturing Institute, was established in August 2012 and will be located in Youngstown, Ohio.[66]

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[61]Mark Muro, "Regional Innovation Clusters Begin to Add Up," The Brookings Institution, February 27, 2013.

[62]PCAST, *Report to the President on Ensuring American Leadership in Advanced Manufacturing*, June 2011, p. i.

[63]"Obama Establishes Office of Manufacturing Policy," *Milwaukee Journal Sentinel* December 12, 2011.

[64]The AMP National Program Office (NPO) at the National Institute of Standards and Technology (NIST) supports the work of AMP partners, coordinate manufacturing programs between agencies, and provide links to public-private partnerships in manufacturing and to other manufacturing organizations. The President indicated at the outset of the program that it was intended to leverage existing programs and initiatives and would entail investments of over $500 million. "President Obama Launches Advanced Manufacturing Partnership," White House press release, June 24, 2011.

[65]NDEMC industry partners include DE, Deere & Company, Lockheed Martin, and Proctor & Gamble. NDEMC provides modeling, simulation and analytics education and training, access to high performance computing, and access to software as a service. <*http://ndemc.org/wp-content/uploads/2012/11/NDEMC1.pdf*>.

[66]"The Next Era of U.S. Manufacturing is Here," *Midland Daily News* (January 31, 2013).

THE IMPACT OF FEDERAL PATENTS AND ANTITRUST POLICY

The U.S. Constitution provides in Article I, Section 8 that Congress shall have the authority "to promote the Progress of science and useful Arts by securing for limited times to Authors and inventors the exclusive Right to their respective Writings and Discoveries." The U.S. patent system enjoyed widespread political support for over a century thereafter including the strong backing of Abraham Lincoln, who had personally secured a patent for an invention of his own and who had litigated patent cases as an Illinois attorney. Later in the Nineteenth Century, the public admired inventor-heroes like Thomas Edison and Alexander Graham Bell, and court decisions upheld Bell's telephone monopoly and a cartel based on Edison's electric lamp patents.[67] In 1890, however, Congress enacted the Sherman Antitrust Act, which prohibited price-fixing, monopolization and attempts at monopolization, and other contracts, combinations, and "conspiracies" in restraint of trade. No other country in the world enacted comparable legislation until after World War II, and the great economic historian Alfred Chandler has observed that the Sherman Act

> *and the values that it represented probably marked the most important noneconomic cultural difference between the United States and Germany, Britain, and indeed the rest of the world insofar as it affected the long-term evolution of the modern industrial enterprise.*[68]

The Sherman Act made industries' attempts to achieve market power through cartels or "trusts" subject to criminal and civil liability, triggering a wave of horizontal mergers in the decade after 1895 in an attempt by various industry sectors to maintain market power, e.g. the ability to control prices and limit competition.[69] But another consequence of antitrust vulnerability was a new emphasis on industrial research and the use of patents to secure legal monopolies that provided the basis for the exercise of market power with lesser antitrust implications.[70] In effect industrial innovation became the only legal avenue to monopoly rents for U.S. manufacturers.

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[67]F.M. Scherer, "The Political Economy of Patent Policy Reform in the United States", *Journal on Telecommunications and High Technology Law* 7:169, 2008, citing U.S. v. General Electric Co. 1926. 272 U.S. 476.
[68]Alfred D. Chandler, *Scale and Scope: The Dynamics of Industrial Capitalism,* Cambridge, MA and London: Belknap Press of Harvard University, 1999, pp. 72-73.
[69]Martin J. Sklar, *The Corporate Reconstruction of American Capitalism, 1890-1916,* Cambridge: Cambridge University Press, 1988, pp. 158-166.
[70]A 1911 consent decree settling a federal antitrust action against General Electric allowed GE to retain its patent licensing regime unmodified, "enabling the firm to maintain an effective cartel within the U.S. electric lamp market for years to come…during the interwar period, DuPont and General Electric both utilized patent licensing agreements as a basis for international cartel agreements. David C. Mowery, and Nathan Rosenberg, "The U.S. National Innovation System" in

During the early decades of the Twentieth Century, the acquisition of large patent portfolios by big businesses such as GE, DuPont, Eastman Kodak, and AT&T was viewed with growing suspicion and concern by the public and many political leaders who saw small enterprises, not big ones as the real source of innovation.[71] This attitude was reflected in the attitude of courts, the antitrust agencies, and the antitrust bar throughout much of the Twentieth Century.[72] Between 1930 and the mid 1970s—the so-called "anti-patent era"—antitrust concerns commonly overrode patent rights in the courts, and numerous measures and judicial opinions had the effect of weakening patent rights.[73] One Supreme Court Justice commented critically in 1949 that "the only patent that is valid is one that this Court has not been able to get its hands on."[74] The anti-patent stance of federal antitrust enforcers was reflected in the so-called "Nine No-Nos" declared by then Deputy Assistant Attorney General Bruce Wilson beginning in 1970, setting forth fee arrangements and terms that could not legally be incorporated in technology licensing agreements.[75]

The anti-patent bias of U.S. antitrust policy during the mid-Twentieth Century was criticized by contemporary observers, but it was not until the advent of stagflation in the 1970s that a fundamental reappraisal of the legal foundations of the U.S. economic system took place.[76] Legal and economic scholars, including Richard Posner, Robert Bork, and economists at the University of Chicago, subjected U.S. antitrust policy to withering criticism, emphasizing, among other things, the inhibitions that antitrust as then interpreted placed on innovation.[77] Chicago School economists urged a

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Richard R. Nelson, ed. *National Innovation Systems: A Comparative Analysis,* Oxford: Oxford University Press, 1993, p. 65n.

[71]President Woodrow Wilson, expressing a common public perspective, commented that "monopoly always checks development" and that the rise of large firms with monopoly power threatened to inhibit the traditional American genius that fostered inventions. "[T]he instinct of monopoly is against novelty, the tendency of monopoly is to keep in use the old thing, made in the old way… [W]ho can say what patents now lying, unrealized, in secret drawers and pigeonholes, will come to light, or what new inventions will astonish and bless us, when freedom is restored?" Richard Hofstadter. "What Happened to the Antitrust Movement?" in *The Paranoid Style in American Politics and Other Essays,* New York: Vintage Books Houghton-Mifflin, 2006, pp. 265-266.

[72]Antitrust Modernization Committee, *Report Recommendation,* 2007, p. 36n.

[73]Anthony Williams, "Governing Innovation Commons: Private Ordering of Intellectual Property Rights." March 2005, p. 5.

[74]Jurgerson v. Ostley & Barton Co. 1949. 335 U.S. 560, 572. Jackson, J, dissenting.

[75]H. Hewitt Pate, "Competition and Intellectual Property in the U.S.: Licensing Freedom and the Limits of Antitrust," Address at the 2005 EU Competition Workshop.

[76]In 1952, economist John Kenneth Galbraith commented that "the showpieces of American industrial progress [were] dominated by a handful of large firms" and that "the foreign visitor, brought to the United States by the Economic Cooperation Administration, visits the same firms as do the attorneys of the Department of Justice in their search for monopoly. Richard Hofstadter. "What Happened to the Antitrust Movement?" in *The Paranoid Style in American Politics and Other Essays,* New York: Vintage Books Houghton-Mifflin.

[77]Robert Bork characterized the emphasis of contemporary antitrust doctrine on deconcentration of economic power and protection of small business as superficially attractive, but basically an expression of social and political attitudes comprised of a "jumble of half-digested notions and

reappraisal of the U.S. patent system in response to "industrial stagnation and a lack of significant technological innovations."[78] An advisory committee established by President Carter to study U.S. innovation policy concluded that "diminished patent incentive" played a role in U.S. economic stagnation.[79]

Important court decisions and administrative actions reflected these changing attitudes. Two Supreme Court decisions, Diamond v Diehr and Diamond v. Chakrabarty, expanded the scope of patentable subjects, with the court declaring in Diehr in which it held that computer programs were patentable, and it Chakrabarty that patentable objects matter included "anything under the sun that is made by man."[80] In 1981, the Department of Justice renounced the Nine No-Nos on IP licensing, and outlined how economic analysis could result in a finding of pro-competitive effects arising out of certain licensing practices previously regarded as problematic.[81] In 1982, Congress created the Court of Appeals for the Federal Circuit (CAFC) giving the new court exclusive jurisdiction over all appeals of decisions of the federal district courts involving patents, an institutional watershed that has led to upholding of the validity of patents on a far more regular basis than was the case during the "anti-patent" era.[82]

Changes in federal antitrust/patent policy in the early 1980s dramatically broadened the rights of innovators to exploit their inventions on an exclusive (e.g. monopoly) basis, arguably driving the surge in U.S. high technology business in the generation that followed.[83] Spokesmen for the U.S. biotechnology industry "generally credited the [Supreme] Court decision in *Chakrabarty* as the beginning of their industry without which genetic engineering would not have made nearly as much progress."[84] A spokesman for

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mythologies" rather than rational economic analysis. Robert Bork, *The Antitrust Paradox: A Policy War with Itself,* Free Press, 1993, p. 54.

[78]Federal Trade Commission, *To Promote Innovation: The Proper Balance of Competition and Patent Law and Policy,* October 2003.

[79]Advisory Committee on Industrial Innovation. *Report on Patent Policy ISS*, 1979.

[80]Diamond v. Diehr. 450 U.S. 175, 182. In Diamond v. Chakrabarty, the Court ruled that human-developed microorganisms ere patentable subject matter and cautioned that courts "should not read into the patent laws limitations and conditions which the legislature has not expressed". 44 U.S. 303.

[81]Abbott B. Lipsky, "Current Antitrust Division Views on Patent Licensing Promotions," *Antitrust Law Journal* 1981-1982, 50:515.

[82]Prior to the creation of the CAFC, courts rejected roughly two-thirds of patents considered that they lacked sufficient novelty or utility, the CAFC upheld roughly two-thirds. "The Federal Circuits new rulings on balance strengthened patent protection, made it more likely that companies found to be infringing patents would pay substantial damages, and hence raised the perceived benefits to companies (and universities) from building strong patent portfolios. Patent applications and patent issues soared in the years following the creation of the CAFC…" F.M. Scherer, "The Political Economy of Patent Policy Reform in the United States", *Journal on Telecommunications and High Technology Law* 7:180, 2008.

[83]Anthony Williams, "Governing Innovation Commons: Private Ordering of Intellectual Property Rights," op. cit.

[84]FTC. *To Promote Innovation,* op. cit., p. 21.

the American Bar Association's section on Intellectual Property law observed in 2002 that

> *Without patent protection, the venture capital which has been critical in fostering the [biotechnology] industry would not have been available. This entire industry, in which the United States is the clear leader, would have languished.*[85]

In 1984, the U.S. enacted the National Cooperative Research Act, which reduced antitrust exposure with respect to interfirm collaborations involving pre-competitive research. This legislation facilitated the formation of research consortia in the 1980s such as the Microelectronics and Computer Technology Corporation (MCC) and SEMATECH.

Most recently, the National Academies urged the "creation of a mechanism for post-grant challenges to newly issued patents, reinvigoration of the non-obviousness standard to quality for a patent, strengthening of the U.S. Patent and Trademark Office, simplified and less costly litigation, harmonization of the U.S., European, and Japanese examination process, and protection of some research from patent infringement liability."[86] Drawing on these recommendations, Congress passed, and on September 16, 2011, President Obama signed the America Invents Act.

Intellectual Property Derived From Government-Funded Research

The federal government has exerted significant influence on U.S. universities through its patent policies with respect to government-supported university-based research. Legislation enacted in 1980 which gave the universities the ability to secure patent rights on technology developed with federal government support has resulted in a dramatic increase in university-based innovation.

At the end of World War II, the federal government was funding an extensive array of university-based research projects with the question of who had primary patent rights to research results being settled in a diversity of inconsistent ways."[87] The question was the subject of study by task forces and the Congress until 1980, when the Bayh-Dole Act was signed into law.[88] Bayh-Dole created a presumption that government grants or contracts to researchers or

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[85]Robert. P. Taylor, *Competition and Intellectual Property Law and Policy in the Knowledge-Based Economy: Hearings Before the Federal Trade Commission and U.S. Department of Justice,* July 11, 2002.
[86]National Research Council, *A Patent System for the 21st Century*, Washington, DC: The National Academies Press, 2004.
[87]F. M. Scherer, "The Political Economy of Patent Policy Reform in the United States", *Journal on Telecommunications and High Technology Law,* 7:180, 2008.
[88]33 USC 200-212.

businesses would normally allow patent rights to be retained by the contractors or grantees, subject to an imprecise exception. An Executive Order issued in 1987 extended the presumption to all government R&D contractors, notwithstanding their size.[89] The Stevenson-Wydler Act also enacted in 1980, required government entities conducting R&D internally to set up Research and Technology Applications offices which were encouraged to negotiate exclusive patent licenses with the private sector for technology developed through research within the government entity.[90]

The Bayh-Dole legislation prompted many universities to establish or expand technology transfer offices and to pursue commercialization opportunities for their research.[91] A 2012 Harvard study of the impact of Bayh-Dole on counties surrounding universities receiving federal research funding, based on the Census Bureau's Longitudinal Business Database concluded that "employment, payroll and average wages grow differentially faster after the Bayh-Dole Act in industries more closely related to the technological strengths of nearby universities. The magnitudes…are considerable and grow with geographical proximity to the university supporting the importance of spatial relationships in the spread of knowledge. Areas surrounding universities that received more federal research funding before the law was passed grow faster after the law than do others; the effect is particularly large for DOD and NIH funding."[92] One example of this phenomenon is the University of Colorado, which undertook a sustained effort to overhaul its technology transfer efforts after Bayh-Dole, and by 2006 could count 60 companies launched utilizing its technologies, "a good majority" of which "have stayed in the Boulder and Broomfield counties."[93]

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[89]Executive Order No. 12591, 52 Fed Reg. 13414. 1987.

[90]15 USC 3701-3717. A 2002 editorial in *The Economist* observed that "possibly the most inspired piece of legislation to be enacted in America over the past half-century was the Bayh-Dole Act of 1980…more than anything, this single policy measure helped to reverse America' slide into industrial irrelevance." "Innovation's Golden Game," *The Economist* December 12, 2002. For a review of the limitations of Bayh-Dole, see David C. Mowery and Bhaven N. Sampat "The Bayh-Dole Act of 1980 and University–Industry Technology Transfer: A Model for Other OECD Governments?" *The Journal of Technology Transfer* 30(1-2):115-127, 2004.

[91]In the years prior to and immediately after Bayh-Dole (1967-82) an average of 1.3 university technology transfer offices were opened per year. In the years 1983 to 1995, the average soared to 7.4 openings per year. Association of University Technology Managers Licensing Activity Study, 2007, cited in Naomi Hausman, "University Innovation and Local Economic Growth and Entrepreneurship," (Harvard Center for Economic Studies, CES-12-10, June, 2012) p. 34. In other cases, existing tech transfer offices expanded dramatically. The University of Minnesota's office grew from a single patent administrator to a staff of 20 by 2000. "The Campus-Company Connection" *St. Paul Pioneer Press* September 17, 2000.

[92]Hausman, "University Innovation," op. cit., 2012, pp. 2-3.

[93]"Stewards of Invention: CU's Technology Transfer Office Helps Ideas Become Companies," Boulder *The Daily Camera* June 19, 2006.

INTERNATIONAL TRADE POLICY

State and regional innovation clusters and the industries based in them are engaged in international competition which is becoming increasingly intense, but states are limited in their ability to respond directly to overseas market barriers or mercantilist foreign practices. U.S. trade policy is administered virtually exclusively at the federal level. Locally-based industries must rely on the federal government to negotiate for and maintain their access to foreign markets. U.S.-based companies also may utilize an array of legal trade remedies administered by the federal government when imports of dumped or subsidized products cause material injury domestically or when imports violate intellectual property rights of U.S. firms. While U.S. trade policy has proven vital to a number of high technology U.S. industries, including semiconductors, supercomputers, and pharmaceuticals, many market-distorting foreign public and private practices exist which have no clearly available legal or public policy remedy.[94]

GOVERNMENT PROCUREMENT

The federal government has affected the evolution of a number of high technology U.S. industries through procurement of products for defense and other public purposes. Government procurement contracts fostered the development of the U.S. aerospace and electronics industries in the generation after World War II.[95] Although the research that developed integrated circuit technology in the 1950s was not federally-financed, it was "undertaken with the clear understanding that, if it were successful, there would be a massive government market." In the early 1960s, NASA decided to use ICs in the guidance system for the Apollo mission, and the Air Force incorporated ICs into the guidance system for the Minuteman ICBM. Government purchases of ICs for these programs enabled U.S. companies to improve yields, reduce costs

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[94]At the Symposium on the U.S. Battery Industry, Senator Debbie Stabenow of Michigan pointed out that although China joined the WTO over 10 years ago, it has not signed the WTO Agreement on Government Procurement, which provides for nondiscrimination in public procurement by designated governmental entities. She pointed out that Chinese procurement policies "are blocking our companies from the ability to sell to their government." Presentation by Senator Debbie Stabenow, in National Research Council, *Building the U.S. Battery Industry for Electric Drive Vehicles: Progress, Challenges, and Opportunities—Summary of a Symposium,* op. cit. See also Thomas R. Howell, "The Multilateral Trading System and Transnational Competition in Advanced Technologies: The Limits of Existing Disciplines," in Marklund, Goran, Micholas S. Vonortas, and Charles W. Wessner, eds., *The Innovation Imperative: National Innovation Strategies in the Global Economy,* Cheltenham, UK, and Northampton, MA: Edward Elgar, 2009.

[95]Stuart W. Leslie, "The Biggest Angel of the All: The Military and the Making of Silicon Valley," in Kenney, ed., *Understanding Silicon Valley*, op. cit., pp. 48-67.

through volume production, and to find wider application for IC technology in industrial and commercial applications.[96]

Government procurement remains a policy tool under discussion in connection with emerging "green" technology industries in the U.S. which confront uncertain near-term demand for their products. The U.S. military is interested in electrification of numerous combat and logistics platforms that would require use of high-performance batteries, including the Army's vehicle fleet and unmanned aerial and undersea vehicles being developed by the Air Force and Navy, respectively. Military demand could provide a market for U.S. battery makers in the event that demand for batteries for civilian vehicles does not grow substantially.[97]

LESSONS LEARNED

In an era in which state budgets are under growing pressure, a vast array of federal programs and research organizations represent a diversity of resources that state and regions can draw on to help support local innovation initiatives.

- A panoply of federal programs is now being directed toward the fostering of local innovation clusters, support for innovative start-ups, enhancement of U.S. manufacturing competitiveness, and the creation of public-private innovation partnerships.
- Federal regulatory policies since 1980 in the realm of competition, intellectual property, and trade have played a critical role in stimulating innovation in the U.S. economy.

[96]National Bureau of Standards, the Influence of Defense Procurement and Sponsorship of Research and Development on the Development of the Civilian Electronics Industry, June 30, 1977.
[97]Presentations by Grace Bochenek and Sonya Zanardelli, U.S. Army Tank-Automotive Command Research, Development and Engineering Center; John Pellegrino, U.S. Army Research Laboratory, National Research Council, "Building the U.S. Battery Industry for Electric-Drive Vehicles: Report of a Symposium," July 26, 2010.

III

REVIEW OF SELECTED STATE AND REGIONAL PRACTICES

Chapter 6

Rebuilding Ohio's Innovation Economy

Efforts underway in Ohio to spur an industrial and economic turnaround are increasingly attracting national attention. Backed by strong and longstanding support from the state government's Thomas Edison and Third Frontier programs, Ohio's growing resurgence reflects local and regional initiatives by small and large firms, universities, and philanthropic foundations. These developments may represent a new paradigm for innovation-driven economic growth that is particularly relevant for older industrial states and regions.

REVIVAL FOLLOWING A GENERATION OF ECONOMIC DECLINE

During most of the first century after its founding, Ohio was a predominantly agrarian state, but it began to industrialize rapidly in the 1870s. Toledo, Cleveland, and Youngstown became centers of steelmaking; Akron, the home of B.F. Goodrich, Firestone, and Goodyear, became the "rubber capital of the world," Dayton produced paper, cash registers, and refrigerators, and Cincinnati made railroad cars, boilers, and machine tools.[1]

The state of Ohio has a rich tradition of innovation. The Wright brothers of Dayton developed the first successful airplane.[2] Michael Owens founded a glass-blowing company that fostered Owens-Corning and Owen-Illinois.[3] Charles Kettering cofounded Delco Enterprises to commercialize his invention, the automatic starter for automobiles.[4] William Proctor and James

[1]"Made in Ohio," *The Columbus Dispatch* August 17, 2003.
[2]"Wright Brothers: Faith to be the First to Fly," *Columbus Examiner* December 16, 2010.
[3]Owens secured 49 patents, including a revolutionary bottle-blowing machine and machinery to make sheet glass and light bulbs, "Long String of Lucky Events Boosted Toledo's Standing in Glass Industry," Toledo *The Blade* April 3, 2007.
[4]"Kettering's Self Starter Was More Than That," *Dayton Daily News* September 13, 1997.

Gamble of Cincinnati built their company around a gentle, inexpensive floating soap they named Ivory.[5] Albert Sabin developed the first oral polio vaccine in Cincinnati. In 1900, Cleveland ranked eighth out of all U.S. cities in total patents granted to residents, and fifth with respect to patents deemed by official examiners to have made significant contributions to the industrial art of the period.[6]

However, in the second half of the Twentieth Century, Ohio experienced a dramatic economic decline as traditional industries like steel, automotive, glass, and rubber were buffeted by foreign competition and in some cases began to move offshore. Average incomes in Ohio fell from 11 percent above the national average in the 1950s to 6 percent below by 2001.[7] Ohio was "mired complacently in what has been labeled the old economy, characterized by production-line manufacturing" but was lagging the nation in knowledge-based areas such as information technology, biotechnology, and business and professional services. As David Morgenthaler, a venture capitalist with deep roots in Cleveland, has noted:

> *"In 1950, Cleveland was king of the world. We had world-class manufacturing facilities. ... We had 50 of the Fortune 500 headquarters, and were one of the leading manufacturing centers of the world." However, Cleveland was slow to respond when change came. The area had a powerful economic driver in the automobile, from 1900 to 1960, "and unfortunately the region rode it for another 40 years without recognizing that we had missed two new industrial revolutions, the electronics revolution and the biotech revolution."*[8]

The *Columbus Dispatch* observed in 2003 that Ohio ranked 36th in per-capita R&D expenditures at doctoral granting institutions. It concluded that "despite some notable exceptions, Ohio's economy is stuck in the past while the world is changing—fast!"[9] Lavea Brachman, Executive Director of the Greater Ohio Policy Center, commented in 2010 that the extent of Ohio's economic decline was "unparalleled" and that the cities had "emptied out," leaving high concentrations of poverty, with Cleveland falling from a population of 900,000 in 1950 to 400,000 in 2010 and Cincinnati dropping from 500,000 to 300,000 in

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[5] "In 1879, P&G Floats Idea for Soap," *Akron Beacon Journal* January 6, 2003.

[6] Naomi, Lamoreaux, "The Decline of an Innovative Region: Cleveland, Ohio in the Twentieth Century," Paper prepared for the 2008 Annual Meeting of the Economic History Association, September 12, 2008.

[7] "Legislators Badly Weaken State Colleges," *The Columbus Dispatch,* November 25, 2001.

[8] See David Morgenthaler, "Welcome and Introduction," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2013.

[9] "State of Stagnation? Bold investment in Human Capital Can Rejuvenate Ohio's Economy," *The Columbus Dispatch* August 10, 2003.

the same period.[10] She observed that Ohio had an unusual diversity of regional economies, with a half dozen metropolitan areas specializing in different industries—Dayton in autos, Toledo in glass, Youngstown in steel, and so on.

The state's historical innovation culture was seen by some observers as having eroded in the latter Twentieth Century. Roy Church, President of Lorain County Community College in northeast Ohio, recalled in 2002 that a hundred years previously, Lorain County was a place where "people were starting companies in garages, second bedrooms, and basements." That same year Stephen J. Gage, president of the Cleveland Advanced Manufacturing Program, complained that "the region lacks innovation…Ohio goes after branch plants—more of the old—rather than something new." Gage said that he saw more innovative ideas every four months when he was in charge of a seed money fund for entrepreneurs in Indiana than he had seen in 11 years in Cleveland.[11]

Notwithstanding a substantial erosion of its manufacturing economy, Ohio remains a major manufacturing state. The sector continues to employ about 600,000 people, or 14 percent of that state's workforce, and is the seventh largest U.S. exporter of manufacturing goods, selling around $34 billion in goods to other countries. The state ranks first, second, or third among U.S. manufacturers in 84 categories of manufacturing based on the North American Industry Classification system.[12] State business and political leaders cite a number of challenges Ohio confronts in engineering an economic turnaround. James Griffith, CEO of northeast Ohio-based Timken Company, contends that the state is heavily taxed, ranking 46th among states in business tax environment.[13] This partially reflects the profusion of governmental entities in the state—86 percent of U.S. states have fewer governmental organizations per square mile than Ohio.[14] "Someone has to pay for those entities," Griffith says, and because of the profusion of governments, it is "confusing to do business here."[15]

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[10]"Several of Ohio's cities have emptied as completely as medieval Europe when it was ravaged by the bubonic plague…within three years of graduation, one-third of Ohio's university alums have left the state." "Amid Migration, Ohio Offers Lessons for Texas," *Dallas Morning News* January 2, 2011.

[11]"Biosciences: The Next Big Thing or One of Many?" Cleveland, *The Plain Dealer* February 17, 2002.

[12]Eric Burkland, "The State Manufacturing Challenge," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.

[13]James Griffith, "Stimulating Manufacturing in Ohio: An Industry Perspective," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.

[14] Lavea Brachman, "Clusters and the Next Ohio Economy: What is Needed," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit. Brachman points out that even if a consensus existed that mergers of some governmental units was desirable, they would not be permitted under state law." Communities Discuss Hurdles of Regionalism: Many at Wednesday Summit Agree merged Government Worth Consideration" *Dayton Daily News*, June 9, 2011.

[15] James Griffith, "Stimulating Manufacturing in Ohio: An Industry Perspective," op. cit.

Box 6-1
Edison Seed Grants

The Edison seed grants required projects to involve small or mid-sized businesses conducting research in collaboration with Ohio colleges or universities. The products developed were required to be produced in Ohio or benefit Ohio-based employment. The industrial partner was required to match state funding with in-kind or monetary contributions, appoint a liaison to interact with university researchers and provide periodic reports on research progress. An example of an Edison-supported seed project involved collaboration between the University of Dayton and Dayton-based inventor Joseph Singleton, which developed a hydraulic cleaning system to soak, wash and rinse semi-tractor trailers in a single quick stop, cutting the time required to wash a rig from 40 minutes to 10 minutes. George Roth, supervisor of experimental and applied mechanics at the University of Dayton commented that "[w]e were able to serve as the company's engineering team. We were able to [review] the design and analyze the reliability and durability on paper, thus reducing cost and saving time."[16]

STATE GOVERNMENT INITIATIVES

The Thomas Edison Program: In 1983 Ohio's legislature created the Thomas Edison Program, a state-funded initiative to encourage universities to cooperate with businesses to link research and technology with start-up companies and other business initiatives. The Edison program supported the establishment of nine business incubators, seven technology centers, and "seed development fund projects" across the state.[17]

By 1990 *The Columbus Dispatch* was characterizing the Edison program as an "unqualified success," citing the fact that the "Ohio corporate community has taken ownership of the Edison program."[18] The most visible manifestations of the Edison program were the thematic Edison technical centers, which fostered university-industry collaboration emphasizing applied research leading to incremental but very practical improvements in processes and products—"small improvements that over time result in big advantages"—

[16]Bright Ideas—Edison Program Helps Inventors Find Their Wings," *The Cincinnati Post* August 27, 1990.
[17]"Effort to Aid Business Draws Praise," *Akron Beacon Journal* January 21, 1986.
[18]"Edison Program is Success—State is Seen as Beneficiary," *The Columbus Dispatch* April 2, 1990.

in areas such as welding, metal-forming, materials, polymers, industrial systems, and biology.[19]

The Third Frontier Program

Ohio's Office of Technology Investments administers the Ohio Third Frontier program, which provides funding to state-based, technology oriented companies, universities, and non-profit research organizations to create new companies, industries, products, and jobs. Third Frontier was created in 2002 and extended in 2010 through 2015 with a budget of $2.3 billion, making it the largest development initiative ever undertaken in Ohio.[20] The Third Frontier is designed to support early-stage research and development efforts "from which the private sector often shies away, the payoff likely too far in the future." [21] Amendments to the state constitution approved by Ohio voters in 2005 and 2010 lifted a longstanding constitutional ban on state investments in private business with respect to the Third Frontier program (but not other programs).[22] An assessment of the program in 2012 concluded that while the Entrepreneurship Signature Program (ESP)[23] had received 30 percent of Third Frontier funding, they accounted for 56 percent of the positive economic impacts.[24]

The Third Frontier program has been the largest contributor to the Ohio Research Scholars Program, which funds university collaborations "so they can woo researchers and their federal research grants and staff members to Ohio."[25] In 2008, the Third Frontier committed $72 million to this effort, augmented by $50 million allocated by the Ohio General Assembly from university endowment funds and $28 million from the state's universities in the form of foregone operating money. This effort was aimed at establishing 26 new endowed faculty chairs at universities in the state.

As of mid-2007, the Third Frontier program had invested nearly half of its total grants—$300 million—in northeast Ohio institutions, organizations, and

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[19]"Edison Program Lights the Way—Centers Help Industry Compete With the Latest Technology," *The Columbus Dispatch*, May 12, 1991.

[20]*Akron Beacon Journal,* "Snapshot of the Region—Northeast Ohio Has Inched Forward in the Knowledge economy, Now it Must Pick Up the Pace." May 22, 2009.

[21]The Third Frontier also sponsors Wright projects, which underwrite capital equipment to commercialize research results that will serve entrepreneurial purposes and contribute to the education and training of the work force. Wright funding is awarded in response to proposals in the fields of alternative energy; instruments; controls and electronics; biomedical; advanced materials; and advanced propulsion. "Initiative Seeks Top Researchers: $143 Million Goes to Universities for Cutting Edge Solutions," Cleveland, *The Plain Dealer* May 21, 2008.

[22]"JobsOhio May Run Afoul of the Constitution," *The Plain Dealer,* February 2011.

[23]See the website of the Ohio Development Services Agency at *<http://development.ohio.gov/bs_thirdfrontier/esp.htm>*.

[24] "Basics of the Third Frontier—the Idea Wasn't to Launch a Venture Capital Firm," *Akron Beacon Journal* September 23, 2012.

[25] Mary Vanac, "State initiative seeks top researchers to rebuild Ohio's economy," Ohio Plain Dealer, May 21, 2008.

TABLE 6-1 Ohio Third Frontier Performance Metrics—2012

	As of June 30, 2012
State funds expended	$907,910,178
Leveraged dollars	$8,048,717,740
Leverage ratio (goal: 3:5/1)	8.9/1
Direct Jobs Created	15,945
Direct and Indirect Jobs Created	95,510
Companies created, capitalized, or relocated	882

SOURCE: Ohio Third Frontier Annual Report—2012.

companies. Of that total, 55 percent went to projects involving biomedicine and bioscience.[26] Third Frontier support has been critical to the operation of the specialized nonprofit technology-oriented economic development organizations that have driven northeast Ohio's economic turnaround.[27] In 2012, the Third Frontier reported that since its inception it had expended roughly $900 million to leverage other investments of over $8 billion, had fostered the creation of nearly 100,000 direct and indirect jobs, and facilitated the creation, funding, or recruitment of 882 companies.

NEW INITIATIVES IN NORTHEAST OHIO

Luis Proenza, President and CEO of the University of Akron, observed in 2011 that a dozen years previously "northeast Ohio largely lacked entrepreneurial drive, risk tolerance, and innovation capital."[28] A 1997 survey of northeast Ohio observed that "look under the hood…and this is what you'll see: a lot of companies that make some pretty basic stuff. Stuff like metals, paint, cement, oxygen tanks, and electric motors."[29] In 2002, three economic development experts told the Akron roundtable that "Northeast Ohio companies are good at making stuff. But they need to get better at innovating new stuff…Northeast Ohio is weak in innovations in products."[30]

Proenza summarized a series of public and private initiatives since the early 2000s that led him to conclude that "today while all the pieces are not yet in place, there is little doubt that the region is moving in the right direction." He noted as positive developments the launch of the Ohio Third Frontier Program in

[26]"Granting Our Wishes: State's Third Frontier Program Has Invested About $300 Million in NE Ohio Technology Efforts," Cleveland, *The Plain Dealer* July 22, 2007.

[27]Ray Leach, the chief executive of JumpStart, (a northeast Ohio initiative to provide intensive assistance to entrepreneurs) commented in 2007 that "if the Third Frontier didn't exist, JumpStart wouldn't exist as we know it today. It would be smaller and dramatically less capable than it is today." Ibid.

[28]Luis Proenza, "Keynote Address," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.

[29]"Manufacturing Still Drives Region's Economy," *Akron Business Journal* June 22, 1997.

[30]"Innovation Key to Region's Economic Development," *Akron Beacon Journal* January 18, 2002.

2002 and a 2010 decision to expand the program's funding, state legislation allowing university faculty to become stakeholders in startups commercializing their research findings, and the economic development efforts of charitable foundations and nonprofit organizations in northeast Ohio.[31] Today, northeast Ohio is the site of robust new clusters forming in biomedicine, advanced materials, and chemistry.[32] As of mid-2011, Cleveland's economic recovery ranked 10th among 50 U.S. metropolitan areas. Rebecca Bagley, President and CEO of NorTech, a nonprofit development organization, founded in northeast Ohio cites recent developments as evidence of a longer-term economic transformation and commented that "the fact that we have this growing innovation ecosystem has become extremely important in sustaining this momentum."[33]

Upgrading Universities

Proenza became President of the University of Akron in 1999, and quickly launched a $200 million effort to remake the University, including upgrading its physical plant, doubling the amount of open space on the campus, and transforming the student base from one dominated by commuter students to one based on resident students, who were more likely to remain in school and graduate. From the inception of his tenure, Proenza emphasized how states and educational institutions could drive economic development.[34] Among other things, he pointed out that polymer science at the University of Akron was the only science program in the state of Ohio ranked in the top five nationally, and that "the program can be an engine for the regional economy."[35]

In 2001, the university established the University of Akron Research Foundation (UARF), a not-for-profit organization to facilitate the transfer of

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[31] Luis Proenza, "Keynote Address," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.

[32] "Can One Region Jumpstart the Entire US Economy?" *The Lawson Constitution* June 26, 2011.

[33] Rebecca Bagley, "The Role of NorTech: Promoting Economic Development," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.

[34] "A New Era at the University of Akron: The Proenza Plan," *Akron Beacon Journal* October 10, 1999; "Ohio's Success Linked to Schools, Proenza Says: UA President Touts Research at Roundtable," *Akron Beacon Journal* December 17, 1999. Between 2000 and 2010 the University made a $500 million investment in a 'New Landscape for Learning,' establishing 20 new buildings, 18 major additions and renovations, 34 acres of new, green space, 30,000 trees and bushes, and walkways, plazas, and terraces. Run-down neighborhoods near the campus were revitalized as University Park, a 50-block upscale mixed residential and retail area. Summary of remarks of Luis Proenza, "Universities and Economic Development: Lessons from the 'New' University of Akron," National Research Council, "Building the Hawaii Innovation Economy: Summary of a Symposium." January 13-14, 2011; "Projects Blossom in Area Near UA," *Akron Beacon Journal* April 26, 2006; "Building Blocks for 50 Blocks—The University Park Alliance Reaches a New Level," *Akron Beacon Journal* October 28, 2011.

[35] "Angels for Akron—The Region Wants to Fulfill the Promise of Polymer? Start With Concrete Plans and a Little Money," *Akron Beacon Journal* June 3, 2002.

research results from the university to public and commercial use. UARF became a focal point of entrepreneurial activity, creating 26 startup companies in a five year period based on university-patented technology and another 15-20 companies based on patents held by others. UARF also created research partnerships with established companies and developed a regional network of angel investors.[36] Finally, UARF recruits Senior Fellows and Entrepreneur Executives, individuals from the business community who function as "guerilla entrepreneurial talent," to identify potential partners for the university.[37]

When Proenza took over as President of the University of Akron in 1999, the school performed about $15 million per year in research. By 2012 the annual figure had grown to $50 million.[38] In 2012 the University's Research Foundation marked a milestone with the launch of the fiftieth startup.[39] In that year, Proenza unveiled "Vision 2020," an 8-year plan to build the institution's annual research activity from $50 million to $200 million, increase enrollment from 29,000 to 40,000, and achieve job placement of 80 percent within six months of graduation in "dynamic careers." The plan builds on the so-called "Akron Model":

> *The university through its research foundation and other avenues is leveraging its talent for local companies and entrepreneurs, serving as something of a research arm or problem-solver in the regional economy.*[40]

The Role of Foundations

Another key asset in the effort to turn around northeast Ohio's economy has been the region's extraordinary century-old philanthropic tradition, which has made it possible to undertake multiple initiatives to promote the establishment of innovative new industries. The Cleveland Foundation, the world's first community foundation and today Ohio's largest grant-making foundation, was launched by Cleveland banker/lawyer Frederick H. Goff in 1912 to foster the "mental, moral, and physical improvement of the inhabitants

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[36]Proenza, "Lessons from the 'New' University of Akron," 2011, op. cit.; "Group Puts Startups on the Right Path: Archangels Network Offers Local Ventures Feedback, Assistance Finding Investors," *Akron Beacon Journal* February 22, 2007.

[37]Proenza comments that "ten years ago we would never have thought of partnering with the hospitals because we didn't have anything in common at the time. Now these Fellows have helped us to see ourselves as partners with the city and community in a broader sense." Proenza, "Lessons from the 'New' University of Akron," 2011, op. cit.

[38]"All About Talent—the University of Akron Wants to be a Leader: Its New Strategic Plan Explains How it Will Do So," *Akron Beacon Journal* January 22, 2012.

[39]"Akron Professor Advocates Polymers for the People; Octogenarian Inventor Creates Useful Products," Cleveland, *The Plain Dealer* September 6, 2012.

[40]All About Talent—the University of Akron Wants to be a Leader: Its New Strategic Plan Explains How it Will Do So," *Akron Beacon Journal* January 22, 2012.

of Cleveland."[41] Other foundations were established by millionaire industrialists in Ohio's first economic heyday in "a region where the ghosts of once-great corporations live on in charitable foundations."[42] At present, about 1780 of Ohio's 3244 foundations are found in northeast Ohio, where the first such organizations appeared and where interest has been compounding, in some cases, for over half a century. Moreover, in present-day northeast Ohio, "there's an expectation that today's corporate leaders will keep alive that tradition of giving," and "everyday folks are known as big givers too, donating twice as much to the United Way as residents of many other cities."[43]

In responding to the economic crisis that overtook Ohio in the late Twentieth Century, the foundations were able "to do something the area's patchwork of city government hasn't always been successful at," and their work has "proven so cutting edge that it was recently [in 2010] showcased at a global summit." David Abhott, the executive director of the Gund Foundation, observes that "the way we are fragmented governmentally impairs our ability to compete globally," but "[now] we're getting into the habits of competing more effectively as a region."[44] Most importantly, in the past decade, the foundations have pooled their funds and backed roughly a half dozen small nonprofit economic development organizations with expert staffs that have functioned as catalysts for innovation-based economic revitalization. In this way, "the old money [of Ohio's first industrial century] is starting new industries. The foundations have really turned themselves into a way of recycling old money into new products."[45]

In 2003, the foundations of northeast Ohio for the first time began exploring how to work together to address the region's economic challenges at a time when most of the foundations had limited staff, confined to making grants.[46] In February 2004, a coalition of foundations and companies created the Fund for Our Economic Future with an initial funding goal of $20 million. These resources were primarily directed to a handful of the best economic development organizations out of "31 organizations that do the kind of work in

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[41]The Fund has assets of nearly $2 billion." The Cleveland Foundation—Our History," <*http://www.clevelandfoundation.org/about/history*>.

[42]The George Gund Fund, established in 1952, was established by a former president of Cleveland Trust Co. who made his fortune after selling a company that had developed on innovative processes for decaffeinating coffee known as Sanka. The Burton D. Morgan Foundation, created by the founder of Morgan Adhesives, supports entrepreneurship in the region. The Kelvin and Eleanor Smith Foundation is named for a co-founder of Lubrizal. "Philanthropy is Our Way of Life of Greater Clevelanders,*" The Plain Dealer,* December 26, 2010.

[43]Ibid.

[44]Ibid.

[45]Hill, Edward "Ned" quoted in "Philanthropy is Our Way of Life of Greater Clevelanders," *The Plain Dealer,* December 26, 2010. Hill says that "digging deep to help one's fellow man is uniquely rooted in Cleveland's DNA. The history of giving in Cleveland is one of our historic strengths. It is a competitive asset. Ibid.

[46]"Foundations to Try to Help the Economy," *The Plain Dealer,* September 4, 2003.

Box 6-2
Ohio's Leading Innovation Based Development Organizations[47]

- ***NorTech,*** a nonprofit organization promoting technology-based economic development, was launched in 1999. NorTech promotes formation of clusters in northeast Ohio, including the creation of detailed sectoral roadmaps in collaboration with local public and private actors.[48]
- ***BioEnterprise,*** a nonprofit spin-off from NorTech, has the mission of growing healthcare companies and commercializing biomedical technologies.
- ***JumpStart,*** founded in 2004, JumpStart is a nonprofit organization to provide direct funding and to arrange venture capital for promising startups.[49]
- ***Team NEO***, established in 2003, Team NEO's objective is to recruit businesses from outside the region to locate in northeast Ohio.[50]
- ***MAGNET,*** the Manufacturing Advocacy and Growth Network was formed in 2006 to support, defend, and educate manufacturing enterprises in northeast Ohio and help them improve their competitiveness.[51]
- ***UARF, the University of Akron Research Foundation,*** was established in 2001 as a boundary spanning organization connecting NE Ohio resources from industry, universities and investment communities for the purpose of wealth creation.[52]

which the Fund [was] interested."[53] The fund's objective was to channel investments into a limited number of projects likely to yield a high impact and "to encourage an entrepreneurial spirit once deeply present and now more of an echo."[54] The chosen development organization have continued to have strong

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[47]For additional information on these organizations, see National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.
[48]Rebecca Bagley, "The Role of NorTech: Promoting Economic Development," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.
[49]JumpStart's original funding sources were the State of Ohio, the Fund for Our Economic Future, the Cleveland Foundation, and the Greater Cleveland Partnership." N, E, Ohio Economy Gets a Boost—Jumpstart Helping Develop Businesses" *Akron Beacon Journal,* November 9, 2004.
[50]"Team NEO Has Work Cut Out—Momentum Needed in Economic Struggle," *Akron Beacon Journal,* January 26, 2003.
[51]"CEO to Speak at Roundtable," *Akron Beacon Journal,* July 18, 2006.
[52]See generally National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.
[53]"Coalition Ready to Dip into Pooled funds to Boost NE Ohio Economy," *The Plain Dealer,* July 27, 2004.
[54]"Foundation for Regional Recovery—A Compelling Voice for All of Northeast Ohio" *Akron Beacon Journal,* November 28, 2004. The *Cleveland Plain Dealer* warned in 2002 that "already

support from the Fund and/or from the donor foundations directly down to the present day, with positive results that have garnered national and international attention.

The Role of Intermediating Institutions

Box 6-2 provides a list of key innovation based development organizations serving northeast Ohio. These economic development organizations and their achievements have begun to win national attention, because Cleveland and the rest of Ohio are making progress in new technologies, particularly in the area of clean energy.

Impact of the Ohio Third Frontier program in Northeast Ohio

Luis Proenza underscored the importance of a statewide program, Third Frontier in the regional turnaround of northeast Ohio. Third Frontier has provided funds to the region's universities and to nonprofits like JumpStart and Team NEO and to individual companies.[55] In 2010, the Akron Beacon Journal published a survey of the effects of the Ohio Third Frontier program in the Akron area. It found that between 2002 and 2010 nearly 20 statewide or regional Third Frontier initiatives were led by Akron organizations, representing nearly $79 million in Third Frontier grants.

The Industrial Revival

During the past decade northeast Ohio companies have also implemented innovation-based turnaround strategies. Timken Company, a highly successful Canton-based manufacturer of steel bearings between 1960 and 1980, suffered from a protracted 20-year slump after 1980—its current President and CEO, James Griffith, commented in 2011 that "I've been there for 26 years and never knew that good time. I've been there for the struggling time." Griffith says Timken's turnaround reflected the 10-year application of a focused strategy, "grow and optimize," based on innovation. While remaining primarily a bearing and steel company, Timken "learned to take the technology and apply it to markets where we could differentiate and expand," diversifying beyond automotive applications to sectors such as aerospace and infrastructure manufacturing. The company has grown very aggressively in Asia and

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there are plenty of [economic development groups] with their snouts in the slop, diluting and draining focus and money." "Why have 30 of them going around town trying to raise resources when you can have one?" asked Dennis Roche, COO of the Greater Cleveland Growth Association." Agents of Change: An Explosion of New Organizations Promoting Economic Development and Opportunities is Igniting in Northeast Ohio," *The Plain Dealer,* December 8, 2002.

[55]"Ohio's Third Frontier Program Awards $14 Million in Grants to Northeast Ohio Organizations," *Crain's Cleveland Business,* December 14. 2012.

Box 6-3
The Akron Model of Industry-University Partnership

In 2012, the Timken Engineered Surfaces Laboratories, a collaboration between Timken and the University of Akron's College of Engineering was launched. The 6,000 square foot facility, with $2.5 million in equipment, focuses on technology to reduce friction on metal surfaces, involving "nano surfaces on products and very, very far-out technology."

Timken is developing its own technology at the new facility in collaboration with the university, but will allow other companies to benefit from technologies relevant to "markets that Timken isn't interested in but others are." The university and the company "worked out how to protect Timken's intellectual property in a way that other manufacturers and industries can benefit." Griffith has commented that Timken had protected the IP for applications it was interested in but the university could use Timken technology for anything other than Timken-protected uses, which "could lead to breakthrough developments in applications completely unrelated to anything Timken does."[56]

The above collaboration serves as a prime example of a university adding value to industry over and beyond feeding the talent pipeline. As Luis Proenza notes, "The University of Akron is a major player in the NE Ohio ecosystem, and by taking a key technology from within Timken, and yet ensuring its protection for Timken-protected use, made it available for the broader markets, thereby impacting many facets of the ecosystem. Some of these facets are open innovation, job creation, talent attraction, moving companies to Ohio, increased supply chain movements, deal flow and many more impacts that time will tell."[57]

developed high quality steel alloys for new markets, offering incentives to its personnel for new product generation—in 2010, Timken exported $35million worth of steel alloy to China, "so when you're selling China steel that is made in Ohio, you're doing something radically different." Timken invested a quarter billion dollars in China and exports as much to China as it makes in China. However, Griffith observes,

> *We looked at our business and saw that there was a big chunk of it we couldn't afford to fix. And the company couldn't survive if we didn't deal with it…we had to divest $1.5 billion worth of business we*

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[56]"Timken, UA Launch Venture—'Open Innovation' Partnership Allows University Students to Develop New Applications of Core Technology," *Akron Beacon Journal* October 20, 2012.
[57]See Luis Proenza, "Relevance, Connectivity, and Productivity: The Akron Model," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.

> *couldn't win in, and we closed 30 manufacturing sites in northeast Ohio. That's the hard side to innovation.*[58]

In 2005, Timken's Griffith told the Akron Roundtable that northeast Ohio's manufacturers were "on the upswing, not the downswing," citing adaptability to global competitive realities.[59] The following year, the Akron Business Journal observed that in many areas of Northeast Ohio "a quiet renaissance is taking place," reflecting the fact that the region's small manufacturers, in particular, were "innovating, automating, adapting, and growing;"[60]

A local economist has observed that "most people underestimate the continued viability of this region as a manufacturer." He said that small manufacturers operating in niche product markets had achieved competitive advantage. "You can offer small production runs and pretty quick turnaround" while not competing with low wage, high volume manufacturers in countries like China.[61] While the onset of the global recession in 2008 dealt area manufacturers a setback, a number of them recovered more quickly than the economy as a whole. Timken, for example, achieved record sales and earnings in the second quarter of 2011, a performance that stood "in stark contrast to the overall economy."[62]

GROWING THE CLEVELAND BIOMEDICAL CLUSTER

At the end of the 1990s Cleveland's business and civic leaders actively discussed the prospects for a local biomedical industry, based around the region's three leading medical research institutions, Case Western Reserve University (CWRU), the Cleveland Clinic and University Hospitals. In 2000, Cleveland's "business, academic and government leaders" drew up a plan to raise $200 million, and "build a cluster of new research facilities and lure top scientists," an effort that would depend on close collaboration between the three research institutions, which had never worked together on a large scale.[63]

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[58]James Griffith, "Stimulating Manufacturing in Ohio: An Industry Perspective," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.

[59]"N.E. Ohio on 'Upswing' Timken President Says—Roundtable Hears Message of Progress," *Akron Beacon Journal* November 18, 2005.

[60]These manufactures include Akron-based Northeast Tire Mold, which had invested $600, 000 to buy state-of-the-art machining equipment, and had its sales increased by 20 percent, Metal Dynamics Co., a small Wayne County-based steel fabricating, laser cutting, and welding company that had invested in new automated machinery and has seen sales rise by 30 percent, and Solmet Technology, based in Stark County, originally a metal-testing company, which has evolved into a maker of custom tool and die parts for machinery as diverse as Disney rides and Caterpillar equipment.

[61]Ibid.

[62]"Timken Raises Outlook," *Akron Beacon Journal* July 29 2011; "Timken Earnings, Sales Soar," *Akron Beacon Journal* October 26, 2011.

[63]"$200 Million Hub for Research Urged," Cleveland *The Plain Dealer* October 28, 2000.

Biomedicine offered a number of attractive characteristics—because of the strict U.S. regulatory environment, the sector was less susceptible to, albeit not immune from, global sourcing, and biomedicine offered the promise of knowledge-based, higher income jobs.[64] Considerable skepticism greeted this initiative—the Cleveland *Plain Dealer* observed in 2002 that "bioscience is a $600 billion industry. Northeast Ohio's piece wouldn't fill a "piggybank."[65] Edward "Ned" Hill, a highly regarded local economic development expert, commented that "all I can guarantee is that if we are trying to get into an area of science and research now that some places have been investing in for 20 or 30 years, we're too late."[66]

In fact, however, public and private actors in northeast Ohio put in place a series of programs, initiatives and actions in 2000-2002—a very short timeframe—that led to the emergence of a thriving biomedical industrial cluster in the Cleveland area in less than a decade that has gained national attention. Perhaps most importantly, an "innovation network" was created, comprised of professional non-profit development organizations and revamped, professionally staffed universities technology-transfer units. Mark Coticchia, who was one of the key founders of this network in the early 2000s, commented in 2007 that "we now have 60 professionals doing high-tech economic development work in Northeast Ohio. That's huge. That wasn't there five years ago."[67]

Third Frontier Funding

Governor Robert Taft unveiled his Third Frontier program in 2002. The biomedical sectors in northeast Ohio subsequently benefited enormously from this program, capturing over $160 million in funds from the inception of the program through mid-2007, a dynamic that enabled the region to secure substantial private sector investments.[68]

Legislation Affecting Faculty Innovations

In 2001, the Ohio legislature enacted legislation providing for the grant of exceptions to conflict-of-interest rules that prohibited faculty members from owning stock in companies that licensed technologies the faculty members had developed at their universities. In 2008, Ken Preston, executive director of the

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[64]"Area Biomedical Industry Thriving at Healthy Pace," *Akron Beacon Journal* April 27, 2009.
[65]"Biosciences: The Next Big Thing or One of Many?" Cleveland *The Plain Dealer* February 17, 2002.
[66]Ibid.
[67]"Case Study in Tech Transfer," Cleveland *the Plain Dealer* (May 13, 2007.
[68]"Ohio Coming Out Ahead in Clinical Trial Research—Most Active State in Midwest Helps Individual, Economy, Business," *Akron Beacon Journal* May 29, 2007; "Granting Our Wishes: State's Third Frontier Program Has Invested about $300 Million in NE Ohio Technology Projects," Cleveland *The Plain Dealer* July 22, 2007.

University of Akron Research Foundation, observed that after this change in the law, "across the state, we saw an immediate jump in university start-ups."[69]

BioEnterprise Corp

BioEnterprise established an incubator in a building purchased from Case Western Reserve University in 2002, secured funding from government, private and foundation sources, and began recruiting young local and out-of-state biomedical companies to the incubator.[70] Less than 20 months after its establishment BioEnterprise reported that the start-up companies it had supported had raised $62 million in capital, exceeding the nonprofit's two-year target figure of $50 million.[71] By 2009, BioEnterprise had had a hand in the formation of 89 biomedical companies in northeast Ohio drawing $859 million in capital and generating 1,900 jobs.[72]

Upgrading University Technology Transfer

In 2000-2001 northeast Ohio's two main sources of technology transfer, the Cleveland Clinic and Case Western Reserve University, recruited technology commercialization professionals to head their technology transfer units—Chris Coburn at the Cleveland Clinic and Mark Coticchia at CWRU.[73] Each individual in turn "hired dozens of professionals to help turn inventions at their respective institutions into licensing income streams, which after lead to commercial projects." According to 2007 comments by Baiju Shah, the CEO of BioEnterprise, Coburn's and Coticchia's "success has been astounding in only a few years." CWRU led Ohio universities in licensing income, with $29.4 million in the three years ending in 2008, compared with roughly $2 million a year prior to 2001. Cleveland Clinics commercialization unit, CCF Innovations,

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[69] "University Startup Companies Rise in Ohio: 2001 Law Beginning to Pay Dividends for Seventh Most Active State," *Akron Beacon Journal* April 2, 2008.

[70] "BioEnterprise Seeks Aid in Attracting Outside firms," Cleveland *The Plain Dealer* February 8, 2002; "Biotech Incubator Sets High Standards: Start-ups to-Get Up-Front Screening," Cleveland *The Plain Dealer,* February 17, 2002.

[71] The sole yardstick used by BioEnterprise to measure its performance was the amount of capital flowing into client companies. "Start-up Firm Exceeds Goal: BioEnterprise Capital Hits $62 Million," Cleveland *The Plain Dealer* February 7, 2002.

[72] "The Man to See to Get a Biomed Business Going: Baiju Shah," Cleveland *The Plain Dealer* June 28, 2009.

[73] Coticchia had previously headed the technology transfer office at Carnegie Mellon University, where he had co-founded Lycos, the Internet search engine. He had experience in the venture capital industry and his mindset was "always that of a venture capitalist," thinking about "the potential for emerging companies, what the risks could be." His hires were people with "attributes that venture capital firms value—technology backgrounds and advanced degrees; sales and marketing experience; and an understanding of how products develop and companies form." "Getting High-Tech Ideas From Campus to Market: CWRU Vice President Helps Turn Research Into Business Success," Cleveland *The Plain Dealer* November 8, 2009.

generated licensing income of $15.6 million in 2003-05, and recorded 409 invention disclosures and 116 patent applications.[74] In 2007, the Cleveland *Plain Dealer* reported in 2007, that "the technology transfer office at Case … has become one of the most prolific and top-grossing offices among its peers nationwide," having helped create 15 spinoff companies since 2001, a year in which "the office did not spin off a single company to commercialize Case technology."[75]

Recruiting Academic Talent

In 2001, the state of Ohio revived a program that had lapsed in 1990 pursuant to which the state Board of Regents could make awards of about $743,000 to endow seven to 11 university chairs to assist local institutions to lure top talent. The Third Frontier Project indicated it would "earmark a significant share of the proceeds from a $500 million bond issue to endow faculty chairs and recruit researchers."[76] Between 2005 and 2007, Case Western Reserve University attracted five eminent researcher-entrepreneurs who secured $60 million in research grants during that period and started companies to commercialize the result of their research.

These individuals (Walter Baron, Mark Chance, Krzysztof Palczewski, Alvin Schmaier, and Dan Simon) brought substantial teams with them to CWRU and recruited others. Dan Simon, for example, brought 15 doctors and scientists with him from the Brigham and Women's Hospital in Boston, and had built up a division of 59 professionals at CWRU's University Hospitals Heart & Vascular Institute by mid-2008.[77]

The emergence of a biomedical cluster in northeast Ohio has become self-reinforcing, attracting new companies, large-scale federal funding, and additional public and private investments. In 2007, the National Institutes of Health announced it would award Case Western Reserve University $64 million over a five year period to streamline the process of getting new drugs and medical devices to market. Case was reportedly chosen, in part, because of a

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[74]"The Clinic and CWRU Leaders in Licensing," Cleveland *The Plain Dealer* March 14, 2007.
[75]"Case Study in Tech Transfer," Cleveland *The Plain Dealer* May 13, 2007. Mark Coticchia's perspective was that translation of research results into practical applications was "part of a researcher's duty; much of their work, after all, is supported through federal grants." The process of "educating researchers about both the rules and logistics of commercializing research at Case requires broad efforts by an office of more than a dozen highly educated staff." "A Tech-Transfer Success Story," Cleveland *The Plain Dealer* July 28, 2006.
[76]"Universities Need to Court Top-tier Researchers," Cleveland *The Plain Dealer* March 31, 2002.
[77]"The Fab Five," Cleveland *The Plain Dealer* July 20, 2008; "Influx of Researchers Boosts NE Ohio Economy: Researchers Pump Millions into NE Ohio Economy," Cleveland *The Plain Dealer* July 20, 2008.

recent track record of technology transfer and collaboration with other institutions.[78]

Medical Imaging

Northeast Ohio entered the last decades of the Twentieth Century with a strong legacy position in medical imaging. Picker X–Ray (subsequently Philips Medical Systems) was founded in Cleveland in 1915, and Ohio-Nuclear Inc., a maker of CT and MRI scanners, established a manufacturing presence in 1958, later becoming known as Technicare Inc.[79] Alumni from the two firms established other imaging firms in the Cleveland area, including USA Instruments Inc., which became a GE subsidiary, and Hitachi Medical Systems America. "Northeast Ohio's long experience in diagnostic imaging has created a pool of workers familiar with the industry," said a Hitachi Medical Systems executive in 2004.[80]

BioEnterprise and other economic development organizations built on this foundation, assisting start-ups and attracting medical imaging companies from outside the region. By 2009, northeast Ohio had nearly 50 medical imaging companies with around 3,000 employees, and recent signs indicate that Cleveland can compete successfully with other regions for medical imaging companies.[81] In 2008, "heavy-hitting investors" on the East and West coasts offered to invest $25 million in ViewRay, a promising start-up with magnetic resonance medical imaging and image-guided gamma-ray treatment technology, but only if the company moved from Gainesville, Florida to a "center of bioscience innovation." ViewRay chose Cleveland following a sales pitch from BioEnterprise, Team NEO and BioOhio, the state bioscience developer.[82]

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[78]The NIH award was given pursuant to a consortium effort called the Clinical and Translational Science Institute that was formed to address the lack of coordination between scientists investigating diseases and doctors diagnosing and treating those diseases. "Benefits of Teamwork: A Big Grant to Speed the Development of Better Medicine Should build Momentum for Local Institution's Cooperation," Cleveland *The Plain Dealer* September 20, 2007; "Case Wins Coveted Grant for Research: NIH Money to Accelerate Medical Breakthroughs" *The Plain Dealer* September 19, 2007.

[79]Eugela Electric Co. was formed in the early 1900s to manufacture x-ray equipment. It was subsequently acquired by Westinghouse and sold to Picker. Picker was acquired by Marconi Medical Systems in the 1980s that was itself acquired by Philips Medical Systems in 2001. SRI International, *Making an Impact,* 2009, op. cit. p. 4.

[80]"Imaging is Everything in Local Medical Field," Cleveland *The Plain Dealer* August 31, 2004.

[81]"Medical-Imaging Startup to Grow: Success Bolsters Local Industry," Cleveland *The Plain Dealer* January 23, 2009.

[82]The basic pitch was that "Northeast Ohio is home of three of the world's top makers of diagnostic imaging equipment; the region's medical institutions are willing to work with innovative technology startups; and the region offers deep technical and engineering talent no medical imaging." "Investors Tip Biotech Firm Into Cleveland," Cleveland, *The Plain Dealer* February 26, 2008.

As a team, they were comprehensively better than anyone we talked to in the other states. They understood what we wanted to do. They were organized, thorough and incredibly supportive across the board."

Philips Healthcare, headquartered near Cleveland, has been expanding its presence in northeast Ohio and spinoffs from Philips local medical imaging operation have created a number of local start-ups. In 2010, it announced that it would open a $38.4 million global R&D center at University Hospitals Case Medical Center where it would develop state-of-the-art medical imaging equipment.[83] At the end of 2011, Philips disclosed that it was relocating the R&D center for its medical imaging business from San Jose, CA to the Cleveland area, bringing 100 new jobs to the region at an average salary of $115,000. Baiju Shah, CEO of BioEnterprise, commented that "these types of moves bringing research-and-development positions from Silicon Valley to Cleveland, sends waves through the health care industry." Ohio Governor John Kaisch was even more effusive, declaring that "this is just a gangbuster day. This is such a giant statement by an amazing, world class company."[84]

Entrants from Traditional Sectors

The emergence of a biomedical cluster in Cleveland has attracted other Ohio firms to niches in the sector. Local metal companies facing stagnant growth in aerospace and automotive applications have branched into applications in specialized medical devices.[85] A 2008 survey by BioEnterprise found that so many manufacturers were entering the medical business that Ohio had the second-largest number of FDA-registered companies among Midwestern states, over half of which were located in northeast Ohio. The manufacturers turning to medical applications were "looking for ways to grow and sustain their manufacturing enterprises … in the face of competition … that has caused much

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[83] The state indicated that the new center would receive $5 million from the Ohio Third Frontier Program. "Medical-Imaging Manufacturer Planning Research Center at OH," Cleveland *The Plain Dealer* June 4, 2010.

[84] "Kaisch's Medical Corridor Lures Jobs," *The Columbus Dispatch* December 21, 2011; "Philips, Steris Adding 200 Medical Jobs to Area," Cleveland *The Plain Dealer* December 21, 2011.

[85] Electrolizing Corp., a local firm making metal coatings for the automotive and aerospace industries, developed TiMed, a color coating for titanium suitable for use in surgical implants and medical instruments, where color-coding reduced medical errors. The Cleveland operation of Precision Castparts, a maker of forged aerospace fuel nozzles, developed a product line of titanium and cobalt-chrome hip replacement implants. Swagelok Co., based near Cleveland, a maker of tube fittings, valves and other parts for fluid systems in the chemical and energy sectors, developed a computer-driven orbital welding system that produces extremely smooth tubing connections required in the biopharmaceutical sector—tight welds that do not offer harbor for organisms that could contaminate sterile, closed systems. "Metals Industry Evolves: Companies Cash in on Burgeoning Bioscience Field," Cleveland *The Plain Dealer* March 8, 2005.

of their work to go overseas or offshore."[86] In 2010, at the request of BioEnterprise, Cleveland's Cuyahoga Community Collage began offering classes in "computer-controlled milling to aspiring medical-device and aerospace workers (many of which had lost old-line manufacturing jobs) to supply area firms with more [skilled] workers, a curriculum supported by a $600,000 grant from the Department of Labor.[87]

Polymer-Based Biomaterials

In 2008, the University of Akron joined with three local hospitals and the Northeast Ohio Universities Colleges of Medicine and Pharmacy (NEOUCOM) to launch a joint R&D initiative. Based in Akron, the BioInnovation Institute would build on the city's leadership in polymers to make the city a world leader in biomaterials, including replacement parts for aging bodies and treatments for skeletal and joint ailments.[88] Of the initial $80 million initial investment, $20 million was provided by the John S. and James L. Knight Foundation, originally based in Akron, which praised the "impressive level of collaboration of hospitals, universities, philanthropic organizations, local governments working together to attract research dollars and build on the area's strengths in polymer sciences and orthopedics."[89] The new organization was named the Austen BioInnovation Institute after the foundation's chairman, Akron native Dr. W. Gerald Austen.[90] In 2009, Dr. Frank L. Douglas, founder of MIT's Center of Biomedical Innovation, was named President and CEO of the new Institute.[91] Douglas, who had not planned to leave MIT, visited Akron in response to a recruiting pitch and over the course of three days, met 65 scientists, doctors, nurses and administrators. He recalls:

> *That's what got my attention—the vision had permeated a couple of levels down from the presidents and CEOs. The people who have to*

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[86] "Small Manufacturers Try a New Line: Medical Devices a Growing Market," Cleveland *The Plain Dealer* March 11, 2008; "Manufacturers Shift Gears Into Growing Biomedical: Ailing Autos, Construction Push Companies Down New Path," Cleveland *The Plain Dealer* June 14, 2009.

[87] "To Get Jobs, Areas Develop Industry Hubs in Emerging Fields," *USA Today* June 6, 2011.

[88] "Partnership in Health—3 Hospitals, VA and Med School Create BioInnovation Institute in Akron, a Multi-Million Dollar Medical Research Program," *Akron Beacon Journal* (October 17, 2008)

[89] "Ready for a Steep Climb—The BioInnovation Institute Goes for Talent," *Akron Beacon Journal* August 30, 2009. Other sources of funds included in-kind contributions by the partners ($20 million), state grants ($8 million), federal grants ($4 million) and $10 million for First Energy for energy-efficiency initiatives. "Institute Seeks Additional Revenue," *Akron Beacon Journal* June 17, 2012.

[90] "Economic Engine Built on Bioresearch Revs Up Akron—14 Researchers Recruited, Veteran Director and Board, Seed Funding Counting for BioInnovation Rejects," *Akron Beacon Journal* September 14, 2009.

[91] "Dr. Frank L. Douglas," *Akron Beacon Journal* January 26, 2010.

make it happen had come on board and were motivated to do something.[92]

The Austen Institute established an internal structure to evaluate ideas generated at its affiliated hospitals and educational institutions and provided doctors and researchers with "tools to turn their good ideas into new products." As recently as 2008, Akron's hospital systems had less than five inventions under evaluation for potential patents; by the beginning of 2012 they had over 100 medical inventions in the pipeline—numbers that the Institute's leaders regard as "evidence of success."[93]

Stem Cell Research

In 2003, the Center for Stem Cell and regenerative Medicine was founded at Case Western Reserve University with a $19.4 million state grant, involving research collaboration by CWRU, University Hospitals, the Cleveland Clinic and Ohio State University, as well as local stem cell companies. The Center raised over $234 million in venture capital between 2003 and 2009 and spun off four for-profit firms in the Cleveland area. Cleveland scientists conducted the country's first four adult stem cell clinical trials in 2003, and "researchers and investors familiar with the adult stem cell industry recognize Cleveland as a national player."[94]

Investment Levels

In 2012, Greater Cleveland attracted $226 million in investment for 43 local innovative medical and health care companies—nearly doubling the prior year's volume and exceeding Chicago, Minneapolis and the rest of the Midwest in investment levels. Prior to 2012, med-tech savvy Minneapolis led in investment levels. The President of BioEnterprise, a promoter of health care businesses in northeast Ohio, commented in January 2013 "It's exciting. Minneapolis has been the benchmark for years. We're playing with the big boys now."[95]

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[92] "Akron Institute's Leader Brings a World of Talent: Innovator Will Try to Combine City's Medical, Polymer Strengths," Cleveland *the Plain Dealer* February 28, 2010.

[93] "Patented Approach to Ideas: Medical Devices Develop Success," *Akron Beacon Journal* January 15, 2012.

[94] "Cleveland Becoming Leader in Adult Stem Cell Industry," Cleveland *The Plain Dealer* August 14, 2009.

[95] "Health Venture Here Lead Midwest Even With Money Tight, NE Ohio Saw Growth," Cleveland *The Plain Dealer* January 10, 2013; "Infusion of Venture Capital Fires Up NE Ohio's Innovation Economy: Study Shows Exponential Growth in Investment and New Companies," Cleveland *The Plain Dealer* September 16, 2012.

GROWING A CLUSTER IN FLEXIBLE ELECTRONICS

Akron is a center of advanced knowledge critical to the emerging field of flexible electronics, which involves the printing of electronic devices on flexible materials such as plastics, paper, fabrics and bendable glass. The area's expertise in this technology is anchored in two of its leading universities.

A pioneer in the development of liquid crystal displays (LCD), Kent State University's Liquid Crystal Institute, established in 1965, spun off a company that created an LCD display for the world's first digital wristwatch, "one of the top inventions of the last century in leading our new IT industry." Professor John West of Kent State's Chemistry Department says that "we are the MIT, we are the Stanford of this industry." [96]

The University of Akron is the site of the largest and broadest polymer science and engineering program in the world and a very strong graduate chemistry program.[97] The University collaborates with Ohio State University, the University of Dayton and 85 companies to operate the National Polymer Innovation Center, which is developing roll-to-roll (R2R) manufacturing technology that will be critical to the commercialization of flexible electronics products. The University's key contribution is workforce development from the technician to the PhD level—"flexible electronics companies are going to use fully automated machines that will be operated by people with advanced degrees."[98]

In 2006, NorTech and Kent State developed the FlexMatters Accelerator initiative, an effort to establish a flexible electronics industry in northeast Ohio that was broadened to include the University of Akron, the

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[96]Presentation by John West, "The Genesis of a New Cluster," National Research Council, "Building the Ohio Innovation Economy: Summary of a Symposium," April 25-26, 2011. Glenn Brown, then head of the Chemistry Department at Kent State, established the Liquid Crystal Institute (LCI) at the University in 1965. James Ferguson joined LCI in 1966 and was one of the inventors of the twisted nematic liquid crystal display, a technology that proved crucial to the development of the commercial flat panel display industry. Numerous LCI technologies were licensed to foreign companies and the display industry moved outside the U.S. In 1989, LCI combined with the University of Akron and Case Western Reserve University to establish the Center for Advanced Liquid Crystalline Optical Materials (ALCOM) with financial support from the National Science Foundation. This effort received about $60 million in federal and state funding through 2002, including $25 million from NSF and additional funding from DARPA. SRI International, *Making an Impact*, 2009, op. cit. p. 45.

[97]"College Expertise Can Turn Research Into Jobs," *Akron Beacon Journal* March 11, 2002. The University of Akron, then known as Buchtel College, was the site of the world's first academic rubber laboratory, serving local companies like Goodyear and BF Goodrich. During World War II the U.S. government contracted with the University to help develop synthetic rubber. At present, the University's College of Polymer Science and Polymer Engineering and the associated research institute comprise the broadest and largest polymer program in the U.S. SRI International, *Making an Impact,* 2009, op. cit. p. 46.

[98]Presentation my Miko Cakmak, Distinguished Professor of Polymer Engineering, University of Akron, "Role of Regional Academic Institutions in Flexible Electronics Development," National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium*, op. cit.

TABLE 6-2 Core Competencies in the Flex Matters Cluster

Core Competency	Description
R&D pipeline	– Electro-optic materials – Semiconductor materials – Materials science and design – Device physics – Novel processes
Technology and innovation	– Particle processing – Coatings processing – R2R and wide web equipment/tools – Polymer film processing
Talent and intellectual capital	– Highly skilled faculty – Masters and PhDs – Engineers and scientists
Intellectual property	– Seminal patents – Know-how – Trade secrets
Commercialized and near-commercialized products and components	– Electro-optic materials and films for curved product designs – Silver conductive inks and pastes for electrodes – Robust, low sheet resistance ITO conductive films – Nanotechnology based coatings for screen protection – Solar devices/components – Lighting components – Thermal heat dissipation components

SOURCE: NorTech, *FlexMatters Strategic Roadmap,* 2010, p. 26.

Center for Multifunctional Polymer Nanomaterials and Devices (a Wright program technology center) and local companies.[99] FlexMatters received a $900,000 grant from the Ohio third Frontier program in 2007 and chose a site in a new research park being established by Kent State, Centennial Research Park.[100] In 2010, NorTech released a detailed roadmap for the development of a

[99]"KSU Dedicates New Research Park," *Akron Beacon Journal* June 9, 2007; "6 Projects Get NorTech Money," Cleveland *The Plain Dealer* November 15, 2006.
[100]"KSU Dedicates New Research Park," *Akron Beacon Journal* June 9, 2007.

flexible electronics industry in northeast Ohio.[101] The ultimate goal of the effort was stated for FlexMatters to create 1,500 jobs, $75 million in payroll and $100 million in capital for the northeastern Ohio economy within seven years. The Roadmap identified "core competencies" that already existed in the FlexMatters cluster and indicated that "to the best of our knowledge, this portfolio of competencies is not duplicated in any other existing centers or clusters." (See Table 6-2.)

The FlexMatters cluster is comprised of a number of university research organizations and private companies. In addition to Kent State's LCIs the University of Akron's College and Institute for polymer science and engineering, and the Center for Multifunctional Polymer Nanomaterials and Devices at Ohio State,[102] the cluster includes the Center for Photochemical Science at Bowling Green State University[103] and the Center for Layered Polymeric Systems (CLIPS) at the Case Western Reserve School of Engineering.[104] Participating companies like Kent Displays and Alpha Micron have started to make a commercial impact.[105]

YOUNGSTOWN—
SOFTWARE AND ADDITIVE MANUFACTURING

Heavily oriented toward steel manufacturing, Youngstown and its surrounding Mahoning Valley region were hard hit by the contraction of that industry in Ohio. Youngstown's population of 82,000 in 2007 was roughly half of what it was 40 year previously and between 2000 and 2012, the Youngstown area lost 40,500 jobs. Thirty-one plants in or near the city shut down between 2001 and 2006. In 2012, a Cleveland-based economist estimated it would take 52 years for the area to return to the employment levels of 2000.[106] A 2012 manufacturing workforce summit at Youngstown State University sponsored by the Mahoning Valley Manufacturers Coalition concluded that a shortage of

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[101]NorTech, *FlexMatters Strategic Roadmap: Accelerating Growth in Northeast Ohio's Flexible electronics Cluster* November 2010; "Banking on Flexible Plastic: Nonprofit Aims to Provide Support for Promising New Industry in Northeast Ohio," *Akron Beacon Journal* November 10, 2010.
[102]The Center develops protocols for manufacturing and nanostructures for polymer photonic components. It received a 22 million grant from the Ohio Third Frontier program in 2005. SRI International, *Making an Impact* (2009) op. cit. p. 47; "Nanotechnology Could Give Ohio the Edge in Global Economy—Emerging Field May Spur Job Growth," *Dayton Daily News* August 7, 2005.
[103]The Center studies the interaction of light with biological, physical and chemical systems. SRI International, *Making a Difference*, 2009, op. cit. p. 47.
[104]CLIPS was launched by an NSF award of $19 million in 2007, and headed by CWRU professor Anne Hiltner, who specializes in the development of layers of plastics with practical applications. "Case Pioneer to Lead Center of Research," Cleveland *The Plain Dealer* February 11, 2007.
[105]"Designing the Future Kent Firm Incorporates Liquid Crystals in Fashion Line," Cleveland *The Plain Dealer* December 29, 2007.
[106]"Mahoning Valley Expert: Region's Recovery Will Take Decades," Youngstown *Vindicator* September 23, 2012.

skilled manufacturing workers in the region was "the most significant challenge" confronting local businesses and could slow the region's economic recovery.[107]

Despite daunting economic challenges, however, Youngstown has attracted national notice for its approach to turnaround. The mayor, Jay Williams, said in 2007 that city planners had decided to accept the fact that Youngstown was and would remain a smaller city than it had been and that it should "accept being smaller and clear away the clutter," demolishing vacant buildings, opening up green space, and making the city more livable.[108]

Youngstown's novel approach to urban renewal was paralleled by a sustained effort to develop local technology-oriented industry. The Youngstown Business Incubator (YBI) was formed in 1995 to support local entrepreneurs with the support of Ohio's Thomas Edison Program's Incubator initiative.[109] In 1998, under the leadership of a new director, Jim Cossler, the YBI chose to focus narrowly on the promotion of business-to-business software enterprises. Specialization allowed it to provide increased value for its tenants, and YBI invested in high-speed fiber optic connections, a software-testing lab, and specialized trade show materials, which would not have been cost-effective for individual small companies. Its first tenant was a power equipment dealer seeking to commercialize a sales development program it had developed, and other tenants followed.[110] One of the new tenants, Turning Technologies LLC, a provider of audience response technology, was drawn by the incubator's "most significant recruitment tool: deeply discounted rent, free furniture, bandwidth, electricity and other utilities."[111] By 2007, Turning reported revenues of $20.6 million, a three year growth rate of 3,909.9 percent, and was named the fastest growing privately held software company in the United States and the 18th fastest growing privately-held company overall.[112]

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[107]A spokesperson for seamless pipe producer V&M Star, which is locating a new facility in Youngstown, said that it received over 16, 000 job applications for 350 openings at its new facility and that it was "hard to find a 10 percent pool of applicants that is qualified, particularly those with millwright or maintenance skills." "Many Valley Workers Lack Skills for Manufacturing Jobs," Youngstown *Vindicator* April 13, 2012.

[108]"Less is More—Faced With Job Cuts and Factory Closings, Youngstown Tries Shrinking Back to Health," *The Cincinnati Post* June 28, 2007.

[109]As of 2006, YBI was receiving $225, 000 of its $400,000 operating budget from the state of Ohio. "Hatching a Revival: Youngstown Business Incubator Using High-Tech Approach to Bring New Life to Regions," Cleveland: *The Plain Dealer* March 26, 2006.

[110]PolicyLink, *To Be Strong Again: Renewing the Promise in Smaller Individual Cities*, 2008, p. 43.

[111]"Hatching a Revival: Youngstown Business Incubator Using High-Tech Approach to Bring New Life to Region," Cleveland *The Plain Dealer* March 26, 2006. Turning's CEO, Michael Broderick, called the abatement of operating costs at YBI "invaluable." He recalled in 2010 that "we didn't have venture funding, we didn't have capital. We started this company with credit cards." "Youngstown Makes Strides Toward Being Technical Hub," Cleveland *The Plain Dealer* January 31, 2010.

[112]The recognition was from Inc. Magazine. Turnings Customers included Fortune 500 businesses, consulting and training firms, universities and K-12 classrooms. "Turning Technologies Rated Fastest-Growing," Youngstown *Vindicator* August 24, 2007.

YBI has added space to accommodate its burgeoning stable of growing software companies. When Turning outgrew its space in the incubator, YBI raised $6 million in federal and state grant funds to build an adjacent 30,000 sq. ft. building next door, the Taft Technology Center, which was entirely leased by Turning. Another 18,000 sq. ft. of space was secured nearby, the so-called Tech Block, whose first tenant, Revere Data, a maker of software for analyzing financial data, was characterized by Cossler as perhaps "the first company ever to move operations from San Francisco to Youngstown—but it won't be the last."[113] These developments helped to propel Youngstown into national and international attention as an example of how a small industrial city turned its self around.[114]

In August 2012, President Obama announced that Youngstown would be the site of the National Additive Manufacturing Innovation Institute (NAMII), a research organization specializing in a potentially revolutionary manufacturing technique based on 3-D printing. The federal government will provide $30 million in funding to be matched by a similar amount from manufacturing firms, nonprofits, and universities and colleges.[115] The National Center for Defense Manufacturing and Machining, which is sponsoring the project, estimates that it will eventually create 7,200 regional jobs. President Obama cited NAMII in his 2013 State of the Union message:

> *A once-shuttered warehouse is now a state-of-the-art lab where new workers are mastering the 3D printing that has the potential to revolutionize the way we make almost everything.*[116]

THE TOLEDO PHOTOVOLTAIC (PV) CLUSTER

In 1970, Toledo, Ohio ranked in the top ten U.S. cities for per capita income. Nicknamed "Glass City," Toledo spawned glassmaking companies like Libby Glass and Owens Corning, and was also a center for the manufacture of

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[113] "Youngstown Makes Strides Toward Being Technical Hub," Cleveland *The Plain Dealer* January 31, 2010. Revere Data's locational decision was reportedly based on cost comparisons, but also because one of its senior executives was a native of northeast Ohio. Rent in Youngstown was reportedly four percent of what the company would have paid in San Francisco. "Youngstown Ohio: A Young Town Again," *The Economist* October 8, 2009; "Research Company to Open Office in Downtown Tech Block," Youngstown *Vindicator* January 12, 2010.

[114] "National Study Applauds Youngstown's Progress," Youngstown *Vindicator* July 22, 2008; "Youngstown, Ohio: A Young Town Again," *The Economist* October 8, 2009.

[115] "Obama Push for 3D Hub to turn 'Rust Belt' City Into "Tech City," *Columbus Examiner* August 17, 2012. Additive manufacturing utilizes 3-D software that creates a blueprint that is sent to a machine that utilizes various materials, including resins, metal and plastic to "print" a product in layers, with little or no loss of materials in the process. "Obama Names Youngstown as Model for New Tech," Youngstown *Vindicator* February 13, 2013. In fact, the Ohio partners have raised $40 million in matching funds.

[116] "Obama Names Youngstown as Model for the New Tech," Youngstown *Vindicator* February 13, 2015.

auto parts and furniture. These industries began a long decline in the 1980s, and by 2000 Toledo had plummeted from its top ten ranking in per capita income to the country's bottom ten. In the decade following 2000, Toledo lost roughly 50,000 jobs, or about 14 percent of total employment, with the automotive sector being the hardest hit.[117]

The Legacy of Glass Manufacturing

In a four-month period between December 2000 and April 2001, unemployment in Toledo jumped from 3.6 percent to 12.1 percent, prompting the formation of a group of business, academic, and government leaders that came to be known as "the partners." The partners agreed that the only way to revive the local economy was to "bring its major institutions together to think boldly and share responsibility for creating jobs."[118] An advantage Toledo enjoyed in attempting a turnaround was its legacy of innovation in all areas of the glass industry, and as the traditional glass business had stagnated in the 1980s and 1990s, local scientists with glass expertise began to explore alternative uses for glass technology.[119] Norman Johnson, a former executive at various Toledo glass companies, and founder of Solar Fields LLC, a developer of thin film solar manufacturing technology, observed in 2007 that "I started in glass and now I'm back in glass." The same year, at a meeting of civic leaders tracing the evolution of Toledo's photovoltaic industry, one of them commented, "How would we be in this business in the first place if it weren't for glass?"[120]

The genesis of Toledo's photovoltaic industry was the work of a local inventor and entrepreneur, Harold McMaster, holder of over 100 patents and characterized as "the glass genius" by Fortune Magazine.[121] In 1984, McMaster and a group of colleagues formed Glasstech Solar, and invested in basic and applied research in solar arrays at the University of Toledo and other institutions. When Glasstech Solar failed to develop a viable technology based on amorphous silicon, McMaster founded a new company, Solar Cells, Inc., to pursue a technological alternative based on cadmium telluride in 1990. By the end of the 1990s, Solar Cells was the industry leader in thin-film photovoltaic technology. According to McMaster's 2003 obituary, "some believe he will be remembered as the father of commercial scale solar energy, having practically

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[117]*USA Today,"*Toledo Reinvents Itself as a Solar-Power Innovator," June 152010; *Toledo Free Press*, "Sun Burn 1: Area Courted Solar Energy with Research," July 19, 2012.
[118]"Toledo Reinvents Itself as a Solar-Power Innovator," *USA Today,* June 15, 2010.
[119]"Toledo Finds the Energy to Reinvent Itself," *Wall Street Journal,* December 18, 2007.
[120]Ibid.
[121]McMaster graduated from The Ohio State University with a combined Masters' degree in Physics, Mathematics, and Astronomy, and in 1939, became the first research physicist ever employed by Libby Owens Ford glass in Toledo. He pioneered in the development of curved tempered glass for ore in automotive and consumer markets. *The Toledo Blade,* "Harold McMaster, 1916-2003." "Inventor Became Philanthropist," August 26, 2003.

handed the needed technology to society in the 1990s."[122] In 1990, McMaster sold Solar Cells to TrueNorth Partners LLC, who renamed it First Solar. The company began manufacturing operations in Perrysburg, Ohio, 11 miles from Toledo, in 2004. By 2009, First Solar had become the largest producer of photovoltaic modules in the world, though this position has since been yielded to a Chinese supplier.[123]

University of Toledo Leadership

The University of Toledo (UT) played a leading role in the development of a major photovoltaic industry cluster in and around the city. McMaster's research collaboration with the university, funded by grants, was the foundation for the formation of additional photovoltaic manufacturers. The university recruited renowned solar researchers.[124] It established: the Wright Center for Photovoltaics Innovation and Commercialization, a university-industry-government collaboration for cost reduction, technology development, and technology transfer from laboratories to factories; the University Clean Energy Alliance of Ohio, which coordinates research collaborations by the state's universities in the field of clean energy; a Clean and Alternative Energy Incubator, which assists green energy startups; and a School of Solar and Advanced Renewable Energy, which trains students in the field of renewable energy.[125] UT's President, Lloyd Jacobs, said in 2011 that in photovoltaics, "we have more scientific knowledge than almost anywhere in the world. We have more scientists doing more complex scientific work than anywhere else in the world."[126]

UT's support facilitated the advent and subsequent development of a number of start-ups in Toledo's photovoltaic sector, including Glass Tech Solar, Solar Fields LLS, and Xunlight. In 2005, UT established the Clean and Alternative Energy Incubator, a facility providing support for spinoffs and startup alternative energy companies, including business assistance, competitive rents and help in identifying federal, state, and local funding and other support.[127]

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[122]Ibid.

[123]"Sun Burn 1: Area Courted Solar Energy with Research," *The Free Press.* July 19, 2012.

[124]*USA Today,* "Toledo Reinvents Itself as a Solar-Power Innovator" June 15, 2010.

[125]University of Toledo, "UT Creates School of Solar and Advanced Renewable Energy," Press Release, April 15, 2009.

[126]*The Blade,* "Solar Incubator Spreads Wings, UT Program Adds Firms, Broadens its Research." July 3, 2011.

[127]SRI International, *Making an Impact,* 2009, op. cit. p. 33.

Support from the State

In addition to the support from a leading-edge public research university, Toledo's solar firms benefitted from a number of local, state, regional, and federal initiatives. Ohio Advanced Energy, a business association representing the state's renewable industries, worked with state officials to develop the Ohio Advanced Energy Portfolio Standard, which mandates that at least 25 percent of Ohio's electricity be generated from clean and renewable sources by 2025. U.S. Congresswoman Marcy Kaptur helped secure $6.4 million in federal funds for two solar demonstration projects in Ohio, at the 180th Fighter Wing at Toledo Airport and Camp Perry, a National Guard training facility.[128]

Between 2003 and 2008, the Ohio Third Frontier program invested over $39 million on the state's photovoltaic research base and in individual companies commercializing solar cell products and processes, including a $2 million Wright Project grant to UT to establish the Center for Photovoltaic Electricity and Hydrogen, which involved research collaboration with local PV firms, and an $18.6 million grant to UT in 2007 to help it launch the Center for Photovoltaics Innovation and Commercialization that absorbed the Center for Photovoltaic Electricity and Hydrogen. The Third Frontier has also invested over $15 million in Rocket Ventures, a program of the Toledo Regional Growth Partnership providing financial support for entrepreneurial commercialization in northwest Ohio.[129]

Initial Rapid Growth

By 2009, the area of northwestern Ohio around Toledo had more cadmium-telluride and glass expertise than any other region in the world.[130] The area's burgeoning photovoltaic industry also increased demand for output from local glass producers, who could offset declining sales in traditional glass markets with sales of thin films to solar manufacturers.[131] By 2011, Ohio ranked second in the U.S. in solar panel output.[132]

Dan Johnson, a former UT professor who now serves as the University's Director of Global Initiatives commented in 2012 that leadership in

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[128]Norman Johnston, "The Toledo, Ohio Solar Cluster" in National Research Council, *The Future of Photovoltaics Manufacturing in the United States: Summary of Two Symposia,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2011, p. 95; Toledo Free Press, "Ohio National Guard Expands Solar Energy Field." January 1, 2010.
[129]SRI International, *Making an Impact,* 2009, op. cit., p. 33.
[130]Norman Johnston. "The Toledo, Ohio Solar Cluster" in National Research Council, *The Future of Photovoltaics Manufacturing in the United States: Summary of Two Symposia,* p. 97.
[131]*Wall Street Journal,*" Toledo Finds the Energy to Reinvent Itself," December 18, 2007.
[132]*The Blade.* "Ohio Ranked 2nd in the U.S. in Solar-Panel Output," July 19, 2007.

photovoltaic science and UT combined with the local presence of the glass industry make the Toledo region the perfect site for solar development:

> *We had a head start on the industry in many ways," Johnson said. "Toledo had the key players involved early on. The University of Toledo researchers—a very active and respected team of researchers—were early leaders of the solar industry in the region. We also had the active participation of our local economic development organizations and professionals. They played their roles and, in my view, played them quite well despite major changes in their own organizations and leadership. Local government officials did what they could, largely adding their moral support and talking up Toledo's budding solar industry. Add to that the significant infusions of venture capital, grants and loans. And, finally, there were the individual entrepreneurs and investors. All the ingredients were in place.*[133]

The Global Photovoltaic Slump

Despite promising beginnings and a strong technology position, Toledo's photovoltaic cluster faces an uncertain future. Global demand for solar modules has declined, reflecting decisions by a number of European governments to curtail subsidies for solar power production.[134] At the same time, global production capacity has grown dramatically, particularly in China and Korea. According to a 2011report by the Swiss Bank Sarasin, in that year, global production capacity for solar modules "soared to 50 gigawatts, but the industry only managed to sell 21 gigawatts of that photovoltaic potential.[135] U.S. companies "complained that solar prices have been negatively affected by China's flooding the world market with solar panels priced below production costs."[136]

By 2012, a global shakeout of the solar industry was underway. Eight of Korea's nine photovoltaic cell manufacturers collapsed or were sold.[137] First Solar indicated in April 2012 that it would cut its global work force by 30 percent, although its Toledo area operations were largely spared.[138] However, some Toledo area photovoltaics firms were reportedly struggling financially. In November 2012, it was reported that the state of Ohio might not be able to recover the full amount of loans totaling $10.3 million to Willard & Kelsey

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[133]Toledo *Free Press,*" Sun Burn IV: UT, RGP, Port Leads Toledo into Solar's Future," August 23, 2012.
[134]*Spiegel Online,* "Twilight of an Industry: Bankruptcies Have German Solar on the Ropes," April 3, 2012.
[135]*Spiegel Online,* "Setting Sun: Eastern Germany Hit Hard by Decline of Solar," April 27, 2012.
[136]Toledo *Free Press,* "Sun Burn 2: Global Changes Slow Solar Growth." July 26, 2012.
[137]*JoongAng Daily Online,* "Lights Go Out for Most PV Cell Makers." June 12, 2012.
[138]*The Blade,* "First Solar to Ax Global Work Force by 30%." April 12, 2012.

Solar Group, which was facing mounting "bills, legal challenges, and financial troubles."[139] Xunlight Corporation was reportedly making interest-only payments on state loans that were supposed to include principal repayments. The shakeout was not confined to Ohio; in May 2013, the largest Chinese producer of photovoltaics went bankrupt unable to serve a burden of debt.[140] The impact of China's policies to encourage the production of solar panels can have major consequences in the viability of Ohio-based firm half a world away.[141]

OHIO'S CHALLENGE AHEAD

While there are many notable initiatives underway in Ohio, the state's economic transformation will not happen overnight, warned participants at the National Academies' symposium on Building the Ohio Innovation Economy.[142] Dan Berglund of the Columbus, Ohio based State Science and Technology Institute noted that raising state income levels requires a long-term commitment and effort by all involved. Research Triangle Park has made significant contributions to North Carolina's economy, he said, but it took thirty years of sustained commitment to accomplish this goal.[143] Reflecting on his own firm's experience with renewal, James Griffith noted that Timken's transformation "came after 10 years of hard work, including a strong focus on innovating and the need to rip out the infrastructure and habits that inhibited innovation within a 100-year-old company." The key lesson from the northeast Ohio experience, he said, is to restructure existing assets to take advantage of regional strengths and

[139]*The Blade, "*Local Solar Firm Awash in Debts," November 11, 2012.

[140]"Chinese solar panel maker Suntech flames out," *The Washington Post* May 3, 2013.

[141]"Meanwhile, in late 2011, a group of U.S. solar panel manufacturers filed an anti-dumping case and won tariffs against Chinese firms. U.S. statistics indicate a sharp drop in imports from China, though some Chinese-made panels might be coming through third countries."Ibid. A spokesman for a rival U.S.-based firm argued that "We believe Suntech suffers from the same unsustainable, distortive industry factors that confront everyone: China's dumped pricing and massive overbuilding… Chinese companies can sell below their costs for only so long before they either go out of business or the Chinese government props them up, extending the anti-competitive problem." Ibid. In 2012, the U.S. imposed antidumping duties ranging from 24 percent to over 250 percent ad valorem, based on the particular company, on imports of solar panels from China. In May 2013, the European Union imposed provisional antidumping duties on imports of solar panels from China, averaging about 47 percent ad valorem. "U.S. Sets Antidumping Duties on China Solar Imports," *Bloomberg* October 10, 2012; "China Sun Panels Face EU Levies," *Financial Times* May 6, 2013. In March 2013, Suntech, a Chinese firm which is the largest producer of solar panels in the world, defaulted on a $541 million bond payment. The company had reportedly been relying on the city of Wuxi to remain solvent. "Chinese Solar Firm Suntech Defaults on Bond Payment," *Houston Examiner* March 19, 2013.

[142]National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium,* op. cit.

[143]For a history of Research Triangle Park, See Albert N. Link, *A Generosity of Spirit: The Early History of the Research Triangle Park,* Research Triangle Park: Research Triangle Foundation of North Carolina, 1995. See also Albert N. Link, *From Seed to Harvest: The Growth of the Research Triangle Park*, Research Triangle Park: Research Triangle Foundation of North Carolina, 2002.

new opportunities, to reinvest in the skills and technologies of the future, to create the right incentives for innovation and entrepreneurship, and to stay the course.

LESSONS LEARNED

Ohio's ongoing industrial turnaround effort employs many policy tools observable in other states and regions, but the effort itself is arguably *sui generis*:

- The state has made major and sustained resources available to promote innovation, most notably through the Third Frontier program, but has not engaged in significant central direction, allowing developmental decisions to devolve onto regional parapublic organizations like NorTech which provide mentoring, networking, and early stage funding.
- The engagement of foundations, which have fostered the emergence of innovation intermediaries, has facilitated the sidestepping of bureaucratic gridlock that could have resulted from Ohio's large number of governmental subunits.
- Innovation initiatives have been highly focused on certain sectors (over half of the Third frontier's investments involve biomedicine and bioscience.
- Ohio's innovation initiatives take an expansive view of the role of universities in the local economy, which work closely with industry in new ways to foster local economic development.
- Civic entrepreneurship, a pervasive philanthropic tradition, and leadership by key industry figures have played an important role in Ohio's industrial revival effort.

Chapter 7

The New York Nanotechnology Initiative

New York state's two-decade long effort to transform the upstate region into a leading center of nanotechnology R&D offers a dramatic example of how the initiative of a single U.S. state can transform the global competitive map in a strategic economic area. Reflecting large-scale investments, particularly in university research infrastructure, and collaborative arrangements with the private sector and regional development organizations, New York has altered the competitive landscape in the semiconductor industry, at least partially staunching the offshore flow of U.S. investment and jobs in this sector that has been a longstanding concern of policymakers and the U.S. semiconductor industry itself. Because the sheer scale of the financial and human capital that New York has been able to deploy cannot be matched by most U.S. states, the applicability of New York's nanotechnology model may be limited. At the same time, New York's success to date raises the question whether essential principles of the model could be employed to address similar challenges, if not on a state-by-state basis, perhaps on a regional one.

The epicenter of New York's semiconductor effort is the State University of New York at Albany. SUNY is the largest university system in the United States with 88,000 faculty and 468,000 students and a research budget of nearly $1 billion.[1] SUNY's audacious goal has been stated by Chancellor Nancy L. Zimpher as serving as a "key engine of revitalization for New York State's economy."[2] SUNY Albany is one of six "NY Innovation Hubs" established to link university-based research to regional innovation, and sustained investments

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[1]Presentation by Dr. Tim Killeen, "The New York Innovation Economy and the Nanotechnology Cluster: The Role of SUNY," National Research Council Symposium, "New York's Nanotechnology Model: Building the Innovation Economy" Troy, New York, April 4, 2013.
[2]Presentation by Dr. Nancy L. Zimpher, "The Power of SUNY," National Research Council Symposium, "New York's Nanotechnology Model: Building the Innovation Economy" Troy, New York, April 4, 2013.

in the university's research infrastructure have it to become one of the foremost centers of nanotechnology research in the world and a regional economic driver.

UPSTATE NEW YORK: THE ECONOMIC CHALLENGE

In the mid-1990s, upstate New York (the region north of the New York Metropolitan Area) had "one of the weakest, if not the weakest, economies of any region in the country."[3] Economic mainstays of the region, such as Xerox, Kodak, and Bausch & Lomb, were shedding thousands of jobs, and companies and individuals were leaving to pursue opportunities in other parts of the country. Between 1995 and 1997, "departures exceeded arrivals in upstate New York by nearly 169,000 people," and population in the region declined by about half of one percent. An engineering major at Syracuse University observed anecdotally in 1997, of the 40 engineering majors that had passed through his fraternity since 1993, only 3 remained in the region.[4] The stagnation of the regional economy, attributed, in particular, to the erosion of the manufacturing sector, contrasted with the nation's generally robust economic performance. Between 1990 and 1996, employment in upstate New York declined by 1.3 percent while the U.S. enjoyed 15.0 percent job growth.[5]

At the same time, upstate New York enjoyed intrinsic advantages in competing for technology-intensive economic development. It was already the site of sophisticated R&D operations by world-class companies such as IBM, Corning and GE.[6] The New York state educational system compared favorably to those of other states at a time when U.S. high tech companies were increasingly complaining about deficiencies in workforce education and training.[7] And as events would show, New York's political leadership proved capable of sustained and persistent commitment to long range economic development objectives despite multiple changes of administration. As a result, in one of the most extraordinary developments in recent U.S. industrial history,

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[3]Mark M. Zandi, Chief Economist, Regional Financial Associates, an economic consulting firm based in West Chester, Pennsylvania, in "As U.S. Economy Races Along, Upstate New York is Sputtering," *New York Times* May 11, 1997.
[4]"As U.S. Economy Races Along, Upstate New York is Sputtering," *New York Times* May 11, 1997.
[5]"Is Upstate New York Showing Signs of a Turnaround?" Federal Reserve Bank of New York, *Current Issues in Economics and Finance* May 1999.
[6]Darren Suarez, Director of Government Affairs, The Business Council of New York State, "Challenges and Opportunities for the New York Innovation Economy," National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy," Troy, New York, April 3, 2013.
[7]Gary Patton, Vice President, Semiconductor Research and Development Center, IBM, recalls that 27 years ago he relocated from California to New York, in significant part, because the schools made it a good place to raise a family. Citing California's Proposition 13, he said "I could see that California schools would be on a downward spiral. New York was much better." He emphasizes the "importance of education for this region and the country." Presentation by Gary Patton, National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy," Troy, New York, April 4, 2013.

upstate New York has given rise to "Tech Valley," the site of the most advanced semiconductor manufacturing operations in the world and arguably the nation's preeminent center of nanotechnology R&D. This effort, which has strategic implications for the U.S., is particularly noteworthy because—despite some federal assistance—it has been driven and funded largely by the state of New York and New York-based companies and implemented by the state university system (SUNY), local development organizations, and local firms.

THE SEMICONDUCTOR ADVANTAGE—AND CHALLENGE

Semiconductors are "the premier general purpose technology of our post industrial era."[8] Today they comprise the basic enabling technology for virtually any device that moves or which stores, transmits and manipulates information. Semiconductors are a premier U.S. export industry, second only in revenue generated to aerospace products, and are a source of high wage employment—accounting for nearly 245,000 U.S. jobs in 2011 with an average salary 2.5 times higher than the average for U.S. workers.[9] Semiconductors are critical to national security because they provide the basic technological underpinning for virtually every U.S. defense system and weapons platform.[10] Ajit Manocha, the CEO of New York-based GlobalFoundries, one of the world's largest semiconductor manufacturers, characterizes semiconductors as "the most important strategic technology on this planet," and regards U.S. advances in semiconductor technology as "the crown jewels of this country."[11]

The semiconductor industry originated in the United States and the U.S. semiconductor sector remains the world leader in technology levels and market share. However, it faces daunting challenges as advances in technology push the reduction in semiconductor circuitry to the extreme physical limits of miniaturization.[12] The cost of R&D and semiconductor fabrication has escalated in a spectacular fashion, with the cost of a current-generation wafer fabrication facility exceeding $3 billion and the next generation escalating to $10 billion or more. Semiconductor companies have responded to these pressures through collaboration and, increasingly, the outsourcing of research and production functions entailing the highest costs and greatest risks. A growing number of U.S. semiconductor firms are "fabless," meaning that they outsource their

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[8]National Research Council, *Securing the Future: Regional and National Programs to Support the Semiconductor Industry,* C. Wessner, ed., Washington, DC: The National Academies Press, 2003, p. 9.

[9]Semiconductor Industry Association.

[10]Industrial College of the Armed Forces, *Electronics 2010*, Industry Study Final Report, National Defense University, Spring 2010.

[11]Ajit Manocha, "Keynote Address," National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy," Troy, New York, April 3, 2013.

[12]See presentation by Dr. Michael Polcari, IBM, "Current Challenges: A U.S. and Global Perspective," in National Research Council, *Securing the Future: Regional and National Programs to Support the Semiconductor Industry,* op. cit., pp. 111-121.

designs to semiconductor "foundries" for production, e.g., companies that manufacture semiconductors on a contract basis in return for a service fee.

As a number of foreign governments have sought to establish and promote indigenous semiconductor industries, the U.S. has found its leadership in the industry challenged since the beginning of the 1980s.[13] The disaggregation of R&D and production functions which began in the 1990s created an opening for national governments to establish semiconductor foundries and other entities providing outsourcing services to the semiconductor industry. This has resulted, in effect, in a partial migration of production functions from the U.S. to those countries. The foreign foundries have offered a cost advantage over U.S.-based production because the foreign operations benefited from lower taxes and massive government financial assistance.[14] In addition, in recent decades, some foreign governments have offered incentives to U.S.-based semiconductor firms to establish local R&D and production operations.[15] In 2006, Craig Barrett, then CEO of Intel, the world's largest producer of semiconductors, commented on the factors underlying his company's decision on where to locate new manufacturing facilities:

> *The cost to build and equip a new wafer fabrication facility today is $3 billion or more. Where, and when, to build a fabrication plant is the largest ongoing financial decision a semiconductor CEO must make…[I]t costs $1 billion more to build, equip, and operate a facility in the U.S. than it does outside the U.S.…[M]ost of the $1 billion cost different (about 70%) is the result of lower taxes; also, if the taxes were combined with capital grants, then as much as 90% of the cost difference occurs [as a result of government policies](emphasis added).*[16]

As a result of these developments, the U.S. was experiencing a migration of production and, to a lesser degree, R&D functions to other countries, particularly in the East Asian region.[17]

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[13]See generally Thomas R. Howell, "Competing Programs: Government Support for Microelectronics," in National Research Council, *Securing the Future: Regional and National Programs to Support the Semiconductor Industry,* op. cit.

[14]See National Research Council, *Securing the Future: Regional and National Programs to Support the Semiconductor Industry,* op. cit.

[15]In 2005 Israel concluded a deal with Intel pursuant to which the company would install a state-of-the-art fab (300mm, 45nm) at Kiryat Gat, in which a $1 billion package of incentives was the decisive factor in Intel's locational decision. "Intel VP: Extra Aid Brought Fab 28 to Israel," *Israel Business Arena* December 1, 2005.

[16]Statement of Craig R. Barrett before Subcommittee on Select Revenue Measures, House Ways and Means Committee June 22, 2006.

[17]Semiconductor Industry Association, *Maintaining America's Competitive Edge: Government Policies Affecting Semiconductor R&D and Manufacturing Activity*, March 2009. As of 2007 Singapore, with a population of only 4 million people, had an "incredible" array of then state-of-the-art 300mm wafer fabs. The CEO of Qimonda, a German firm which operated one of the five

The prospect of large-scale out-migration of semiconductor manufacturing operations has troubling implications for future U.S. competitiveness and security. Process R&D capabilities—that is, the know-how necessary to operate semiconductor manufacturing facilities—tends to be co-located with the state-of-the-art plants. Loss of those plants to other countries normally means the loss of the people and the know-how needed to run them. Similarly, the complex supply chains needed to support wafer fabrication and other production and testing functions tend to migrate with the fabs themselves. The prospect of the substantial relocation of much of the infrastructure of the semiconductor industry, as well as the associated jobs, to sites outside the United States threatens to have adverse ripple effects throughout the U.S. economy.

NEW YORK'S OPPORTUNITY

The mounting competitive pressures on the U.S. semiconductor industry presented an opening to New York policymakers seeking to reverse economic decline in the state's Capital region. In the early 1990s, New York's then-Governor George Pataki convened a group of stakeholders to address the fact that much of upstate New York was an "economic shambles," hemorrhaging manufacturing jobs in traditional sectors like steel as well as high-tech jobs from companies like GE, Xerox, and Kodak. The Pataki group decided that an integrated R&D, education and commercial strategy built around a Governor's Center of Excellence and anchored by a university was needed. With the encouragement of IBM, the governor's group chose "nanotechnology"—that is, the ability to manipulate matter at the atomic level—as the thematic area for this effort.[18] Nanotechnology was chosen because of the cross-cutting nature of the technology, with potential applications in many sectors. This choice also reflects the influence of then SUNY-Albany Professor Alain Kaloyeros, a physicist specializing in materials science who was active in the field.[19] The first sector to feel a substantial impact from New York's commitment to nanotechnology was the semiconductor industry.[20]

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fabs, gave the rationale for choosing Singapore as the site: "In Singapore, we have found excellent conditions. The overall package of low taxation, incentives and factors such as highly skilled labor and strong infrastructure makes Singapore our place of choice to implement our fully-owned volume production in the Asian market." *Ibid*, citing "Resurrection of 12" Fabs in Singapore," *Sikod* April 27, 2007.

[18]Presentation by Pradeep Haldar, Vice President and Professor, SUNY-Albany CNSE, National Research Council symposium, New York's Nanotechnology Model: Building the Innovation Economy, Troy, NY, April 4, 2013.

[19]Interview with Karen Hitchcock, President, SUNY-Albany, 1996-2004, Troy, NY, April 4, 2013. Nanotechnology applications exist in telecommunications, electronics, clean energy, aerospace, pharmaceuticals and medicine, and national defense.

[20]In 1993, Alain Kaloyeros helped persuade the state to fund the Center for Advanced Thin Film Technology at SUNY-Albany, a technology with microelectronics applications. "How SUNY

New York state has long been a site for "captive" production of semiconductors for internal use by IBM, which has operated production sites at East Fishkill, NY since the 1960s. Although IBM's capabilities in microelectronics were typically state of the art, by the 1980s the company recognized that as the costs and risks associated with microelectronics escalated, even a firm with IBM's resources and scale would be required to rely to an increasing extent on external sources of supply and/or collaborative arrangements to ensure a stable source of state-of-the-art components for its information technology products and systems. IBM was actively involved in a number of industry and public policy initiatives to address the growing technological challenges facing the industry and ensures a stable base of vendors capable of producing the quality and volume of devices the company required. The most important of these initiatives was the 1987 formation of SEMATECH, a U.S.-based, industry- and federally-funded research consortium created to enhance U.S. production quality and competitiveness in semiconductor manufacturing.

Box 7-1
SEMATECH

SEMATECH originated in 1987 as an R&D consortium intended to halt the erosion of U.S. manufacturing competitiveness in semiconductors, and reflected recommendations by the industry, the Defense Science Board, and key members of Congress and the Reagan administration. It was originally co-funded by industry participants and the Department of Defense at a level of $200 million per year. All of the principal U.S. device makers participated and—in a unique development—committed their top talent to collaborative R&D in the public-private partnership. SEMATECH made major progress in enhancing process technology in areas such as lithography, deposition, plasma etch, and furnace and implant, and also played a key role in sustaining the infrastructure of U.S. tool and materials suppliers. SEMATECH is widely credited with contributing to the U.S. semiconductor industry regaining world market leadership from Japan in the 1990s. Most federal support for SEMATECH ended in 1994, but in a credit to its success, the industry participants have continued to support the consortium—which now includes international members—down to the present day.[21]

Albany Shocked the Research World and Reaped a Bonanza Worth $850 Million (and Counting)," *The Chronicle of Higher Education* February 7, 2003.

[21]In addition to the technical contributions of SEMATECH, the recovery of the U.S. semiconductor industry also depended on the 1986 Semiconductor Trade Agreement with Japan and the inventiveness and commitment of the U.S. companies in repositioning themselves. The trade agreement prohibited dumping product below cost in both the U.S. and foreign markets. It also contained provisions aimed at increasing the market share in Japan of U.S. producers to counter the closure of that market. The implementation of this agreement was essential, first to the recovery, and then to the growth of the U.S. semiconductor industry. The combination of these factors has been described as a "three-legged stool," with each factor critical to the industry's recovery but

New York's political leadership has sought to enhance the state's position in semiconductors since the mid-1980s. New York made a strong, albeit unsuccessful bid to provide the original site for SEMATECH when the consortium was formed in 1987.[22] In 1988, Governor Mario Cuomo's SUNY Graduate Research Initiative supported the establishment of an advanced semiconductor program at the State University of New York (SUNY) at Albany. In 1995, SUNY-Albany launched a major effort to enhance its capabilities in the sciences.[23] In the early 2000s IBM and SUNY-Albany cooperated to create the world's only site of a 300-mm wafer nanoelectronics R&D and prototyping complex.[24] The state followed up with large-scale grants to develop research infrastructure for semiconductors, initiatives which were met with a strong matching response from industry and, in some cases, the federal government:

- The state provided $85 million of a total public/private commitment of $185 million to create the Center of Excellence in Nanoelectronics and Nanotechnology (CENN) in collaboration with IBM.[25]
- The state committed $100 million to a $300 million-total project with Tokyo Electron Limited at the Albany Center of Excellence to develop semiconductor manufacturing technology.[26]
- The state invested $35 million to support the Interconnect Focus Center for Hyper-Integration, concentrating on nano-scale interconnect

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likely insufficient on its own. See National Research Council, *Securing the Future: Regional and National Programs to Support the Semiconductor Industry,* op. cit., p. 82; Kenneth Flamm and Qifei Wang, "SEMATECH: Revisited: Assessing Consortium Impacts on Semiconductor Industry R&D," in National Research Council, *Securing the Future: Regional and National Programs to Support the Semiconductor Industry,* op. cit., pp. 254-81; Andrew A. Procassini, *Competitors in Alliance: Industrial Associations, Global Rivalries, and Business-Government Relations*, Westport, CT: Quorum Books, 1995, pp. 194-6; see generally, National Research Council, *Rising to the Challenge: U.S. Innovation Policy for the Global Economy*, C. Wessner and A. Wm. Wolff eds., Washington, DC: The National Academies Press, 2012, pp. 333-335.

[22]New York offered SEMATECH a site at the Rensselaer Technology Park in North Greenbush, New York. "Fall Meeting Planted Seed for Deal," Albany, *The Times Union* July 18, 2002.

[23]"How SUNY Albany Shocked the Research World and Reaped a Bonanza Worth $850 Million (and Counting)," *The Chronicle of Higher Education* February 7, 2003.

[24]Significantly, the state's funding of the University of Albany's nanotechnology enjoyed bipartisan support. Key players were Republican Governor Pataki, Republican Senate Majority Joseph Bruno, and Democrat Assembly Speaker Sheldon Silver.

[25]"IBM Executive Shares Vision of High Tech Future," *The Times Union* February 23, 2003. IBM "pledged in April 2001 to pay $100 million over three years to help construct the nation's only university-based facilities that support research in the design and manufacture of ultrathin silicon wafers with a 300-milimeter diameter." "How SUNY Albany Shocked the Research World and Reaped a Bonanza Worth $850 Million (and Counting)," *The Chronicle of Higher Education* February 7, 2003. College of Nanoscale Science & Engineering, University of Albany, "Center of Excellence in Nanoelectronics and Nanotechnology (CENN)," <cnse.albany.edu/LeadingEdgeResearchandDevelopment2/CenterofExcleence.aspx>

[26]"U Albany Lands R&D Center," *The Times Union* November 21, 2002.

technology, a project co-funded by DARPA and the Microelectronics Advanced Research Corporation (MARCO).

The R&D infrastructure for a number of these projects was partially funded by private investments through the Fuller Road Management Corporation, a private not-for-profit corporation created through a partnership between the Research Foundation of the State University of New York and the University at Albany Foundation to manage the nanotechnology facilities.[27]

Perhaps the region's biggest coup arose out of the leadership of then-New York governor George Pataki. In September 2001 he met privately with SEMATECH President Robert Helms and made it clear that New York "wanted to be in SEMATECH's expansion plans." Pataki and a small team of assistants worked to persuade SEMATECH to open its second research facility in New York. SUNY Albany's Alain Kaloyeros, who was part of that team, said that "Pataki was intimately involved, keeping the momentum going from that [original] September meeting."[28] The deal, which was announced in mid-2002, provided for a research collaboration between SUNY-Albany and SEMATECH pursuant to which the state contributed $160 million and SEMATECH $40 million to a joint research effort; SEMATECH and SUNY-Albany agreed to contributions of $120 million in in-kind investments (including SEMATECH's know-how); IBM contributed $100 million in equipment and other resources to the university; and the state contributed another $50 million towards the construction of two semiconductor research laboratories in Albany.[29]

The arrival of SEMATECH (from Austin Texas) and Tokyo Electron in the 2000-02 period heralded the beginning of a sustained and expanding movement of semiconductor device, equipment and supply chain firms into the Albany area. Both Tokyo Electron and International SEMATECH "were drawn by the university's construction of a 300-millimeter semiconductor research center, an expensive technology off-limits to all but the largest companies." Alain Kaloyeros, observed in 2002 that the semiconductor industry was engaged in a "tricky and expensive" transition from making chips on silicon discs 200 millimeters in diameter to 300mm, a move that would ultimately drive down costs dramatically but which entailed an unprecedented level of investments in R&D and plant. Albany's 300-mm center "gives companies access to equipment owned by a precious few, largely because the cost is so prohibitive." Through

[27]"Sematech Pact with UAlbany is Finalized…Company Officials in Town for Announcement by Pataki," Schenectady, *The Daily Gazette* January 28, 2003.

[28]"Fall Meeting Planted Seed for Deal," Albany, *The Times Union* July 18, 2002. The working group reportedly included Pataki himself, his higher-education aide, Kaloyeros, Hitchcock and about five individuals from SEMATECH. "How SUNY Albany Shocked the Research World and Reaped a Bonanza Worth $850 Million (and Counting)," *The Chronicle of Higher Education* February 7, 2003.

[29]"SEMATECH Touts the Benefits of its New York Alliance," *Austin American-Statesman* July 19, 2002.

large scale investments in research facilities that could be made available to companies, the state had "assembled the key parts necessary to form a cluster of nanotechnology companies…They're coming here because of the university's investment in 300-millimeter technology."[30] Daniel Armbrust, President and CEO of SEMATECH, comments that

> *We came to Albany because of shared investments. We share the infrastructure that's been put in here. In Texas we were on our own. At $13 billion and counting, there was no way to do it on our own. R&D costs would have consumed all of our revenue. Most jurisdictions—except New York state and a little bit of federal—have concluded this industry is mature, let's just let it run.*[31]

Other locational factors favored the Albany region. IBM's head of technology, John E. Kelly, a driving force behind the emerging nanotechnology cluster, had local roots in the region, having earned a bachelor's degree from Union College in Schenectady and a masters in physics from Rensselaer Polytechnic Institute in Troy. The company already had a considerable history working with the State University of New York at Albany on a "wide variety of research projects" and had hired numerous graduates from the institution. Kelly cited the company's advocacy of the Albany site as also deriving from the fact that New York has an "educated, skilled work force" and "political leadership support, especially from Governor Pataki."[32]

During and after 2005, new investments by microelectronics companies in the Albany area snowballed. In 2005, ASML, one of the world's largest makers of semiconductor manufacturing equipment, announced a $325 million investment in Albany. IBM, Advanced Micro Devices, Micron Technology and Infineon joined in a $600 million consortium ($180 million provided by the state) to integrate the technical capabilities of the companies to develop lithography, a project dubbed INVENT. In September 2005, IBM and Applied Materials committed to joint new investments of $300 million in

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[30]"U Albany Lands R&D Center," *The Times Union,* November 21, 2002. "Many researchers and industry officials…praise SUNY Albany officials for their vision and commitment to building highly competitive research facilities. They say it is an unusual approach in higher education, one that focuses on identifying an area of research to pursue and then assembling an aggressive team to win money and equipment to pull in top researchers and key investors." "How SUNY Albany Shocked the Research World and Reaped a Bonanza Worth $850 Million (and Counting)," *The Chronicle of Higher Education* February 7, 2003.

[31]Presentation by Daniel Armbrust, National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy," Troy, New York, April 4, 2013.

[32]"IBM Executive Shares Vision of High Tech Future," *The Times Union,* February 23 2003. Pataki, a Republican, enjoyed bipartisan support for then-Senator Hillary Clinton, who cosponsored a bill in Congress to provide multiyear funding for nanotechnology research. She noted President Clinton's launch of the National Nanotechnology Initiative in 2000 and observed in 2002 that "as I recall it was one of the very few things my husband did that Newt Gingrich agreed with." "Sec. Clinton Wants Research to Result in Jobs for Region," *The Daily Gazette* November 21. 2002.

Box 7-2
The Center for Economic Growth

Founded in in 1987, the Center for Economic Growth (CEG) is a private, not-for-profit organization promoting economic development in New York's 11-county Capital Region.[33] It is funded by its industry members as well as Empire State Development's Division of Science, Technology and Innovation, the National Institute of Standards and Technology (NIST), National Grid, and the federal Manufacturing Extension Partnership (MEP). CEG was set up because the local private sector did not want economic development consigned only to government organizations. CEG works to help the Capital Region compete internationally for investment. In semiconductors, CEG has been instrumental in outreach to tool and material companies whose local presence is necessary to support semiconductor manufacturing operations.[34]

nanotechnology research in the Albany area.[35] AMD announced plans to build a $3.2 billion semiconductor wafer fabrication plant in Saratoga County in 2006, the culmination of over eight years of talks between the company and state economic development officials.[36] In 2008, IBM concluded a $1.6 billion deal with New York State that included establishment of a 120,000 square foot, 675-employee, R&D center dedicated to semiconductor packaging technology that would be owned and operated by the College of Nanoscale Science and Engineering (CNSE).[37] In 2010, SEMATECH indicated it would move most of its remaining workers from its base in Austin, Texas, to Albany or replace them with new hires.[38]

The various university-industry research collaborations in microelectronics which emerged after 2000 grew out of necessity—as the former President of the University at Albany, recalls, "we knew that if we went into this field [nanotechnology] we needed partners because of the cost involved. We needed companies to invest in academics, and they did," she notes, citing the funding of post-doc fellowships and equipment by IBM and other industrial partners. IBM's "$100 million gift was the big, early investment" and led to the first example of co-location by industry and

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[33]"New York's Capital Region generally refers to the four counties surrounding Albany, the state capital.
[34]Interview with David Rooney, Senior Vice President, CEG, Malta, New York, April 3, 2013.
[35]*The Daily Gazette*. 2006. "U Albany Ready to Organize Itself in Nanotech Research," February 26.
[36]"For Planning Growth, the Future is Now—Changes that AMD Could Bring to the Region Must Be Anticipated, Executive Warns," *The Times Union* March 25, 2007
[37]"Region Wins $1.6 Billion IBM Pact," *The Times Union* July 16, 2008.
[38]"Key SEMATECH Program, Jobs Moving to New York," *Austin American-Statesman* October 13, 2010.

university researchers at a single site.[39] Co-location is necessary because the partners "couldn't afford it otherwise." This commitment led to collaboration by individuals involved in basic and applied research, prototyping and commercialization "all in a single site," which allowed unique "interactions over a coffee cup." As the collaborations moved ahead, "the Governor kept putting up matching funds. Also, the Assembly, the Senate all came together" to support the effort.[40]

THE COLLEGE OF NANOSCALE SCIENCE AND ENGINEERING (CNSE)

In 2004, the University of Albany launched the College of Nanoscale Science and Engineering (CNSE) to train a specialized nanotechnology work force.[41] The governor was reportedly convinced that formation of CNSE would "lead to clustering," an expectation events proved to be correct. Faculty was drawn from other universities and from companies; in addition, CNSE brought in some scientists (including several from IBM and SEMATECH) who worked on site but did not have teaching assignments.[42] By 2007, CNSE had grown from an initial student body of 40 to 120 and had succeeded in recruiting Dr. Ji Ung Lee, a preeminent scientist from GE Global Research specializing in carbon nanotubes, to its faculty.

In 2006, *Small Times* magazine, a trade publication, named CNSE as the "number one college for nanotechnology."[43] In 2007, SEMATECH agreed to house the headquarters of International SEMATECH at CNSE and the college built a $100 million 250,000 square foot facility to accommodate the research consortium.[44] In a 2008 presentation, SEMATECH CEO Michael Polcari indicated that while its research in Albany had been largely limited to lithography, "going forward almost all major [SEMATECH] research will be done in Albany, including development of three-dimensional interconnect technology." He observed that

> *many of the technological advances that SEMATECH members are trying to achieve by making computer chips more powerful and more*

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[39]In 2001, IBM agreed to contribute $100 million to SUNY's microelectronics program with the state of New York contributing another 50 million. "SUNY Albany gets $150 Million for Development of Microchips," *New York Times* April 24, 2011.
[40]Interview with Karen Hitchcock, Troy, New York, April 4, 2013.
[41]The new College absorbed 25 faculty members and 40 students currently matriculating in the university's School of Nanosciences and Nanoengineering and was expected to double its faculty size and expand enrollment to 500 graduate students. "U Albany to Have Nanotech College," *The Times Union* January 8, 2004.
[42]Interview with Karen Hitchcock, Troy, New York, April 4, 2013.
[43]"U Albany NanoCollege Tops Rising Star at GE," *The Times Union* February 9 2007.
[44]"SEMATECH News boon for Albany," *The Times Union* October 17, 2007; "SEMATECH Deal Brings Business, High-Tech Jobs," *The Daily Gazette* February 24, 2008.

TABLE 7-1 Growth of CNSE Facilities

Facility	Cost (Millions of Dollars)	Cleanroom	Thousands of Square Feet	Completed
NanoFab 200	16.5	4k	70	6/97
NanoFab South	50	32k	150	3/04
NanoFab North	175	35k	228	12/05
NanoFab Central	50	15k	100	3/09
NanoFab East	100	-	250	3/09
NanoFab Xtension	365	60k	250	12/12

SOURCE: Presentation by Pradeep Haldar, CNSE Vice President, April 3, 2013.

> *profitable are happening now at the NanoCollege* [CNSE]. *The NanoCollege has been leading advances in so-called extreme ultraviolet lithography, which uses light of extremely short wavelengths to etch ever-smaller components and circuits on a wafer.*[45]

As of early 2013, CNSE had grown from an initial enrollment of 10 graduate students to over 300 graduate and undergraduate students studying curricula in NanoBioscience, NanoEconomics, NanoEngineering, and NanoScience. It operates 800,000 square feet of facilities space which will be augmented by another 500,000 square feet.

A senior manager of silicon technology for IBM characterized CNSE's facilities as "unparalleled" in the industry, noting that "most computer chip innovations that IBM invents in its labs are tested first on CNSE's clean room equipment.[46] In 2008, the National Institute of Standards and Technology (NIST) announced that it would collaborate with CNSE to establish standard

[45]"SEMATECH Boss Touts NanoCollege Research," *The Times Union* May 20, 2008.
[46]Ibid.

measurements for nanotechnology. CNSE was "not ordinary."[47] Its lab

> *is considered to be a Switzerland for semiconductors, and the University serves as the neutral intermediary. Researchers from rival for-profit companies like IBM, and GlobalFoundries collaborate in an innovative partnership with the school, without worrying about their technology falling into the competitors' hands.*[48]

To a significant degree, the evolution of CNSE into what is considered "the nation's premier research facility for nanotechnology" reflects the vision and persistent efforts of Alain Kaloyeros, who was originally recruited in 1988, after receiving a Ph.D in experimental condensed matter physics from the University of Illinois, under an initiative by Governor Pataki to encourage graduate research at SUNY-Albany. Kaloyeros saw the potential of the location to support innovative research, and "found a partner in IBM to persuade private-sector technology companies to move in and spend hundreds of millions of dollars to outfit new quarters at the site with matching state funds." Kaloyeros has played a catalytic role, proving "adept at navigating Albany politics, befriending aides to leaders and the leaders themselves, and touting how his project would be good for business, the economy, for New York." Key political figures whose support was secured over time include Senate Majority Leader Joseph L. Bruno and U.S. Senator Chuck Schumer.[49] At present Kaloyeros serves as CEO and Senior Vice President of CNSE.

RENSSELAER POLYTECHNIC INSTITUTE

In addition to CNSE, semiconductor and other high tech companies locating in the Albany area have benefitted from the presence of the nation's oldest technical university, Rensselaer Polytechnic Institute (RPI) in nearby Troy, New York.[50] RPI's President, Shirley Ann Jackson, emphasizes that the institution's core mission is the preparation of students for careers in the sciences and engineering. Reflecting RPI's preeminence in this role, GlobalFoundries, currently the largest local semiconductor manufacturer, recruits more of its workforce from RPI than anywhere else.[51] RPI is engaged in research partnerships with local firms such as IBM, GE and GlobalFoundries.

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[47]"NanoCollege Welcomes New Gov't Partnership," *The Daily Gazette* April 22, 2008; *The Record*"Feds UAlbany form Partnership for Nano Research" April 22, 2008.
[48]"High Tech Companies Team Up on Chip Research," *Wall Street Journal* August 27, 2012.
[49]"It's About Achievement," Albany, *The Times Union* July 8, 2012. "Alain Kaloyeros: Nano Czar Studies Paranoia, Crazy Bosses," *The Times Union* September 29, 2010.
[50]Rensselaer Polytechnic Institute was founded in 1824 by Stephen Van Rensselaer and Amos Eaton for the "application of science to the common purposes of life" and is the oldest technological university in the English-speaking world.
[51]Keynote Address by Shirley Ann Jackson, President, RPI, National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy," April 4, 2013.

RPI's Center for Automation Technologies and Systems (CATS) is a state-funded research center involving nearly fifty faculty members, nine departments and a five person research staff with core competencies which include advanced manufacturing, modeling and control, and vision and sensing. CATS works with partner companies to solve specific manufacturing challenges. Most of its industrial partners are small companies or startups.

GLOBALFOUNDRIES

In 2009, AMD concluded a deal with an investment fund owned by the government of Abu Dhabi, Advanced Technology Investment Co. (ATIC), pursuant to which AMD would transfer its manufacturing operations to the investment fund in phases through the creation of a new entity, GlobalFoundries. GlobalFoundries would operate as a pure play foundry and AMD would continue as a "fabless" semiconductor producer, using GlobalFoundries to manufacture the microprocessors and other chips it designed.[52] In 2009, GlobalFoundries disclosed plans for a state-of-the-art semiconductor wafer fabrication facility to be built at the Luther Forest Technology Campus in Malta, NY, about 25 miles from Albany, at an estimated cost of $4.2 billion. The State of New York reportedly pledged $1.2 billion in incentives to support the project, despite "crushing budget problems."[53] It would become the largest public-private partnership in the history of the state and perhaps the country.[54] For the most part, the state's large scale financial commitment to this enterprise has had no federal counterpart.[55]

GlobalFoundries' choice of location was influenced by a number of factors. The new fab would initially feature 28-nanometer design rules, scaling down to 14-nanometers, at a time when the semiconductor industry was transitioning to 32-nanometer technology. U.S. export control rules and the Wassenaar Arrangement, a multilateral agreement between the U.S. and its allies, limit the geographies in which the most advanced microprocessor manufacturing technologies can be deployed, foreclosing, for example, sites in

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[52] "GlobalFoundries Puts Its Chips on the Table," *The Times Union* May 1, 2009. A "pure play foundry" does not produce semiconductors for sale under its own brand. It provides manufacturing services in return for a fee for other semiconductor manufacturers. The first and largest pure play foundry is Taiwan Semiconductor Manufacturing Corporation (TSMC). A fabless semiconductor company separates the design of its chips from manufacturing, with its capital intensive requirements.

[53] "More State Funding for Global Foundries," *The Times Union* June 24 2009. AMD had originally announced plans for a new fab in 2006 at a cost of $3.2 billion. Ibid.

[54] "GlobalFoundries Chip Plant Fosters a Ripple Effect Felt Far and Wide," *The Saratogian* July 24, 2012.

[55] "There hasn't been much federal investment in GlobalFoundries. The infrastructure here has all been New York state. There has been no federal money, no foundation money. It's all state money." Interview with Mike Russo, Director of Government Relations, GlobalFoundries, Malta, New York, April 3, 2013.

Box 7-3
The Case for Onshore Semiconductor Manufacturing

During the past two decades, semiconductor manufacturing operations have been characterized by movement offshore from what are regarded as relatively high cost geographies in North America, Japan and Europe, to lower costs regions, particularly East Asia. While this movement has been viewed as inevitable given the economic pressures confronting individual producers, countervailing forces working in favor of retention and even expansion of onshore manufacturing capability in this industry are increasingly evident. The defense community has long expressed concerns over the implications raised by the manufacture of components which form the core of key defense systems outside the U.S., particularly in venues like China.[56] A 1999 earthquake in Taiwan, where many U.S. firms' chips were being fabricated, and the 2011 Fukushima earthquake and tsunami in Japan, drove home the risks associated with overconcentration of semiconductor production in the Pacific Rim "ring of fire."[57] Added to these risk factors favoring diversification to more stable and secure sources of supply is the abiding reality that "customers like to do business in their own neighborhood."[58]

China. New York's education system compared favorably to those of other states. New York's geology offered a stable foundation for wafer fabrication.[59] The region around Albany was already the home of GlobalFoundries' research partners, the University at Albany's CNSE as well as Rensselaer Polytechnic Institute and IBM. And "perhaps most crucially," the state of New York put forward a major incentives package. An investment analyst commented that

> *It's kind of like competing for baseball stadiums these days. Cities around the world, regions around the world, are competing for all*

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[56]Report of the Defense Science Board Task Force on Secure Microchip Supply, February 2005. The Task Force expressed concern that chips fabricated offshore could be implanted with "Trojan Horses" and other unauthorized design features that could compromise U.S. defense systems incorporating such devices. The Task Force was also concerned about dependency on foreign production sources that could be compromised in a national emergency. *Ibid*, pp. 22-24.
[57]"Quake Disrupts Taiwan Chip Mfg.: Implications for China Relations," *China Online* September 22, 1999; "Japan Earthquake Impact on Semiconductor Industry," *Digitimes* March 15, 2011.
[58]Interview with Mike Russo, Director of Government Relations, GlobalFoundries, Malta, New York, April 3, 2013.
[59]Presentation by Mike Russo, Director of Government Affairs, GlobalFoundries, National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy." Troy, New York, April 4, 2013.

> *sorts of manufacturing activity, and semiconductors are high-tech, high human capital, and high-wage.*[60]

In 2012, ATIC pledged $1.8 billion to support the acquisition by GlobalFoundries of Singapore-based Chartered Semiconductor Manufacturing, Ltd., which made GlobalFoundries the world's number two pure play foundry, trailing only Taiwan's TSMC.[61] The Malta fab, currently known as "Fab 8", became operational in 2012 as ATIC acquired full control of GlobalFoundries.[62] In January 2013, GlobalFoundries announced that it would invest another $2 billion to establish a new global R&D facility in Malta, for which it did not seek state incentives. Governor Andrew Cuomo issued a statement to the effect that GlobalFoundries' decision validated the state's sustained commitment to nanotechnology:

> *This significant expansion demonstrates that the investments we have made in nanotechnology research across New York state are producing the intended return — the creation of high-paying jobs and generation of economic growth that is essential to rebuilding our state. New York has become the world's hub for advanced semiconductor research, and now the Technology Development Center will further help ensure the innovations developed in New York, in collaboration with our research institutions, are manufactured in New York.*[63]

As of early 2013, GlobalFoundries was the site of the world's most advanced wafer fab, Fab 8, the culmination of $8.5 billion in investments, which will have a capacity of 60,000 300mm wafer starts per month when fully ramped up. GlobalFoundries is "making 14nm chips today," involving the most sophisticated design rules employed in the industry to date.[64] The $2.2 billion Technology Development Center will literally be located "right next to the fab," which offers the real time advantages. This means that the same engineers that operate the fab can participate in R&D and "collaboratively discuss challenges—there is no substitute for right next door." Although GlobalFoundries' future plans are uncertain, it is contemplating building one or

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[60] "AMD Spinoff Setting Up Shop in NY—State Incentives, Desire for U.S. Plant Help Lure Local Foundries," *San Jose Mercury News* July 24, 2009.
[61] *The Times Union,* "Deal Puts Fab 2 in the Chips," January 21; "GlobalFoundries Says Customers Now Using its 28nm Technology," *Taipei Times Online* September 15, 2011.
[62] "GlobalFoundries has started Production," *The Saratogian* January 14, 2012; "Abu Dhabi Gets Full Ownership of GlobalFoundries," *The Daily Gazette* March 6, 2012. Fab 8 produces 300mm wafers using 28 nm and below design rules at a maximum capacity rate of 60,000 wafers/month, or the equivalent of 135,000 200mm wafers/month.
[63] "GlobalFoundries to Invest $2 Billion in New Malta Research and Development Facility," *The Saratogian* January 8, 2013.
[64] Ajit Manocha, "Keynote Address," National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy," Troy, New York, April 3, 2013.

two more fabs on the same site, each 50 percent larger than the current Fab 8, which would entail approximately $30 billion in additional investments.[65]

GlobalFoundries has had significant effects on the economic development of the surrounding region. Like the advent of an anchor tenant in a shopping center, the arrival of GlobalFoundries has prompted a build-out of infrastructure (power grid, water supply, roads, sewers) that are now available to other companies. Together with CEG, GlobalFoundries has launched the Tech Valley Connection for Education and Jobs, a model for transforming K-12 and higher education, which is the largest education/workforce development initiative of its kind in the United States. The company's presence has led over 200 other companies to locate or expand their presence in the region, and GlobalFoundries expects its own investments may create as many as 15,000 indirect support jobs by the end of 2014.[66]

THE GLOBAL 450 CONSORTIUM

In September 2011 Governor Andrew Cuomo announced that New York state had entered into agreements with IBM, GlobalFoundries, Samsung, Intel and TSMC to develop the next generation of semiconductor technology based on 450mm wafer size at a site in upstate New York. The state committed to invest $400 million in CNSE, with no state funds going to any individual company. The five member firms pledged investments of $4 billion, and Intel agreed to establish a 450mm East Coast Headquarters to support the project. Global 450 is comprised of two projects:

- IBM and its technology partners will focus on developing and producing the next two generations of semiconductor devices.
- The five participating companies will focus on the technological transition from 300mm to 450mm wafer size.

Global 450 was expected to facilitate the establishment of 450mm wafer fabrication plants in New York state at investment costs exceeding $10 billion per plant. Global 450 was also forecast to create 2500 new high technology jobs in upstate New York.

The project was also expected to provide 1500 construction jobs in Albany.[67] Perhaps as important, as a result of the "New York state decision on a

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[65]Interview with Mike Russo, Director of Government Affairs, GlobalFoundries. Malta, New York, April 3, 2013.

[66]Presentation by Mike Russo, Director of Government Affairs, GlobalFoundries, National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy." Troy, New York, April 4, 2013.

[67]Presentation by Pradeep Haldar, CNSE Vice President, Troy, New York, April 3, 2013; "Governor Cuomo Announces $4.4 Billion Investment by International Technology Group Led by Intel and

TABLE 7-2 Global 450 Employment Forecast

Location	New Positions
CNSE Albany	800
IBM—Yorktown/East Fishkill	950
SUNY Utica	450
CNSE Canandaigua	300

$400 million investment," the research and development for the transition from 300mm to 450mm "will be done in right here in Albany, not overseas."[68]

To date, the state of New York has invested over $2 billion in the development of the Albany nanotechnology cluster, funds that have been skillfully leveraged to induce far higher levels of private investment.[69] Technology companies have moved to the Albany area based on their "opinion of where the future of nanotechnology was located."[70] The investments in nanotechnology are transforming the Albany area's economy. Two thousand, five hundred jobs were created at the SUNY at Albany alone and the nanotechnology R&D activity has fostered an "ecosystem" of support firms providing materials, tools and specialized services. GlobalFoundries employed 2,000 people at its hub in Malta in early 2013 and expected to grow by another 1,000 by the end of 2014.[71] The flow of highly educated people into the region has produced a "brain gain" and the Albany region now ranks eighth in the U.S. in share of population with a graduate degree.[72] "The revitalization of downtown Schenectady, Albany, and Troy is driven by the economic activity that has resulted" from the nanotechnology initiative, observed a local economic development official in 2009. "There is a buzz going on that enables us to sustain a level of economic stability in a time of tremendous crisis."[73] President Obama visited Albany in 2012 and commented that "I want what's happening in Albany to happen in the rest of the country."[74]

IBM to Develop Next Generation Computer Chip Technology in New York," Press Release, Andrew M. Cuomo, Governor, September 27, 2011.

[68]Interview with David Rooney, Senior Vice President, Center for Economic Growth, Malta, New York, April 3, 2013.

[69]Pradeep Haldar, "New York States Nano Initiative," in National Research Council, *Growing Innovation Clusters for American Prosperity: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2011, p. 62. According to one source, $13 billion had been invested in Albany nanotechnology activities by a total of 300 companies by 2012. It is unclear whether some or all of GlobalFoundries investments are included in that total. "Nanotech Makes U.S. Job Creation Special," *The Times Union* September 19, 2012.

[70]"GlobalFoundries Constructor Moving HQ from Albany to Wateruliet," *The Saratogian* February 9, 2010.

[71]"GlobalFoundries Plans New York R&D Center," *EETimes* January 9, 2013.

[72]"Jobs Bring Brain Gain," *The Times Union* June 1, 2012.

[73]"Nano Center a Job Magnet for Albany," *Observer-Dispatch* July 19, 2009.

[74]"Nanotech Makes U.S. Job Creation Special," *The Times Union* September 19, 2012.

Box 7-4
The Role of Community Colleges

New York's community colleges enroll some 270,000 students. In addition to preparing many of these students to move on to 4-year institutions, the community colleges provide skills training relevant to the economic needs of the regions in which they are located.[75] The Hudson Valley Community College (HVCC), for example, offers a 25-credit semiconductor technology certificate program providing specialized knowledge of semiconductor and nanotechnology necessary to qualify for entry level positions in the semiconductor industry. Most of these courses are taught at HVCC's TEC-SMART facility (Training and Education Center for Semiconductor Manufacturing and Alternative and Renewable Technologies) in Malta, where GlobalFoundries' manufacturing operations are located. Many of the students enrolled in this program are in their late 20s and 30s, seeking to "reinvent themselves," and some are over 40.[76] In 2012 GlobalFoundries' staffing manager for Fab 8, Pedro Gonzalez, said in an interview that about 65 percent of the company's hires were "technicians" directly involved in the manufacturing process, and that roughly 50 percent of total hires come from within the region. He observed that "the local community colleges, such as HVCC, provide a great associate degree program in semiconductor manufacturing."[77]

START-UPS

New York's burgeoning nanotechnology cluster is virtually entirely comprised of the operations of large established companies which were indigenous to the state (IBM) or recruited (GlobalFoundries, Tokyo Electron, SEMATECH) and their established supply chain companies. There is no readily apparent New York equivalent of Intel or Google which grew from a local start-up venture to a successful established company. The first student spin-off from CNSE did not occur until 2012, eight years after the establishment of the NanoCollege.[78] While the dearth of start-ups in the midst of a high tech boom is worthy of separate study, New York policymakers are concerned about the fact that "New York lags behind other states in attracting venture capital." While

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[75]Presentation by Drew Matonak, President, Hudson Valley Community College, National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy," Troy, New York, April 4, 2013.
[76]"Training Technicians, Hudson Valley Style," *Semiconductor Design and Manufacturing* May 3, 2012.
[77]"Talking About Fab 8's Work Force," Albany, *The Times Union* September 9, 2012.
[78]CNSE, "UAlbany NanoCollege Enters Into Licensing Agreement with its First Student Spin-off Company to Spur Green Energy Innovation and Growth," press release, October 1, 2012.

nearly half of all U.S. venture capital is invested in California, "New York companies only attract 4 percent of the total." To address this shortfall, Governor Andrew Cuomo has proposed the NYS Innovation Venture Capital Fund to encourage start-ups. In addition, the Governor has proposed creating the Innovation NY Network, a networking initiative which will convene academics, venture capitalists, patent lawyers and business leaders to promote technology transfer from universities and investment in start-ups, based on the example set by Stanford and MIT.[79]

NANO BEYOND MICROELECTRONICS

To date, most of the commercial activity associated with nanotechnology in upstate New York has involved semiconductors. However, the state's involvement in nanotechnology envisions a much broader application of the emerging technology. Alain Kaloyeros commented in 2007 that "the computer chip is leading the way, but I include nanobiology and nanomedicine, and health applications, along with renewable and sustainable energy, as some of the leading emerging applications."[80] A number of initiatives are under way in upstate New York to broaden the applications of nanotechnology to new fields. The Photovoltaic Manufacturing Consortium, in which CNSE and SEMATECH are key partners, supports R&D to develop next-generation photovoltaic manufacturing technologies.[81] RPI's Vice President for Research, Jonathan Dordick, advocates extension of New York's "nanotech model" to a wide range of biotechnology applications, including pathogen decontamination, drug discovery, toxicology screening, and sensor-based healthcare.[82] In addition, as Brian Toohey, President of the Semiconductor Industry Association (and former Senior Vice President of the Pharmaceutical Research and Manufacturers of America) points out, semiconductor technology itself has widespread

[79]"Stanford University and the Massachusetts Institute of Technology have perfected this practice—known as tech transfer. It is commonplace for top scientists at these schools and their students to form their own companies based on their discoveries that attract tens of millions of dollars in venture funding. The schools, which share in the profits, put enormous resources behind these commercialization efforts." "Cuomo's $50M Venture Fund Seeds Startups," Albany, *The Times Union* January 23, 2013.

[80]"Interview with Dr. Alain Kaloyeros," *Innovate* November 2007.

[81]The Photovoltaic Manufacturing Consortium involves a total investment to date of $300 million from the U.S. Department of Energy, New York state, and the private sector. Presentation by Pradeep Haldar, CNSE Vice President, National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy," Troy, New York, April 3, 2013.

[82]Presentation by Jonathan S. Dordick, "Advancing Nano-Biotechnology," National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy," Troy, New York, April 4, 2013.

application in the life sciences areas, including electronic implants in the human body, biometric monitoring, and synthetic biology.[83]

SEMICONDUCTORS: THE ON-GOING CHALLENGE FROM ABROAD

A combination of enlightened public policy measures and committed industry initiatives appears to be producing a success story for the U.S. semiconductor industry in New York, including the opportunity for leadership in the transition from 300mm to 450mm technology and a partial reversal in the offshore movement of semiconductor manufacturing. However, the industry continues to confront stark technological and competitive challenges exacerbated by persistent efforts by foreign governments to capture leadership in this most strategic of all industries. Recently, for example, India launched its Modified Special Incentive Package Scheme (M-SIPS), offering $4 billion in incentives to companies that set up local facilities to manufacture computer chips, photovoltaic solar cells, and telecommunications equipment.[84] Without continued sustained investments in R&D and seamless collaboration between industry, universities and the state government, the gains achieved to date could easily prove ephemeral.

The nanotechnology initiative's economic impact on upstate New York should also not obscure the region's abiding economic problems. Nanotechnology is bringing thousands of jobs to the region as well as new companies and advanced technologies. But in January 2013 unemployment in the Capital region was 8.4 percent and rising, the highest figure for any month since figures were collected starting in 1990. Unemployment levels are even higher in Syracuse, Glens Falls, Buffalo, and Binghamton.[85] These figures indicate that despite the extraordinary achievements of the past decade, more needs to be done. This would include a redoubled commitment to education and training at both university and community college levels, as well as steps to encourage public and private investments in innovation, and measures to encourage investments in start-ups.[86] Perhaps most of all, the political consensus that has underpinned the region's success and the public-private partnerships that have made it possible will need to be sustained and expanded as opportunities occur. Above all, policymakers at the regional, state, and

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[83]Brian Toohey, "Convergence: Semiconductor, Pharmaceutical, and Medical Device Industries," National Research Council symposium, "New York's Nanotechnology Model: Building the Innovation Economy," Troy, New York, April 4, 2013.

[84]"India to Offer Incentives Worth $4 Billion for IT Manufacturing," *The Times of India* January 12, 2013.

[85]"Area Jobless Rate Rises," Albany, *The Times Union* March 13, 2013.

[86]For example, the region may not be concentrating sufficient resources or drawing sufficient attention among its firms and universities to the federal SBIR/STTR programs that provide some $2.8 billion in grants and contracts annually.

national level need to recognize the intensely competitive global environment for the design, production, and application of semiconductors.

LESSONS LEARNED

The New York nanotechnology initiative is an example of state-level industrial policy on a scale comparable to that observable on a national level outside the U.S. In this case, however, the driving force was not a government ministry but the SUNY university system and the flagship SUNY Albany. Through investments in SUNY Albany, the state of New York leveraged far more substantial private financial investments, facilitating the establishment of an enormously expensive, state-of-the-art research infrastructure at the university with a powerful gravitational pull on leading semiconductor devices, equipment, and service infrastructural companies. In little over a decade a semiconductor industry supply chain has been assembled in upstate New York, which is poised to lead the global industry into a new era based on 450mm wafer technology. While many actors played important roles in this effort, including government and industry leaders, regional development organizations, and private firms such as IBM and GlobalFoundries, the initial catalyst was arguably the university itself.

Few would argue that New York's nanotechnology development model has widespread applicability elsewhere. Most states cannot afford investments on a comparable scale, and New York may be unable or unwilling to do so itself going forward. However, some aspects of the New York experience are noteworthy and relevant to other states and regions:

- New York's commitment to this effort was focused, substantial, and sustained by a bipartisan consensus through successive state administrations.
- While state incentives were provided, much of the state money was invested in a build-out of university research infrastructure that attracted private investment. State investments were matched by private sector investments through a cohesive, well-run public-private partnership.
- The state's educational system attracted not only high technology companies but key individuals, able to provide high level research and institutional leadership.
- The thematic era in which the largest initial investments were made (microelectronics) is a large, developed market. These investments now permit SUNY Albany to leverage its success into more nascent technology areas such as biomedicine and energy that hold great promise.

Chapter 8

New Initiatives in Illinois and Arkansas

The symposia held pursuant to this project identified a large number of noteworthy state and regional efforts to foster innovation clusters. Some of these stand out because of their apparent success, such as New York's nanotechnology initiative. Others warrant attention because while their success or failure remains in the balance, they reflect sustained collective efforts by local stake holders to mobilize available resources, forge an innovation community, and confront longstanding intractable challenges posed by geography, historical industrial and cultural legacies, and international competition.

GROWING A BIOTECHNOLOGY CLUSTER IN ILLINOIS

Illinois confronts an innovation conundrum commonly found in advanced societies—the fact that excellent science does not necessarily translate into local economic growth. Former Provost of Northwestern University Lawrence Dumas observes that

> *The infrastructure and raw material of science and discovery are abundant across the Chicago region. We have every kind of powerful tool and multiple sites of leading-edge research, such as Argonne National Labs, multiple research hospitals, leading companies in drug development and prominent research universities. In spite of those assets, we just haven't seen enough companies starting here.*[1]

David Miller, leader of the Illinois Biotechnology Industry Organization (iBIO) echoes this concern, observing that the state has always been strong in research

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[1]Thomas O' Halloran, "Disruptive environments that seed discovery and promote translation," in National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* C. Wessner, Rapporteur, Washington, DC: The National Academies Press 2013.

but lacked the ability to translate the research into companies that remain in Illinois—companies instead leave for the coasts and even Indiana, Michigan, Wisconsin and other places that have "more jobs, a good tax base, greater wealth creation, taxpayer-financed resources, and more excitement." Miller faults the state for reliance on a "big company strategy," seeking to attract large companies to establish new facilities or expand existing ones, comparing this to trying to win a baseball game by "hitting only slam home runs."[2] Thomas J. Meade, a Northwestern University professor, who started up a biomedical company, said with respect to the venture capital situation that in California, he could "raise angel money in a coma" whereas "the Chicago ecosystem is more like a dry well."[3]

Illinois has one of the largest concentrations of university, nonprofit and government research institutions in the world, and the University of Illinois has one of the largest research budgets in the country.[4] The Argonne National Laboratory, 25 miles from Chicago, was the site of the first creation of stem cells from adult cells in 2003. Chicago is home to eleven medical schools and enrolls more medical students than any other city in the country, but historically has been a net exporter of graduates with medical degrees.[5] Illinois was site of the first planted biotechnology field in the world—tomatoes genetically engineered by Monsanto to ward off pests—in 1987, but has seen home-grown biotechnology companies and startups migrate to other regions.[6] In 2013 a report by the Chicago Metropolitan Agency for Planning warned that in the preceding decade the Chicago region had lost nearly half of its private research and development jobs and was losing ground to smaller innovative regions like San Diego, San Francisco, Silicon Valley and Boston:

> *As these regions enhance the R&D intensities of their manufacturing clusters and the Chicago region lags behind, it becomes harder for northeastern Illinois to adopt new technologies and compete in global advanced manufacturing…While in 2000 the region produced the fourth most patents in the nation, by 2010 its rank had dropped to eighth. As manufacturing relies on R&D*

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[2]Presentation of David Miller, "Early-Stage Finance and Support in Illinois," National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit.
[3]*Chicago Sun-Times,* "Micro-Dollars—Nanotechnology Entrepreneurs See Small Window for Venture Funding," March 30, 2009.
[4]"Magazine Ranks Illinois Top State for Biotechnology," Campaign-Urbana *the News-Gazette* July 23, 2005. The University of Chicago Comprehensive Cancer Center, affiliated with the University of Chicago, has been responsible for path finding discoveries in cancer research, including the development of a new MRI procedure for the detection of early breast cancer, discovery of the molecular mechanism by which tamoxifen blocks the effects of estrogen, and the identification of the first chromosomal abnormality in leukemia.
[5]"Fertile Ground for a Biotechnology Hub," *Daily Herald* March 8, 2001.
[6]Amgen started business in 1984 in an incubator in Chicago flanked by four hospitals, but eventually left the state for California. "Fertile Ground for a Biotech Hub," *Daily Herald* March 8, 2001.

> *support to fuel next-generation technologies and productivity gains, the region's R&D decline contributes greatly to the challenges the cluster faces today.*[7]

Numerous public and private initiatives are currently underway in the Chicago area to reverse these trends and promote innovation-based economic growth. Governor Patrick Quinn pressed for a public works bill in 2009 in a "very tough economy" which secured funding for broadband deployment in the region, including in a newly-created Chicago "medical district" encompassing four large hospitals and the University of Illinois at Chicago.[8] In 2011, the Governor announced the launch of Startup Illinois, a web-platform to connect fledgling entrepreneurs with mentors, advisers, service suppliers, and sources of potential government funding.[9] Chicago's leading universities are upgrading their research infrastructure and technology transfer programs.[10] The University of Illinois operates a Research Park at its Urbana campus, which includes an incubator providing SBIR collaboration, a Mobile Development Center, and other resources. The Research Park has worked with 140 start-ups in the past decade and has helped raise over $400 million in venture capital. The Research Park features a number of special programs:

- **1-Start Professional Launch** is designed to free entrepreneurs from the distraction of all of the professional services they require in the early stages of development, delivering those services in a suite so the entrepreneur can concentrate on running the company.
- **Entrepreneurs-in-Residence** pairs serial entrepreneurs, VCs, and industry executives with early-stage companies to help them adapt to the realities of the commercial world.[11]

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[7]"Region's R&D Spending Plummets," Crystal Lake *The Northwest Herald* March 3, 2013.
[8]Presentation by Governor Patrick Quinn, National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit.
[9]"Governor Quinn Announces Startup Illinois Institute," *Chicago Examiner* May 20, 2011.
[10]Robert Easter, "The Role of Illinois Universities" National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit. See also in the same volume, Caralynn Nowinski, "New Initiatives at the University of Illinois." At Northwestern University, the technology transfer office has been reorganized as the New Ventures Office with new rules requiring two-way collaboration between university researchers and companies with full data sharing. Richard B. Silverman, "University Technology Transfer: Lessons Learned from Lyrica," National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit.
[11]Presentation by Caralynn Nowinski, "New Initiatives at the University of Illinois, National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit.

Box 8-1
The Challenge of Early-Stage Financing

In most of the states surveyed in this project, local leaders cite the inadequacy of early stage financing for start-ups as a significant impediment to innovation-based economic development. The problem confronts small states like Hawaii and Arkansas and large states like Illinois and New York. Nationwide, most small firms that need financial backing are in the proof-of-concept, start-up or seed capital phases, and need $500,000 to $1 million for prototype development.[12] For the most part, this need is not being met; seed stage investments by the U.S. venture capital industry fell by 48 percent in 2011 to $919 million, or only 3 percent of all venture capital investment.[13] Venture capital has been moving downstream, toward safer investments in established enterprises and technologies, a phenomenon that makes it harder for innovative start-ups to acquire funding.[14] Both of the states examined in this chapter are responding by seeking to create local institutions to close the gap in early-stage financing.[15]

The Illinois Science & Technology Coalition

The Illinois Science & Technology Coalition (ISTC) was created by the Illinois legislature to promote innovation and coordinate state, university and federal efforts in research and the sciences. Its mission includes fostering of public-private partnerships for R&D and innovation; attracting technology and innovation-related federal funding to Illinois; and advocating state and federal policies to advance innovation. The ISTC has been active in a number of innovation-related initiatives:

Early-Stage Financing

The state of Illinois recently succeeded in leveraging $78 million in federal funds from the Small Business Credit Initiative, part of which is being

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[12]National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium*, C. Wessner, Rapporteur, Washington, DC: The National Academies Press, 2012, pp. 56-62.
[13]PriceWaterhouse 2013 Money Tree Report.
[14]The current VC investment is $8.3 million, large-scale funding that is normally reserved for firms that already have substantial revenues. National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit., p. 59.
[15]This growing gap in early-stage financing is addressed in part, but only in part, by the federal SBIR program. The program provides some $2.5 billion in phased federal support to start-ups and small established companies to help meet government missions in security, health, energy, and the environment. Its grants and contracts often serve as a first step towards commercialization for many firms.

used by a venture capital fund, Invest Illinois Venture Fund, which supports young innovative companies with high growth potential. As of mid-2012, this fund had invested $4.2 million in 14 deals, leveraging about $16.7 million in private investments.

Illinois Nanotechnology Collaborative (INC)

The INC represents an effort to coordinate the work in nanotechnology underway at over 20 departments and divisions in Illinois universities and hospitals. It has developed Proof of Concept Centers to accelerate commercialization; a Shared Facilities Program to make expensive and specialized tools available for research; and a Work Force Development Program.

Support for Research and Technology Parks

The ISTC is working to increase available space at the 1981 Digital Tech Incubator, a 50,000 sq. ft. technology park that supports technology-based startups, and is helping to "reinvigorate" the Illinois Science and Technology Park in Skokie.[16] ISTC is also working to "reinvigorate" the Illinois Science and Technology Park in Skokie as a public-private partnership, backed by a $20 million capital commitment from the state and the collaboration of the Forest City Science and Technology Group. Partners include the city of Skokie and community colleges that will use it for technology training programs. The site is also designed as a location for spin-offs from Northwestern University, and already hosts nanotechnology firms which include NanoInk, Nanotype, and NanoSonix.

Fostering Biotechnology

The Illinois biotechnology Organization (iBIO) was formed in 2001 through a merger of the state's two largest biotech coalitions to promote development of the biotechnology industry in the state.[17] David Miller, the president, warned in 2003 that while Illinois was good at building infrastructure for biotechnology, "other states are providing support at every level in the process, and we aren't."[18] In 2007, an Illinois biotech executive said that he did not

> *even try to get state grant money as it was too little financing for all the trouble. Instead he blamed the lack of venture capital in the area*

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[16]Mark Harris, "Illinois Science and Technology Coalition," in National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit.
[17]"Chicago Stakes Claim to Biotech Supremacy," *Chicago Sun-Times* December 17, 2001.
[18]"Biotech Progressing Without State Support," *Chicago Sun-Times* October 20, 2003.

for making many small biotech companies look to either of the two coasts for more adventurous financial backers.[19]

iBIO has taken a number of actions to reverse trends evident in the early 2000s. iBIO was the driving force in creating a state tax credit for angel investments, and has supported legislation to re-fund the Technology Development Account that provides start-ups with early stage financing. iBIO launched the PROPEL program and co-founded Chicago Innovation Mentors, two programs that provide expertise and advice to startups. PROPEL was assisting 44 active companies as of mid-2012, and in 2011 42 U.S. and international patents were issued and over 145 patent applications were filed by PROPEL firms. iBIO's David Miller said in 2012 that in biotechnology, the Chicago region has "the essential outlines of a critical mass," and that the task is now to "shore this up and bolster it." He points out that iBIO was forced to become involved in some of the state's macroeconomic issues because unless the state's fiscal problems were resolved—most notably costs associated with pensions and debt service—"we had no hope of making this one of the top life sciences centers of the world."[20]

Nanotechnology at Northwestern

In 2000, Northwestern University established the International Institute for Nanotechnology. The Institute has grown to 190 faculty and 500 graduate students. By 2007, Northwestern's nanotechnology research had succeeded in attracting state and federal funding totaling $350 million, including $100 million for new and upgraded equipment and infrastructure.[21] In 2005, Ford and Boeing announced a research partnership on nanotechnology with transportation applications with Northwestern.[22] Chad Mirkin, the current director of the Nanotechnology Institute has launched a series of companies to commercialize nanotechnologies developed at Northwestern:

- ***Aurasense Therapeutics*** was established to commercialize a spherical nucleic acid platform to target disease, and it has amassed a patent portfolio of 70 filings in numerous countries.[23]
- ***Nanosphere,*** a molecular diagnostics company, commercialized technology combining gold nanoparticles and nucleotides to create a

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[19]"Will Biotech Firms Keep Flocking to North Suburbs?" *Gurnee Review* August 2, 2007.
[20] David Miller, "Early Stage Finance and Support in Illinois," National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit.
[21]"Call it Nano U—NU's Visionary Leader Seized the Day," *Chicago Sun-Times* August 13, 2007.
[22]"Ford, Boeing, Northwestern in Partnership on Anotech," *The Anniston Star* October 7, 2005.
[23]"What the Giant of Teeny-Tiny is Up to Now," *Crain's Chicago Business* October 13, 2012; Van Crocker, "The Industry Perspective on Illinois," in National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit.

detection system for nucleic acids and proteins. Based on this technology, the company has raised $100 million in private and $180 million in public funding.[24]

Chemistry of Life Processes Institute

Chicago's universities are implementing institutional innovations to break down disciplinary silos and foster start-ups. The Chemistry of Life Processes Institute (CLP) was established at Northwestern University in 2004 with the mission of becoming one of the U.S.'s leading centers of biomedical research. CLP seeks to foster collaborative research in the interface areas between the chemical, physical, engineering, and life sciences.[25] CLP recruited leading scientists in synthetic chemistry, proteomics, molecular imaging, materials science, synthetic biology, and other overlapping fields. CLP is characterized by its founding director, Dr. Thomas O'Halloran, as a "common playground for many disciplines" and "an effort to lower the hurdles in getting scientists to work across their chosen disciplines."[26]

CLP has encouraged entrepreneurialism in the biomedical sector. One of O'Halloran's first acts as director was to recruit an entrepreneur-in-residence, Andrew Mazar, as a CLP faculty member to whom members of the CLP community could "go to and say, 'I've got a result, I've got a patent; what do I do next?"[27] CLP fostered two start-up companies that ended up operating outside of Illinois because they could not raise local venture capital and "the investors they found were in North Carolina and in Madison, Wisconsin, where the companies are now operating." However, OhmX, founded by CLP professor Thomas Meade, secured funded from an investment team headed by a CLP Board Member and began operations in nearby Evanston, Illinois, developing bioelectronic protein-specific monitoring devices.[28]

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[24]Roger Moody, "Industry Perspective on Illinois," in National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit.

[25]CLP's director of operations, Sheila Judge, has a doctorate in biochemistry and works directly with the faculty to assemble team-based science grants and facilitate interconnections between fields such as endocrinology, materials science, and synthetic chemistry. Ibid.

[26]CLP's building occupied in 2009, is designed so that faculty from different disciplines work together on every floor and the environment is designed to make best use of "collisions" between different programs. Thomas O' Halloran, National Research Council, *Building the Illinois Innovation Economy: Summary of a Symposium,* op. cit.

[27]Mazar had previously served as chief science officer and senior vice president of R&D at Attenuon Laboratories, a biopharmaceutical company in San Diego. *Longview News Journal,* "Health Center Receives Almost $7.8 Million Grant," October 28, 2005.

[28]Ibid.

Educational Programs to Foster Entrepreneurialism

A number of educational programs have been implemented in Illinois to foster entrepreneurialism in a local culture, which is frequently said to inhibit start-ups. Caralynn Nowinski, Associate Vice President for Innovation and economic Development at the University of Illinois, summarized a number of these initiatives at the symposium convened for this project in Chicago in 2012.

- **Innovation Living Learning Community (Innovation LLC).** Innovation LLC is a dormitory with 130 students from different fields of study who are interested in becoming entrepreneurs. The dorm features a garage where they can work on prototyping (including a 3-D printer), programs to foster interaction and mentorship, and a curriculum centered on idea development.
- **Business Plan Competitions.** The University of Illinois introduces students with business skills to those with engineering/science competencies and encourages them to find commercial applications. One of these programs, Tech Ventures, partners business school students with the University tech transfer office to create a business plan and identify a commercial application. Some of these projects have resulted in successful start-ups, such as OrthoAccel Technologies, which secured funding and in 2011, won FDA clearance for a medical device to accelerate the orthodontic process.
- **IP Coffee Breaks.** In this program, faculty and grad students discuss IP protection, disclosures, and getting assistance forming a company.
- **Proof of Concept.** These programs, at the Chicago and Urbana campuses, provide up to $75,000 to faculty entrepreneur teams and helps companies prepare SBIR applications.

DEVELOPING ARKANSAS' WORKFORCE AND WIND POWER

Arkansas is a small state that has grappled with economic forces largely beyond its control for over half a century. After World War II, when automation of agriculture eliminated many farm jobs, the state government managed to attract manufacturing firms from other states on the basis of its low costs, low taxes and favorable business climate, factors that still work in its favor today.[29] Many of these industries began moving offshore in the 1970s, and the state has

[29]In 1955, Arkansas' state legislature established the Arkansas Industrial Development Commission (AIDC) with a mandate to promote industrial development, and under its first Chairman, Winthrop Rockefeller, began to recruit out-of-state businesses. The result was an influx of manufacturers and the addition of 51,000 jobs between 1955 and 1960. Watt Gregory, "Evolution of Innovation in Arkansas," in National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit.

continued to fight a steady erosion of manufacturing jobs. Arkansas business, academic and government leaders have been working closely together for roughly fifteen years to expand the number of knowledge-based jobs and companies in the state and in the process to raise the state's per-capita standard of living. A key concern, expressed by University of Arkansas Chancellor David Gearhart, is the fact that roughly one quarter of the state's college graduates leave the state after graduation—"if graduates are leaving to go where [established] businesses already are, how do you reverse the process and attract these businesses to your region?"[30]

Although Arkansas has long faced a bleak economic landscape, the state enjoys a number of advantages in the global competition for investment, technology and jobs. Arkansas entrepreneurs have founded a number of world-class companies that began as start-ups within the state.[31] The state's location in the center of the North American market, supported by a modern infrastructure of road, rail and river based transportation, have given it an edge in attracting new manufacturers, particularly those for whom transportation costs are key competitive factors.[32] Finally, the state's work force, although faulted by some would-be employers for its low education and skills levels, has been prized by others for its deeply-ingrained work ethic and can-do spirit.[33]

Arkansas has also benefitted from a strong commitment to economic development by a succession of Democratic and Republican governors, a supportive legislature, and groups of business, academic and government leaders working on a volunteer basis to study the challenges facing the state and develop a strategic response.[34] For decades, Arkansas government authorities have used economic development incentives to considerable effect in attracting and

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[30]David Gearhart, "Arkansas 180: Teaching and Research," University of Arkansas website, *<http://chancellor.vark.edu/13132.php>*.

[31]J. B. Hunt, which began in 1961 as a small "Arkansas trucking firm (five trucks and seven refrigerated trailers) had become this country's largest trucking firm by the 1990s. Tyson foods, based in Springdale, Arkansas, began as a farmer driving one truck to deliver chickens to Chicago and evolved into the largest U.S. poultry processer and the world's second largest processer of chicken, beef and pork. Wal-Mart, which started out with a single retail outlet in Rogers, Arkansas in 1960 became the largest retailer in the U.S. in 1991.

[32]River Bend Gets Kosmo Work," *Plastics News* November 7, 2011; Interview with Joe Brenner, Vice President for Production, Nordex, in Wind Systems January 2011; "Nucor Makes Blytheville Steel Capital of the South," *Arkansas Business* December 16, 1996.

[33]"Mitsubishi Breaks Ground on Nacelle Facility in Arkansas," *North American Windpower* October 8, 2010; "Nucor Makes Blytheville the Steel Capital of the South," *Arkansas Business* December 16, 1996.

[34]One of the civic groups, Accelerate Arkansas, commissioned professional studies of the Arkansas economy, most notably a 2004 report by the Milken Institute that represents the most comprehensive study ever undertaken of the Arkansas economy. The study, which laid out the steps the state needed to take to move toward a knowledge-based economy, formed part of the intellectual base for Governor Mike Beebe's development of a long range strategic plan. Watt, "Evolution of Innovation in Arkansas 2010, op. cit.; Milken Institute, *Arkansas' Position in the Knowledge-Based Economy: Prospects and Policy Options,* 2004; Arkansas Strategic Plan, 2009.

retaining innovative companies in the state.[35] In 2007, the General Assembly created the Quick Action Closing Fund, which was intended to empower the Governor to "act quickly and decisively in highly competitive situations to finalize an agreement with a company to locate" in the state, and the fund has repeatedly demonstrated its effectiveness as a policy tool.[36]

For roughly the past 15 years, Arkansas has implemented a sustained array of initiatives to foster the emergence of a knowledge-based economy in the state. Accelerate Arkansas, a group of business leaders working on a volunteer basis, commissioned a series of studies about the Arkansas economy, the challenges it confronted in transitioning to knowledge-based economy activities, and possible policy initiatives. Ultimately, the studies have provided the basis for a systematic, sustained strategic effort to address the principal challenges facing the state, which included work force development, upgrading education at all levels, and fostering entrepreneurship, innovation and the start-up of new, technology-oriented companies.[37] The most recent survey of the state's economy concludes that "Arkansas has enjoyed clear economic benefit from activities to create a knowledge-based economy, and is now poised to take critical next steps to maintain momentum."[38]

Workforce Development

Arkansas is taking a number of steps to meet its increasing need for highly educated and skilled workers.[39] The Arkansas Task Force on Higher

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[35]"Choosing a Greenfield Site: Steelmakers are Drawn to Rural Areas," *Iron Age* March 1992; "Factory Closing Shocks Community Into Opening Wallets for Economic Development," *The Regional Economist* October 2010; "Arkansas Legislators Present Their Proposal for Tax Breaks for Proposed Steel Mill," *Arkansas Democrat-Gazette* December 7, 1987.

[36]Letter from Arkansas Economic Development Commission Executive Director Maria Haley to Senator Mary Anne Salmon and Representative Tommy Lee Baker, Arkansas Legislative Council, August 22, 2011; Caterpillar Opens New Arkansas Factory Hiring 600," *Cleveland.com* September 1, 2010; "Windstream Picks Little Rock, AR for HQ," *Business Facilities* July 13, 2010.

[37]These efforts are summarized in National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit., pp. 14-20.

[38]Battelle Technology Partnership Practice, *Arkansas' Knowledge Economy Initiatives: Analysis of Progress and Recommendations for the Future*, November 2012. In support of its conclusion, Battelle cited the fact that (1) knowledge-based initiatives based on research has received $61.2 million in state funding in the period 2008-2011 leveraging $191.8 million in non-state support; (2) that the state's innovation initiatives has fostered 135 new companies directly employing 1,259 workers; and (3) job gains in high-wage, typically knowledge-intensive industries exceeded 6,000 jobs during a period in which the state experienced a net decline in private sector jobs.

[39]Arkansas Department of Education, *Combined Research Report of Business Leaders and College Professors on Preparedness of High School Graduates*, January 2007. Similarly, the human resources manager at Kagome/Creative Foods, a food processor with a facility in Mississippi County, Arkansas, said in 2010 that despite the county's high unemployment, it was "very, very hard to find people to work," partly a case of "too many undereducated, unemployable youth." Susan C. Thompson, "Factory Closing Shocks Community into Opening Wallets for Economic Development," *The Regional Economist*, October 2010.

Education Remediation, Retention and Graduation Rates was formed pursuant to legislation enacted by the General Assembly in 2007 to increase the percentage of citizens with bachelor's degrees. At that time, the percent of adults in Arkansas holding bachelors' degrees was 22.3 percent—well below the average for the 16-state Southern Regional Education Board (SREB). While Arkansas exceeded many Southern Regional Education Board (SREB) states in the number of high school graduates entering college, a greater percentage of those entering college failed to complete bachelors' degree programs.[40]

Acknowledging that the state lags in per capita baccalaureate degrees, where it stands 49th in the nation, Governor Beebe noted in his keynote address to the National Academies symposium on Building an Arkansas Innovation Economy that he was determined to change that ranking.[41] The state has initiated policies that include higher standards, higher expectations, and more advanced placement. The state has approved a lottery, with all of its available revenues targeted for college scholarships. "There will be no excuse for Arkansas to stay 49th in per capita BA degrees," he said.

Arkansas has 11 four-year colleges and universities, including four with a major research orientation, the University of Arkansas for Medical Sciences, the University of Arkansas—Fayetteville, Arkansas State University and the University of Arkansas at Little Rock.[42] A study by Battelle Technology Partnership released in 2009 found that Arkansas's growth in investments in university research between 2001 and 2007 was strong, albeit from a low base, exceeded the national average (20 to 51 percent) and vastly outpaced the national average in key "hard" research disciplines.[43]

A 2012 study by the Battelle Technology Partnership Practice found that Arkansas universities were outperforming the national average in technology transfer activity relative to the size of the research base, measured in terms of licenses and startups per $10 million in research expenditures.[44]

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[40]The Arkansas General Assembly set an ambitious goal in 2007of increasing the percentage of degree-holding Arkansans to the regional average by 2015. Describing a recently released update, Jim Purcell, director of the Arkansas Department of Higher Education, noted that "despite significant improvement in the rate at which high school graduates who enroll in college—very nearly the national average, in fact—the percentage of Arkansas residents with college degrees is on the decline." *Arkansas Business*, "Purcell Seeks to Raise Rates of Graduation," March 5, 2013.
[41]Recognizing these realities, *Governor Mike Beebe's Strategic Plan for Economic Development* points out that Arkansas is "at a critical disadvantage in competing for opportunities in the 21st century economy," and that the state had "not kept pace" with the requirements of the global knowledge-based economy. See, the Executive Summary of *Governor Mike Beebe's Strategic Plan for Economic Development,* Little Rock: Arkansas Economic Development Commission, 2009.
[42]The University of Arkansas at Pine Bluff is sometimes regarded as a fifth research university because of its work in the field of aquaculture.
[43]Battelle Technology Partnership Practice, *Opportunities for Advancing Job-Creating Research in Arkansas: A Strategic Assessment of Arkansas University and Government Lab Research Base*, 2009.
[44]Battelle Technology Partnership Practice, *Arkansas' Knowledge Economy Initiatives: Analysis of Progress and Recommendations for the Future*, November 2012, p. 18.

TABLE 8-1 2001-7 Growth Rate in University R&D Funding

Field	Arkansas (percent)	National Average (percent)
Biological Sciences	133	55
Physics	94	31
Chemistry	205	44
Other engineering	105	28
Other life sciences	443	50.5

The state's universities have benefitted from substantial upgrading of their cyberinfrastructure, which includes capabilities in high performance computing, visualization technology, data repositories and storage systems, advanced instruments, and the advanced networks which link such resources. Led by the University of Arkansas High Performance Computing Center, a committee of external experts was convened to assess the state's cyberinfrastructure needs, and on the basis of its recommendations the state launched the Arkansas Cyberinfrastructure Initiative.[45] Underlying that initiative was the recognition that computing has become the most important general purpose instrument of science, and research in a number of key fields requires millions of hours of computing time annually.[46] Arkansas launched the "Star of Arkansas" in 2008, a computer at the High Performance Computing Center

TABLE 8-2 Technology Transfer Performance from Arkansas Universities

	Licenses per $10 Million in Research		Startups by $10 Million in Research	
Year	Arkansas	U.S. Average	Arkansas	U.S. Average
2007	0.50	0.18	0.84	0.32
2008	0.31	0.04	0.78	0.12
2009	2.92	0.14	0.77	0.11

[45]The Arkansas High Performance Computing Center supports research at the University of Arkansas in computer science, nanoscience, computational biomagnetics, and chemistry, material science, and spatial science. The Arkansas Cyberinfrastructure Advisory Committee, comprised of external experts, was partially funded by NSF through the University of Arkansas and the Arkansas Science and Technology Authority. The Advisory Committee drafted a strategic plan for the buildout of the state's cyberinfrastructure. National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit., p. 24.

[46]Recent nanotechnology device research at the University of Arkansas required 70 million hours of computing time annually. Another project seeking to create three-dimensional models of alloys that do not yet exist, using 20 million or more atoms, required 6 million hours of computing time annually. Ibid.

capable of storing five times the data found in the entire Library of Congress. In 2011, the Center acquired another powerful supercomputer, "Razor."[47] The University of Arkansas cyberinfrastructure has been linked to, and supports, the state's other research universities and four-year colleges.

The state is also taking steps to improve PreK-12 education. A decade ago, the shortcomings in the state's PreK-12 educational system were sufficiently severe that the Arkansas courts declared the state's system of school funding to be "inadequate under … The Arkansas Constitution."[48] In 2007, the percentage of freshmen entering the University of Arkansas at Pine Bluff requiring remedial courses was 75.5 percent for English, 84.9 percent for math, and 73.6 percent for reading.[49] A 2006-7 survey which asked Arkansas college faculty members to grade the Arkansas public schools on preparing students for college found that over half gave the schools grades of D (50.2 percent) or F (9.6 percent).[50]

The constitutional challenge to the state's funding of the public schools led to a court order that pursuant to the state constitution, financing of the schools should be sufficient to provide an "adequate educational system" based on a cost study, a decision that was upheld by the Arkansas Supreme Court in 2002. The net result has been a substantial increase in state funding for operations and facilities in elementary and secondary schools as well as overhaul of the curriculum, increased teachers' salaries and increased requirements for accountability from school districts.[51] Arkansas is now winning accolades for levels of per-pupil funding, test scores, transparency, accountability, standards, and increase in advanced placement students.[52] A 2012 assessment of state K-12 science standards concluded that between 2005 and 2012, the Arkansas school system had moved from a grade of D to B.[53]

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[47]Ibid. Both of these machines were partially funded by the NSF. "Rick McMullen Appointed Director of the Arkansas High Performance Computing Center," University of Arkansas Newswire, July 31, 2012.
[48]Lake View School District No. 25 v. Huckabee No. 1992-5318 (Pulaski County Chancery Court) May 25, 2001.
[49]Arkansas Department of Education, *Combined Research Report of Business Leaders and College Professors on Preparedness of High School Graduates,* January 2007.
[50]Ibid.
[51]By 2008, over half of Arkansas's students scored "proficient or above" on state tests of mastery of grade-level knowledge compared with levels of 20 to 40 percent a decade previous. In 2007 Arkansas was singled out along with Massachusetts by U.S. Secretary of Education Margaret Spellings as an example of a state educations reform program worthy of emulation by other states. Arkansas Task Force on Higher Education Remediation, Retention and Graduation Rates, *Access to Success: Increasing Arkansas' College Graduates Promotes Economic Development*, August 2008.
[52]See the summary of the keynote speech by Governor Mike Beebe in the Proceedings chapter of National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit.
[53]The report observed that "Arkansas presents a well-organized and generally sound set of science standards, with thorough and excellent treatment of most—though not all—disciplines. Curricula that are well-aligned to this document ought to be solidly grounded and, provided they are staffed by

Also playing a key role is the Arkansas Science Technology, Engineering and Math (STEM) Coalition, a statewide partnership of leaders from the business, government, education and community sectors whose goal is to develop and implement policies to improve STEM teaching and learning in the state. Among other initiatives, the coalition has secured funding for 27 elementary school science specialists, sought state grants to STEM teachers to increase their income, established a web portal for STEM lesson plans, and advocated differential pay for STEM teachers.[54]

Early-Stage Funding

Arkansas's efforts to foster innovation have long been hampered by the dearth of early-stage funding for start-ups. In 2002, a state task force seeking to foster the creation of knowledge-based jobs concluded that "a key element that has been missing from the entrepreneurial equation in Arkansas is the lack of venture capital to keep new knowledge-based businesses in the state.[55] A 2012 study by Battelle Technology Partnership Practice found that "formal venture capital and private equity investments have been stagnant in Arkansas, with an average of less than one formal venture capital investment per year since 2007.[56] Battelle commented that "as long as Arkansas lacks a locally based early-stage venture capital fund, the prospects for substantial investment of initial rounds of venture capital in emerging companies are not promising."[57]

A number of public and private institutions are currently working to ensure that early stage financing is available to innovative start-ups.

- The state provides extreme early-stage financing to start-ups via Business tax Incentives, the Arkansas Risk Capital Matching Fund, and the ASTA Seed Capital Fund.[58]

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scientifically competent teachers, classrooms of the Natural State could do a fine job of science education. Thomas B. Fordham Institute, *The State of State Science Standards*, 2012, p. 23.

[54]Michael A. Gealt, "Arkansas STEM Coalition Activities," in National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit.

[55]*Report of the Task Force for the Creation of Knowledge-Based Jobs*, September 2002, p. 26.

[56]Between 2002 and 2006, the number of Arkansas companies receiving private equity and formal venture capital investments was 22, a figure that fell to 15 for the 2007-11 period. Battelle Technology Partnership Practice, *Arkansas' Knowledge Economy Initiatives: Analysis of Progress and Recommendations for the Future*,November 2012.

[57]Ibid. p. 25. At the Arkansas symposium convened for this project, Jeff Johnson, recounting the start-up of his company, ClearPointe (a Little Rock-based managed service provider) said that his company's only original source of capital was its receivables. ClearPoine did not succeed in raising venture capital in the early 2000s so it was forced to rely on loans from local banks, which "are not the best way to start a company, but we had no other options." He identified access to funding as his company's highest hurdle to overcome. National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit., p. 32.

[58]The Business Tax Credit program provides transferable tax credits to start-ups that do not have state tax liabilities given that they have little or no income at the early stages of growth. The ASTA

- Arkansas Capital Corporation Group (ACCG), a private not-for-profit organization, provides early-stage funding through an affiliate, Diamond State Ventures (venture capital investments of up to $20 million) and Arkansas Capital Corruption (ACC) (long-term fixed-rate loans).[59]
- ASTA Technology Development Grants averaging $100,000 per year, are provided to state-based companies commercializing new technology-oriented products and processes involving royalty-based agreements.[60]

The Arkansas Development Finance Authority has encouraged out-of-state venture capital firms to monitor deal flow in Arkansas and to invest in the state, and ADFA has invested in six external venture funds, which have in turn invested in 4 deals in Arkansas.[61] Battelle (2012) reported that between 2007 and 2012, state initiatives to promote innovation had assisted 135 new companies employing 1,259 workers in industries with average wage levels more than double the state average.[62]

Innovation-Based Development

Arkansas has implemented a broad array of policy measures to promote the establishment and expansion of knowledge-based industry in the state. The Arkansas Research and Technology Park has been established adjacent to the University of Arkansas at Fayetteville to nurture technology-based companies with a "set of core R&D competencies at the university."[63] In 2011, Arkansas State University at Jonesboro opened a commercial innovation technology incubator at its Arkansas Biosciences Institute Commercial Innovation Center, which provides offices and laboratory facilities for businesses seeking to turn biological innovations into services and products.[64] In 2011, Governor Mike

Seed Capital Fund provides an annual average of $750,000 for working capital to support initial capitalization and/or expansion of technology-based start-ups in the state. The Arkansas Risk Capital Matching Fund, administered by the Arkansas Development Finance Authority provides Technology Validation funding to assist very early stage start-ups in proof of concept, prototyping, market research, and other commercialization milestones. National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit., p. 31; Battelle (2012) op. cit., p. 7.

[59]National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit., p. 31.

[60]Battelle (2012), op. cit., p. 31.

[61]According to Battelle (2012), Arkansas's innovation initiatives have fostered a number of start-ups through the angel-financed stage, and the funds are pursuing wider investments and later stage deals. Ibid. p. 24.

[62]Battelle (2012), op. cit., p. ES-2.

[63]Jay Chesshir, "Research Parks in Arkansas," National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit.

[64]"Brian Rogers Named Director of Commercial Innovation Technology Incubator," Arkansas State University press release, January 5, 2011.

Beebe signed a memorandum of understanding with the U.S. Food and Drug Administration providing for establishment of a center of excellence in collaboration with the National Center for Toxicological Research (NCTR) at Pine Bluff, Arkansas to develop and commercialize nanotechnology products and processes associated with toxicology.[65]

Arkansas is leveraging federal resources to foster local knowledge-based economic development. The University of Arkansas for Medical Sciences (UAMS) at Little Rock operates a medical incubator, UAMS BioVentures, which as of 2009 had 44 start-up projects underway or under review and in which in 2008 accounted for $29.4 million in revenues from new products, services and research, and $52.4 million in economic output from BioVentures companies.[66] The National Science Foundation, which funds Materials Research Science and Engineering Centers (MRSEC) at universities, has established a joint MRSEC with the Universities of Arkansas and Oklahoma to conduct interdisciplinary research in nanotechnology that had produced six spinoff companies as of early 2010.[67] NSF has established an Industry/University Cooperative Research Center (I/UCRC) for engineering and logistics in a collaboration involving Sam's Club and the University of Arkansas.[68]

Wind Power Manufacturing

Arkansas state and local authorities have augmented the state's natural advantages and technological legacy in the electric power industry with incentives and support from state universities to establish the state as "a manufacturing powerhouse for the wind industry." Arkansas is located at the edge of the "Saudi Arabia of wind," the U.S. Great Plains, and its strategic geographic position is cited by manufacturers of wind power equipment as an important factor in their decision to locate facilities in the state.[69] In addition, the University of Arkansas is the site of the National Center for Reliable Electronic Power Transmission (NCREPT), which emphasizes industrially-relevant research into future energy systems and operates as a testing, prototyping and

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[65]The collaboration will involve five Arkansas universities and will examine research themes such as evaluation of drugs for medical use, food contaminants, and detection of terrorist threats. "Beebe, FDA Sign First of its Kind Agreement at NCTR," *Arkansas Business* August 12, 2011.
[66]Michael Douglas, UAMS BioVentures, "From University Research to Start-Ups: Building Deals for Arkansas," National Research Council, "Building the Arkansas Innovation Economy: Summary of a Symposium," March 8, 2010.
[67]Greg Salamo and Alex Biris, "Nanotechnology," in National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit.
[68]National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit., p. 34.
[69]Joe Brenner, "The Wind Industry in Arkansas: An Innovation Ecosystem," National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit.

industrial collaboration center for users of electricity.[70] The competencies of the University of Arkansas in electric power were cited in a 2007 study by the Battelle Technology Partnership as a factor favoring the emergence of a local electric power-based industrial sector.[71]

Wind power manufacturers began to establish facilities in the state in 2007, citing locational advantages, support from the states' political leadership, incentives, and the availability of an "able workforce." Governor Beebe commented in 2008, when the state won a competition for the location of a plant by L. M. Glasfiber, a Danish firm making about one-third of the world's turbine blades, that the state had run into work force issues in the past, and that "we had prioritized changing that."[72]

One of the wind equipment manufacturers investing in Arkansas was Nordex USA, a subsidiary of Nordex SE, a German producer of wind turbines that was one of the pioneers of developing wind power technology. The company's manager's cited factors underlying their decision to locate a manufacturing facility for 2.5 MW wind turbines in Jonesboro, Arkansas—one of the most technologically sophisticated facilities of its kind in North America—as the availability of a trainable work force, Arkansas' geographic location, the nearby presence of Arkansas State University, and the demonstrated commitment of state and local political leaders to economic development.[73]

Before the Nordex plant opened, the company developed a relationship with Arkansas State University, which implemented a workforce training

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[70]Alan Montooth, "Research in Advanced Power Electronics: Status and Vision," National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit.

[71]Jerry Adams, "Understanding the Battelle Study," National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit. Little Rock is the headquarters for the southwest Power Pool (SPP), a cooperative organization that manages the flow of electrical power to nine states. SPP manages the flow of electric power over networks, operates as a wholesale sales agency for power and sells transmission services. General Cable, a major producer of electric power transmission equipment, operates a plant in Malvern, Arkansas. Presentation of Nick Brown, "Arkansas' Role in energy Transmission Management," National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit. "Backers, State Will Benefit," Fort Smith *Times Record* November 21, 2011.

[72]In 2009, Mitsubishi Power Systems Americas (MPSA) chose Fort Smith, Arkansas, as the site for a $100 million manufacturing plant to produce wind turbine nacelles. The City of Fort Smith agreed to extend a street and water and sewer lines to the plan site. State and local revenue bonds were used to underwrite some of the projects cost. Certain fees associated with the construction were waived. The Fort Smith Regional Chamber of Commerce provided an undisclosed amount of financial support. The University of Arkansas at Fort Smith agreed to support the plant through its training and certification programs. The University's chancellor, Paul Berau traveled to Japan to meet the Mitsubishi team that would be sent to Fort Smith. The university's assistant provost, a Japanese national, served as translator and helped with cultural affairs in the negotiations with Mitsubishi. Finally, Governor Mike Beebe made two "secret visits" to Fort Smith to speak with Mitsubishi executives. "Fort Smith Lands Wind Power Plants 400 Jobs," *Arkansas News* October 16, 2009.

[73]Joe Brenner, "The Wind Industry in Arkansas: an Innovation Ecosystem," National Research Council, *Building the Arkansas Innovation Economy: Summary of a Symposium,* op. cit.

program in a type of "mechatronics" which involves teaching a combination of electrical and mechanical skills that are specific to the manufacture of wind turbines. The university worked with Nordex and Beckmann Volmer, a supplier to Nordex of turbine mainframes and other wind power components, to create specific classes and degrees to meet the unique needs of the wind power industry. Complementing these initiatives, Nordex built a 10,000 square foot training academy at its factory site. The city of Jonesboro authorized an industrial development bond issue of $100 million to finance the construction of the Nordex plant. Nordex responded that $125 million would be required. The city agreed to the increase. At the federal level, Nordex received $22 million in tax credits pursuant to the American Recovery and Reinvestment Act of 209 for its Jonesboro facility.[74]

The innovative wind manufacturing complex that has evolved in Arkansas since 2007 is now exporting wind equipment to wind farms in the Great Plains and Middle West, where its location gives it a transportation cost advantage relative to production bases in Europe and China.[75] In 2011, Governor Beebe, who was serving as chairman of the National Governors Association Natural Resources Committee, noted that the wind power industry was a growing sector within Arkansas' economy, and while the state's own wind resources were not ideal—reflecting inconsistent wind patterns—he hoped the wind power industry in the state would continue to grow:

> *At some point we have to realize that our national security interests are best pursued when we're not dependent on parts of the world that don't like us very much ... We weren't satisfied jut to sit back and let other folks take the lead on that wind power.*[76]

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[74]Interview with Joe Brenner, Vice President of Production of Nordex USA, in *Wind Systems* January 2001; "Beckmann Volmer Breaks Ground on Osceola Plant," *Paragould Daily Press* September 14, 2011; "Nordex Opens Arkansas Wind Energy Plant," *REVE* October 31, 2010; Jonesboro Asked to Increase Bond Issue for Plant," *Arkansas Business* August 24, 2009; "Nordex Gets Council's OK to Raise bonds to $125 M," *Arkansas Business* August 24, 2009; "Firm building Jonesboro Plant to Get $22 million Stimulus," *NWA Online* January 11, 2010.

[75]"Jonesboro's Nordex Plant Secures Turbine Contract," Associated Press State Wire: Arkansas February 24, 2012; "Nordex Wins 75-MW Project in Repeat Order," *Windpower Engineering* December 2, 2010; "Nordex USA Wins 41 MW Wind Energy Order from Wind Farm," *REVE* November 10, 2010; "Nordex USA Wins Two New Wind Turbine Orders for Iowa," *REVE* November 23, 2011; "Texas Wind Farm to Use 30 2.5 MW Wind Turbines," *Windpower Engineering* December 19, 2011; Way Wind and Nordex USA Announce New Wind Power Venture in Nebraska," *Windpower Engineering* June 21, 2011; "Nordex, Michigan Firm Partner on 300 MW Wind Power Project in US,"*REVE* March 23, 2011.

[76]"Beebe Calls for More Wind-Power Growth in Arkansas" *Associated Press State Wire: Arkansas* March 24, 2011.

LESSONS LEARNED

Illinois and Arkansas are each undertaking a comprehensive effort to address the core factors that act as a drag on innovation.

With respect to Illinois a key issue has been a low level of new entrepreneurialism reflecting factors such as a cultural aversion to commercial risk, the difficulty in securing early stage financing, and policymakers' traditional emphasis on attracting and keeping big companies. State leaders are confronting these weaknesses through initiatives to support start-ups, university programs designed to foster entrepreneurialism and creation of new institutions to provide early stage financing.

Arkansas's long standing weakness has been the low average educational and skills level of its workforce and the difficulty of starting new companies in the state, above all a reflection of the dearth of early-stage financing. The state has made substantial strides in improving its work force profile through substantial and sustained investments in its universities, programs to improve the caliber of K-12 education, and partnerships with companies to train workers in specialized competencies. The state has fostered a number of initiatives to increase the availability of early stage funding, but this remains an area of vulnerability.

IV

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V

ANNEX A:
STANFORD
AND SILICON VALLEY

Annex A

Stanford and Silicon Valley

Many, if not most, state and regional initiatives to develop innovation clusters use California's Silicon Valley as an important point of reference. While it is generally recognized that it would be impossible to fully replicate the unique mix of individual genius, fortunate happenstance, and regional advantage that gave rise to today's Silicon Valley, individual factors underlying the Valley's successful innovation dynamic are considered worthy of study and emulation. One of the most important of these is the historic role played by Stanford University in the origins of Silicon Valley and in sustaining the survival and flourishing of high technology industries in the surrounding region.

Many narratives exist regarding the origins of Silicon Valley, some of which diverge or even conflict with each other.[1] However, in virtually every account, Stanford University occupies a central role. Even Gordon Moore, who argues the role of Stanford in the creation of Silicon Valley can be overstated, credits it with creating firms that accounted for half the revenues generated in the Valley between 1988 and 1996 and with an "exemplary" contribution to "local labor market needs."[2] "In a region in which most successful firms began as start-ups, Stanford is known for its "startup culture…[I]t's almost an unwritten rule that you have to start a company to be a successful professor at Stanford."[3] As of 2011 nearly 5,000 companies existed which could trace their roots to Stanford, including Hewlett-Packard, Cisco Systems, Sun Microsystems, Yahoo, and Google.[4] Electronics pioneer William Hewlett wrote

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[1]On this point, see Timothy J. Sturgeon, "How Silicon Valley Came to Be", in Kenney, Martin, ed., *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region,* Stanford: Stanford University Press, 2000.
[2]Gordon Moore and Kevin Davis, "Learning the Silicon Valley Way." SIEPR Discussion Paper No. 00-45, Stanford Institute for Economic Policy Research, July 15, 2001, p. 11.
[3]"Upstarts and Rabble Rousers…Stanford Fetes 4 Decades of Computer Science," *San Francisco Chronicle* March 20, 2006.
[4]"Sowing the Seeds of a Startup: StartX Seeks to Propel Young Entrepreneurs to Forefront of their Field." *San Jose Mercury News* December 29, 2011.

in 1991 of the role of Stanford Professor and its former Provost, Frederick Terman

> *The presence of Stanford University was a key factor in the development of the technology enterprise now known as Silicon Valley. More than anything, it was Terman, his students, and the encouragements and opportunities that he gave them that enabled this great enterprise to flourish.*[5]

Stanford University was founded by Leland Stanford, a former governor of California and U.S. Senator who had made his fortune in the railroad industry. From its inception in 1891, Stanford's leaders saw its mission as service to the Western United States, to serve as a counterpoise to the region's exploitation by Eastern economic interests.[6] Stanford looked to MIT as a model, reflecting the fact that MIT functioned as an incubator of new firms. "Stanford and MIT were both committed to an endogenous strategy of encouraging firm formation from academic knowledge." The university's founders believed that it could achieve greatness only if it were surrounded by technology-intensive industries, which, because they did not exist in California at the time, would need to be created.[7] Executing this task was the responsibility of Stanford's Engineering School, which was a "repository of trained people and existing technical knowledge that could be utilized for firm formation, even before the development of advanced research as a spin-off source." In 1900, California depended on the East for electrical equipment, so Stanford's first president and a number of faculty members invested in start-ups launched by recent Stanford graduates in the electrical business.[8]

THE LEGACY OF FREDERICK TERMAN

Frederick Terman grew up at Stanford, where his father was a faculty member, and earned an undergraduate degree in chemistry and a master's degree in electrical engineering from the university. He earned a ScD at MIT in 1924,

[5]C. Stewart Gillmore, *Fred Terman at Stanford: Building a discipline, a University, and Silicon Valley.* Stanford: Stanford University Press, 2004, p. 230.
[6]"A sense of solidarity permeated the eleven western states in the first half of the Twentieth Century. Westerners complained about having a 'colonial' relationship with the East; their raw material base—with corresponding jobs, profits, and economic growth—was 'plundered' by distant forces. The region's perceived exploitation at the hands of eastern interests fueled booster like attempts to build indigenous and self-sufficient local industry" Steven B. Adams, "Regionalism in Stanford's Contribution to the Rise of Silicon Valley," *Enterprise & Society* 4(3): 522-23, 2003.
[7]Henry Etzkowitz, "Silicon Valley: The Sustainability of an Innovation Region," pp. 2, 5, 2012.
[8]Ibid. p. 5. Perhaps the most important spin-off was Poulsen Wireless Telephone and Telegraph, later renamed Federal Telegraph, established in 1909 by Stanford graduate Cyril Elwell with the substantial backing of David Starr Jordan, the president of Stanford's Engineering Department. Federal Telegraph made major contributions to the early development of radio communications. Sturgeon, "How Silicon Valley Came to Be," op. cit. p. 19.

where his advisor was Vannevar Bush. He became a member of Stanford's engineering faculty in 1925, designed a curriculum in electronics featuring circuits, vacuum tubes, and instruments, and authored a book, *Radio Engineering,* which went through numerous editions. In the early 1940s, Terman answered a call from Vannevar Bush to lead a major research project at Harvard to develop radar countermeasures.[9] This effort was so successful that he concluded that the government would continue to fund comparable research after the war and that the government should fund basic research at universities.[10] At war's end, he returned to Stanford and became Dean of the School Engineering in 1951 and Provost of the University in 1955.[11]

In the 1930s, as a young member of Stanford's engineering faculty, Terman encouraged his students to consider the commercial possibilities of electronic devices and to engage in multidisciplinary research with theoretical and practical potential. He took his students on visits to local technology-oriented firms, a number of which had been founded by Stanford graduates, "and Stanford [has] had people go from the universities to companies ever since."[12] He urged two students, William Hewlett and David Packard, to found a company to commercialize an audio-oscillator that Hewlett had developed through his academic work, giving rise to one of the most famous founding legends of Silicon Valley. Terman—a veritable one-man incubator—helped Hewlett and Packard with the technical development of their product, helped arrange financing, rented property containing the now-famous garage where they began work, and helped them secure patent rights.[13] Terman provided

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[9]Terman brought roughly thirty Stanford students and colleagues to the Harvard project over time, where they received practical experience in microwave engineering. Terman was responsible for developing new radar jamming devices and for teaching government contractors such as GE and Bell Labs how to manufacture them. Stuart W. Leslie, "The Biggest Angel of them All: The Military and the Making of Silicon Valley," 2000.

[10]In *Science, The Endless Frontier*, his 1945 report to the President of the United States, Vannevar Bush called for an expansion of government support for science, and he pressed for the creation of the National Science Foundation.

[11]Terman's tenure at the Radar Countermeasures Lab at Harvard put him in a position to observe innovation activities in Cambridge. In a letter to Stanford's treasurer, he warned that if Stanford did not follow the MIT model of aggregating federal research dollars after the war, it would be reduced to the status of a teaching university, "a Dartmouth College." Etzkowitz, op. cit., p. 9. In fact, after the War, Stanford reaped huge benefits from federal support; "Without massive federal investments (mostly for defense) in Stanford's academic programs and in the surrounding industrial community, neither the university nor the region could have grown as strong as quickly." I the year 2000, Stanford remained near the top of the list of university recipients of defense contracts, as did Stanford Research Institute. Stuart W. Leslie, "The Biggest Angel of the All: The Military and the Making of Silicon Valley," in Martin Kenney, ed., *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region, Stanford:* Stanford University Press, 2000, pp. 66-67.

[12]Computer History Museum, "Lewis Terman: Reminisces of Fred Terman," April 15, 2010, p. 4.

[13]Annalee Saxenian, "Creating a Twentieth Century Technical Community: Frederick Terman's Silicon Valley," 1995, Paper prepared for the inaugural symposium on the Inventor and the Innovative Society, the Lemelson center for the Study of Invention and Innovation, National Museum of American History, Smithsonian Institution. Carolyn Tajnai, "Fred Terman, the Father of Silicon Valley" Stanford Computer Forum: Stanford University, May 1985.

financial and technical support to other start-ups during the 1930s, most of them launched by Stanford graduates and some of these, such as Varian Associates and Litton Industries, grew into major electronics firms. Speaking of the western United States, Terman believed that "if Western industry and Western industrialists are to serve their own enlightened long-range interests effectively, they must cooperate with Western universities wherever possible and strengthen them by financial and other assistance."[14]

Stanford Industrial Park

Frederick Terman was instrumental in the establishment of Stanford Industrial Park, the first University-owned industrial park in the world. At the end of World War II, Stanford faced financial difficulty and sought ways to raise additional revenue. The University owned vast tracts of land but Leland Stanford's will precluded its sale. However, the will did not bar leasing the land and, the university drew up plans to establish a light industrial park on land that it owned. Terman characterized the park as "our secret weapon" and sought to encourage technology-oriented companies to locate there.[15]

Varian Associates became the first tenant in the Park in 1951, followed by Hewlett Packard, GE, Eastman Kodak, Lockheed, and Shockley Semiconductor Laboratory, which spun off Fairchild Semiconductor—"a corporate seedbed spawning over 38 new companies which were started by former employees," including Intel.[16] Terman used his former student, David Packard, to promote the park; Terman later recalled that "people would come to me to see about locating a business in the park and I would suggest they also talk to Packard to find out want it meant to be close to a cooperative university. When people came to him first, he would reciprocate. Our goal was to create a center of high technology." By 1977, the Park was the site of 75 companies with 19,000 employees.[17]

By 1958, the Palo Alto Chamber of Commerce found 123 electronics and electronics-related firms were operating on the Peninsula, including 56 firms in Palo Alto and at Stanford. A 1958 account of the electronics community around Stanford commented that the "creative center of this great scientific activity is Stanford University…The name of Dr. Frederick E. Terman…is the magnet that continues drawing renewed scientists to the faculty and nationally known electronics research firms to the Palo Alto area."[18]

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[14]Saxenian, "Twentieth Century Technical Community," op. cit.

[15]Terman advocated limiting leases to the park to high technology companies that might benefit Stanford. Tajnai, "Father of Silicon Valley," op. cit.

[16]Carolyn Tajnai, "From the Valley of Heart's Delight to the Silicon Valley: A Study of Stanford University's Role in the Transformation," Computer Forum: Stanford University, 1996, p. 6.

[17]Saxenian, "Twentieth Century Technical Community." op. cit.

[18]Hugh Enochs, "Electronics Research Community Develops Around Stanford Laboratories" *The Tall Tree,* May 1958, cited in Gillmore, *Fred Terman at Stanford,* 2004, op. cit., p. 328.

Honors Cooperative Program

In the 1950s, Terman oversaw the establishment of the Honors Cooperative Program at Stanford, which enabled engineers at electronics companies to enroll in graduate courses in order to enable them to remain current technologically. Through the Honors Cooperative Program—that has no counterpart at MIT—"Stanford offered an important advantage to small companies that sought to attract top talent but were unable to provide the continuing education and training needed in a fast-changing technological environment."[19] Terman also launched an industrial liaison program pursuant to which company affiliates that pledged $5000 a year for five years received access to Stanford's research projects, research results, and graduate students through vehicles such as seminars, guest lectures, and periodic reports.[20] Participants in this program were invited by Stanford "to drop in on the labs casually, bring technical problems of a nonproprietary nature to faculty and to help shape the direction of future research.[21]

STANFORD AND THE SEMICONDUCTOR INDUSTRY

Terman played an instrumental role in persuading William Shockley, the co-inventor of the transistor, to found his own transistor company, the Shockley Semiconductor Laboratory, in the Bay Area where it became a tenant in the Stanford Industrial Park in 1956.[22] Shockley gathered a team of brilliant engineers, but in 1957, chafing under his management style, a group of them, the so-called Traitorous Eight—which included Robert Noyce and Gordon Moore—departed to form Fairchild Semiconductor, which became a subsidiary of Syosset, New York-based Fairchild Camera and Instrument Corp.[23] In 1959, a team led by Noyce developed the first commercially viable integrated circuit, a single chip incorporating multiple transistors and other devices.[24] In the decade that followed, hundreds of companies introduced electronic products based on integrated circuit technology, many of them founded in the Bay Area by Fairchild alumni. Noyce and Moore left Fairchild to form Intel Corporation in 1968. Other Fairchild veterans who founded semiconductor companies included Charles Sporck (National Semiconductor Company), Wilf Corrigan (LSI Logic),

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[19]Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Cambridge, MA and London: Harvard University Press, 1996, p. 41.
[20]Enochs, Hugh. "Electronics Research Community" Op Cit.
[21]Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* op. cit., p. 67.
[22]Gillmore, *Fred Terman at Stanford,* op. cit., p. 311
[23]"Tales of Silicon Valley Past: Legendary founders Talk About Early Days at Fairchild," *San Jose Mercury News,* May 13. 1995.
[24]Jack S. Kilby of Texas Instruments produced an integrated circuit in 1958, and Kilby and Noyce generally are regarded as co-inventors of the IC. "Growth of a Silicon Empire: Bay Area's Fertile Intellectual Ground Helped Sprout High Technology Industry," *The San Francisco Chronicle* December 27, 1999.

and Jerry Sanders (Advanced Micro Devices).[25]

Stanford's curriculum kept abreast with the rapid pace of the IC technology development. Each improvement in IC products and processes was closely followed by the introduction of courses to prepare future engineers to work in the new technology. Stanford's Department of Electrical Engineering introduced a course in the design and fabrication of integrated circuits soon after these devices became available in 1961. Stanford's abiding commitment to offer a contemporarily-relevant curriculum in integrated circuitry led it eventually to establish its Center for Integrated Systems in 1983. Terman sought out the most talented and informed engineers at Silicon Valley companies and appointed them as "adjunct professors" at Stanford to teach both students and faculty about the most recent developments in the field.[26]

STANFORD AND PERSONAL COMPUTING

The trustees of Stanford established the Stanford Research Institute (SRI, now known as SRI International) in 1946 to foster innovation that would ultimately spur the economic development of the region.[27] In 1968, an SRI scientist, Doug Engelbart, gave a 90-minute demonstration to an audience of about a thousand people in San Francisco which was one of the first public demonstrations of the computer mouse, developed by Engelbart and his colleague Bill English in 1963, as well as a demonstration of teleconferencing over a computer screen, online collaboration, real-time text editing, and the first use of hypertext links. Thirty years later a member of the audience recalled that the demo was "unlike anything else I've ever seen…just mind-boggling." The audience responded to the demo with a standing ovation "that went on and on."[28]

When federal funding for Engelbart's computer research ended in 1977, he and nearly half of his SRI research team moved to join Xerox's Palo Alto Research Center (Xerox PARC).[29] PARC was established in 1970 by Xerox then-CEO C. Peter McColough to develop "the architecture of

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[25]"Tales of Silicon Valley Past: Legendary founders Talk About Early Days at Fairchild," *San Jose Mercury News* May 13. 1995.

[26]Nathan Rosenberg, "America's Entrepreneurial Universities" in David M. Hart, *The Emergence of Entrepreneurship Policy: Governance, start-Ups, and Growth in the U.S. Knowledge Economy,* Cambridge: Cambridge University Press.

[27]SRI had a dual mission of conducting defense-related R&D and providing research support for companies operating on the West Coast. SRI was charged with pursuing science for practical purposes that "might not be fully compatible internally with the traditional roles of the University." Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, op. cit., p. 23.

[28]"Gathering Recalls the Unveiling of Innovations That Led to the Personal Computer," *Pleasanton Tri-Valley Herald* December 10, 2008. "Silicon Valley Celebrates Birth of the Mouse That Roared," *The San Francisco Chronicle* December 4, 1998.

[29]"Of a Mouse and the Man…30 Years: Inventor Saw it as a Tool to Expand the Community of Computing," *San Jose Mercury News* December 8, 1998.

information," and it quickly earned a reputation as "the smartest think tank on the planet."[30] Xerox chose the Stanford Research Park as the site for PARC on the recommendation of its first director, George Pake, who "had been a professor at Stanford and knew the area well and liked it."[31] PARC's location in the Stanford Research Park allowed Stanford graduate students and faculty to participate in PARC research projects and PARC staff to collaborate on academic projects. The relationship between PARC and Stanford was so close that the boundaries were decidedly indistinct.[32]

In 1979, Xerox acquired 100,000 shares of Apple Computer stock and opened PARC's doors to Apple's Vice President for Research and Development, Steve Jobs. In a now legendary visit, Jobs witnessed a demo of the prototype mouse, as well as features such as "windows" that opened on a computer screen and visual images…"icons"…that could be clicked upon rather than commands to be memorized. Jobs "flipped" at the demo.[33] Apple subsequently hired a number of PARC employees and went on to introduce its Lisa (in 1983) and its McIntosh personal computers (in 1984) that incorporated PARC's graphics interface innovations. Robert Spinrad, who served as PARC's director between 1978 and 1982, recalled later that

> *At PARC, we developed the underlying technologies for what is now the modern personal computer: windows, word processors, graphic displays, icons, drop-down menus, image processing, laser printer, the Ethernet…you name it.*[34]

TECHNOLOGY TRANSFER—THE STARTUP OF GOOGLE

Stanford's Office of Technology Licensing opened in 1970, and in four subsequent decades disclosed roughly 8300 cumulative inventions and executed over 3500 licenses. Notable inventions licensed by the office include FM sound synthesis (created by a small Yamaha music chip developed by the music

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[30] "CEO Set Gears in Motion for Valley's Tech Revolution…Xerox Chief Remembered for Research Center," *San Jose Mercury News* December 29, 2006.

[31] "The Genius of Location…Siting Search for Xerox PARC Picks Palo Alto," *San Jose Mercury News* December 29, 2006.

[32] In a 1991 interview a Xerox executive recalled a seminar he had presented at PARC: "The seminar at PARC was held in a large hall, and I noticed that about a third of the audience were not wearing Xerox employee badges, although they participated actively in the discussion. I learned afterwards that they were Stanford faculty, who have an open invitation to all PARC seminars." Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* p. 67.

[33] "Apple Transplanted Xerox Seed," *San Jose Mercury News* December 18, 1989. Larry Tesler, who conducted the demo, later recalled that "Jobs was pacing around the room, acting up the whole time. He was very excited. Then, when he began seeing the things I could do onscreen, he watched for about a minute and started jumping around the room, shouting "Why aren't you doing anything with this? This is revolutionary!" "Creation Myth: Xerox PARC, Apple and the Truth About Innovation," *The New Yorker* May 16, 2011.

[34] "CEO Set Gears in Motion for Valley's Tech Revolution…Xerox Chief Remembered for Research Center," *San Jose Mercury News* December 29, 2006.

department), recombinant DNA technology, functional antibodies, and digital subscriber line (DSL) technology commercialized by Texas Instruments.[35] The University's very well-known licensee is Google, which was created by two Stanford graduate students over a four-year period under the mentorship of the late Stanford computer science professor Rajeev Motwani.[36] Katherine Ku of Stanford's Office of Technology Licensing, recalls that the two students, Larry Page and Sergey Brin,

> *Worked on a project for the library for about four years. They used Stanford resources to develop a search engine that we tried to market to the big four search engine companies, but nobody was interested. The two guys were frustrated, and decided to start their own company. We gave them an exclusive license, but we didn't know if they knew how to do business. We took a little bit of equity, and eventually that 2 percent share brought in about $337 million in equity. We're happy that we were able to give them that start that they needed.*[37]

Stanford initially took 1.8 million shares in Google in return for the right to use Internet search technology developed by Page and Brin at Stanford. The University retained the patent and licensed it to Google pursuant to a multi-year deal. Stanford President John Hennessy sits on Google's board of directors, although not voting on issues related to the University. Stanford sold 10 percent of its stake for $15.7 million in 2004 and the remainder for $336 million in 2005.[38] Katherine Ku of Stanford's Office of Technology Licensing indicates that the Google experience was atypical—only a handful of inventions have generated large returns for the university. Only about ten percent of the University's licensing deals are with start-ups or about 10-12 per year. Over half of the University's licensees are non-exclusive "because we believe that universities should get a fair share when we contribute our technology to a product in the marketplace."[39]

While Stanford's role in the fostering of Silicon Valley unfolded over several generations, it continues to serve as a model for other institutions and

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[35] Katherine Ku, Office of Technology Licensing, Stanford University, "40 Years of Experience With Technology Licensing," National Research Council, "Building Hawaii's Innovation Economy: Summary of a Symposium," January 13-14, 2011.

[36] "Professor Who Mentored Founders of Google Found Dead in Home Pool," Bend, OR: *The Bulletin* June 8, 2009.

[37] Ku, "40 Years of Experience with Technology Licensing," 2011, op. cit.

[38] "Stanford Earns $336 Million Off Google Stock," *San Jose Mercury News* December 1, 2005.

[39] Katherine Ku, "40 Years of Experience with Technology Licensing," National Research Council, "Building Hawaii's Innovation Economy: Summary of a Symposium," January 13-14, 2011. Grant of a non-exclusive license does not actually ensure that the university will realize licensing income from future licensees, a prospect which is speculative. However, for policy reasons, the university may wish to avoid unduly restricting the universe of entities benefiting from its inventions.

regions seeking to foster local innovation.[40] Georgia Tech recruited a former Stanford Dean of Engineering as its President, established innovation institutions patterned on the Stanford Industrial Park and Research Institute, and, like Stanford, have pursued an innovation model based on local start-ups rather than recruitment of established companies to the region.[41] "The examples of Massachusetts Institute of Technology and Stanford University…in stimulating regional high-technology development are often highlighted for emulation."[42] In the symposia convened for this study, Stanford's experience was shared "as an example of what a University can do to make technology transfer effective."[43] But as the work of Annalee Saxenian and others has indicated, differences in regional innovation culture will limit the extent to which the Silicon Valley model can be replicated elsewhere.[44]

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[40]See generally, Stuart W. Leslie and Robert H. Kargon, "Selling Silicon Valley: Frederick Terman's Model for Regional Advantage," *The Business History Review* Winter 1996.
[41]Jan Youtie and Philip Shapira, "Building an Innovation Hub: A Case Study of the Transformation of University Roles in Regional Technology Development," *Research Policy* 37: p. 1194, 2008.
[42]Ibid, p. 1190.
[43]Katherine Ku, "40 Years of Experience with Technology Licensing," National Research Council, "Building Hawaii's Innovation Economy: Summary of a Symposium," January 13-14, 2011.
[44]Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* op. cit.

VI

ANNEX B:
NORTH CAROLINA'S
RESEARCH TRIANGLE PARK

ANNEX B

North Carolina's Research Triangle Park

From a local economic development perspective, North Carolina's Research Triangle Park (RTP) stands as something of a counterpoise to Silicon Valley as well as to conventional wisdom about how to foster innovation. Unlike Silicon Valley, RTP did not spontaneously evolve out of the interaction between local universities and the surrounding region, nor has its success at any point been primarily associated with start-up firms, although many start-ups are attributable to RTP. While local universities were essential to RTP's ultimate success, they were to some extent recruited for the effort by local civic boosters as part of a broader out-of-state recruitment strategy of the sort that is sometimes disparaged by analysts of technology-driven economic development. Research Triangle Park "is the only one of the three celebrated high-tech clusters [the others being Silicon Valley and Route 128] that was conceived of before it existed, and the only one where government and academia were equal partners with private industry during the initial development phase."[1] "[I]n RTP, we see a centrally planned rather than organic process driven by established firms rather than start-ups."[2]

RTP thus is arguably of considerable relevance to states and regions that have not been blessed with the dense networks of universities and innovative local industries that characterized the Boston area and the San Francisco Peninsula in the first half of the Twentieth Century. During that same period, North Carolina was an economic backwater facing a future of long-run economic decline and low per capita income, a prospect that many states and regions still regard with concern today. When RTP was formed in the 1950s, per-capita income in Raleigh, Cary, and Durham, where RTP is located, was far below the state and national averages. Today, half a century later, the RTP region's per capita income greatly exceeds the North Carolina average and is

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[1]Jay Schalin, "An Accident of Planned Growth," Pope Center, January 2, 2011.
[2]Damien M. Ibrahim, "Building the Next Silicon Valley: The role of Angel Investors in Economic Development," University of Wisconsin Law School, September 2008.

significantly above the U.S. national average. "In the 1960s, it was one of the poorest regions in the southeastern United States and today is among the wealthiest in the southeast."[3]

THE FOUNDERS

Although a number of individuals in the North Carolina of the 1940s envisioned that the state's universities could play a role in economic development, the idea of Research Triangle Park is generally conceded to have been conceived by Romeo H. Guest, a North Carolina entrepreneur who was trained as an architectural engineer at MIT, where he saw how research could contribute directly to a local economy. Guest moved to Greensboro in 1936 to open a branch of his family's construction business and began to develop contacts with out-of-state companies seeking locations for factories in the South. Between 1939 and 1942, he sought to persuade Merck & Company to locate in Aberdeen, NC but the firm chose a site near the University of Virginia's teaching hospital. As a result of this experience, Guest began to advocate establishment of a planned research center in North Carolina drawing on the resources of Duke, North Carolina State University, and the University of North Carolina at Chapel Hill (UCNC), and the recruitment of companies with a research orientation.[4] He traveled outside the state with former state treasurer Brandon Hodges and other industrial recruiters to talk about the state with businesses. On October 10, 1953, Guest later recalled, "I wrote down Research Triangle Park [in my diary]", the first use of that term.[5]

Hodges had been elected state treasurer of North Carolina in 1948 and sought to bring new industries to the state, particularly those with a technological orientation, to help it diversify its economic base beyond its principal traditional industries, tobacco, textiles, and furniture, all of which employed low-wage workers. In 1952, North Carolina ranked third from the bottom among states with respect to per capita income. Hodges took Guest's Research Triangle idea to Governor Luther Hodges (no relation) but the Governor was initially unreceptive and apparently not aware of the role technology could play in economic development. Hodges secured the help of William Newell, director of the North Carolina Textile Research Center, a

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[3]Rick L. Weddle, "Research Triangle Park: Past Success and the Global Challenge," in National Research Council, *Understanding Research, Science and Technology Parks: Global Best Practices—Summary of a Symposium,* C. Wessner, ed., Washington DC: The National Academies Press, 2009, pp. 104.

[4]The three research universities had a strong reputation in the mid-Twentieth Century. However, given the lack of employment opportunities for graduates, "North Carolina was experiencing serious 'brain drain', with many of its college graduates moving to other states in search for employment. J.W. Hardin, "North Carolina's Research Triangle Park," *Pathways to High-Tech Valleys and Research Triangles: Innovative Entrepreneurship, Knowledge Transfer, and Cluster Formation in Europe and the United States,* Dordrecht: Springer, 2008.

[5]"Romeo Guest Was Force Behind Research Triangle Park," *Wilmington Star News* April 31, 1983.

proponent of research, who drafted a report, "A Proposal for the Development of an Industrial Research Center in North Carolina". The next meeting with the Governor went better and the Research Triangle project became known as the "Governor's Research Triangle".[6] In 1956, Governor Hodges established the Research Triangle Committee Inc. with the stated mission of encouraging and promoting "the establishment of industrial research laboratories and other facilities in North Carolina primarily in, but not limited to, that geographical area or triangle formed by the University of North Carolina at Chapel Hill, North Carolina State college of Agriculture and Engineering of the University of North Carolina at Raleigh, and Duke University at Durham."[7]

Romeo Guest initiated meetings with the three research universities in 1955, finding them to be "wary" with respect to the Research Triangle concept. William Carmichael, representing the UNC system, supposedly commented to Guest in 1956—

> *Let me see, if I really understand what we are talking about here, you want the professors here and all of us to be the prostitutes and you're going to be the pimp.*[8]

While some representatives of the university community were active in the Research Triangle initiative, the Research Triangle Committee's work reflected an intention that the universities would maintain a certain distance from industry.[9] The Committee adopted the following guideline:

> *It is not anticipated that the three universities in the Triangle shall engage directly in the conduct of industrial research, except under carefully designed and administered policies. Rather, the principal functions of the Universities are to stimulate industrial research by the research atmosphere their existence creates, and to supplement industrial-research talents and facilities by providing a wellspring of*

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[6]Dennis P. Leyden, and Albert N. Link, "Collective Entrepreneurship: The Strategic Management of Research Triangle Park," La Jolla: Strategic Management of Places Conference, December 11, 2011. p. 3.

[7]The Research Triangle Committee was a non-profit, non-stock benevolent, education and charitable corporation to promote industrial research laboratories in North Carolina, particularly in the triangle.

[8]Albert N. Link, *A Generosity of Spirit: The Early History of the Research,* Research Triangle Park: The Research Triangle Foundation of North Carolina, 1995, pp. 28-29.

[9]Howard Odum, Chairman of the Sociology Department of UNC-Chapel Hill, conceived of a research institute to coordinate and integrate the work of the three research universities, suggesting a site near the regional airport at Raleigh. George Simpson, Odum's student, who was appointed in 1956 to the post of director of the Research Triangle Committee, was a professor of sociology at the UNC-Chapel Hill. William Friday, acting president and then president of the University of North Carolina system, played a key role in the formation of the Research Triangle Committee. William Little, a professor of chemistry at UNC-Chapel Hill solicited businesses to locate in the Park and is credited with securing the first industrial tenant, Chemstrand Corp., in 1961. Doug Campbell, "High Tech Down South" *Region Focus,* Summer 2005, p. 39. Fred M. Park, "Research Triangle Park: Turning Poor Dirt into Pay Dirt," *MetroNC* December 1999.

> *knowledge and talents for the stimulation and guidance of research by industrial firms.*[10]

The Research Triangle Committee raised some funds from private investors that were used to take out options on land under the name of a for-profit company, Pinelands.[11] When the for-profit scheme appeared to stall, boosters of the Triangle project turned to Archie Davis, Chairman of Wachovia Bank and Trust Company, to promote the sale of Pinelands stock. Davis immediately faulted the for-profit business model and sought to demonstrate that more capital could be raised more quickly through appeals to wealthy and established North Carolinians to make contributions on a philanthropic basis based on their interest in serving the state of North Carolina. Davis toured the state at his own expense advocating the research park for the good of the state, and raised $1,425,000 within several months from over 800 anonymous individuals. The funds were used to acquire the land that had been purchased by Pinelands and to transfer control of Pinelands to a non-profit Research Triangle Foundation.[12] In addition, the funds supported the establishment of a separate Research Triangle Institute to perform contract research for government and industry and construct a building for the Institute in the park.[13] George Simpson, a faculty member at UNC-Chapel Hill, became director of the Institute and addressed the UNC faculty in 1957, articulating his vision of the Research Triangle:

> *Our problem in North Carolina and in the South is not essentially technical; we have available to us the same scientific information as is available elsewhere; we have the same books and substantially the same facilities for training young people in science. Our problem is essentially cultural—it is the failure of our people to grasp the uses of science in industrial development, the failure to put to work what is available, the failure to begin those chain reactions of research and invention and developing which are the hall mark of mid-twentieth century life. These three institutions, located so closely together are really a sort of improbable peak standing above the relative Sahara of scientific application to industrial development…I suggest therefore, that great advantage will accrue to the University if the Triangle area develops as we hope and becomes known as the research center of the*

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[10]Albert N. Link, *A Generosity of Spirit: The Early History of the Research,* op. cit., pp. 28-29.

[11]An early major investor was Karl Robbins who had experience in the states' textile industry but had relocated to New York. Robbins invested $2,705,000 that was used to option parcels of land. He lost interest in further investments by North Carolina residents. Layden and Link, "Collective Entrepreneurship," op. cit., p. 5.

[12]Davis consulted with Thad Eure, who had served as North Carolina's secretary of state for nearly half a century, and managed to win tax-exempt status from the IRS despite the fact that the new entity involved a partial rollover from private stock. "They virtually set a legal precedent—out of court." Park, "Poor Dirt into Pay Dirt", Op. cit. p. 4.

[13]Albert N. Link, *A Generosity of Spirit: The Early History of the Research,* op. cit., p. 73.

South and as one of the major research and scholarly concentrations in the nation.[14]

Research Triangle Park opened its doors in 1959. Simpson developed an inventory of the research strengths and faculty activities at the three universities, determining that significant competencies of potential interest to industry existed in pharmaceuticals, electronics, and chemistry. "With hundreds of prospects, Simpson targeted key faculty members who could become traveling salesmen in their respective fields, and the triangle recruitment show hit the road in all directions".[15] Simpson assembled "one of the most unusual teams of traveling salesmen ever seen in business offices," comprised of faculty members who each developed industry-specific brochures based on their academic specialties.[16] Professor William Little of the Chemistry Department at UNC-Chapel Hill visited roughly 200 companies during the academic year of 1958-59, reporting significant interest by companies who "needed a supply of graduates to staff future research projects."[17] The first company to purchase land in the park, Chemstrand Corporation, a joint subsidiary of Monsanto and American Viscose, was one of Little's targets, acquiring land in 1959, and went on to originate Astroturf at its R&D facilities in the Park. Other first wave organizations to enter the park included textile firms such as Hercules Beunit and the American Association of Textile Chemists and Colorists. Despite the recruitment of some companies, Research Triangle Park remained "largely empty" until 1965, despite extensive recruitment efforts throughout the U.S. and Europe, and by 1964 was reportedly on the brink of bankruptcy.[18]

The Park's fortunes were substantially improved as a result of Terry Sanford's election as governor in 1960. Sanford supported the presidential candidacy of John F. Kennedy despite the fact that Kennedy's Catholicism entailed local political risk for Sanford. Sanford campaigned for Kennedy, raised money for his campaign and subsequently helped former Governor Hodges become Kennedy's Commerce Secretary. After his election, Kennedy supported Sanford's efforts to expand the Research Triangle Park through major land acquisitions.[19] Sanford secured a commitment from the President to build an "Environmental Health Sciences Center in Research Triangle Park"—Sanford later recalled "I really leaned on him to get that environmental health center put

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[14]Albert N. Link, *A Generosity of Spirit: The Early History of the Research,* op. cit., p. 49.
[15]Park, "Poor Dirt into Pay Dirt," op. cit., p. 3.
[16]Albert N. Link, *A Generosity of Spirit: The Early History of the Research,* op. cit., p. 42.
[17]Ibid. p. 3. Little was enthusiastic about the project because of his unhappiness with the fact that many of North Carolina's graduates in science and engineering "inevitably left for jobs in large, often Northern cities". In 2005, at age 75, he remembered that "I couldn't do anything with my work in Chemistry in North Carolina. Campbell, "High Tech Down South," p. 39, 2005.
[18]*North Carolina History Project. "*Terry Sanford (1977-1998)". *<http://www.northcarolinahistory.org/encyclopedia/547/entry>*.
[19]Ibid. Southern Oral History Program, "Oral History Interview with George Esser", Interview L-0035, June-August 1990.

here, and so I went several times to see him about that and leaned on him hard. That's what I turned my green stamps in for."[20] Reflecting these efforts in 1965, the federal government decided to locate its new environmental initiative in Research Triangle Park.[21] The Park became the site of the National Institute of Environmental Health Sciences, at the time the only arm of the National Institutes of Health located outside of Bethesda, Md. This deal was reportedly facilitated by an offer of free land for the project from the Research Triangle Foundation.

The same year, IBM agreed to establish a presence in the park; the Foundation's Vice President, Akers Moore, who managed much of the negotiation, declined to provide details in an interview 15 years later, except to observe that, "it was the most secretive, cloak-and-dagger deal you can possibly imagine". According to one source, the state clinched the deal with a commitment to link the Park with Raleigh and Cary with a 4-lane highway, which has become today's Interstate 40.[22] According to another source, the courtship of IBM was a 7-year effort in which a key role was played by UNC Professor Fred Brooks, a former IBM researcher who developed the System/360 computers and operating system software. Four decades later, IBM remains RTP's largest employer, with 11,000 workers.[23] In the decades that followed, IBM brought about 40 IBM organizations to RTP, including a significant part of its product development and headquarters functions. By 2002, its RTP facility was one of the company's largest in the world.[24]

By the early 2000s Research Triangle Park was the base for over 150 industrial and government facilities employing over 45,000 people, and RTP was regarded as the "engine for economic growth in the region."[25] A 2000 study documented over 1,000 technology-based start-ups in the Triangle counties since 1970, over 150 of which were traceable to RTP universities. Employment in those start-ups exceeded employment levels in the RTP itself.[26] Governor James B. Hunt, speaking at a 40th anniversary commemoration of RTP, recalled

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[20] *The News and Observer,* "Sanford Answered History's Knock, Changed Course of RTP," April 27, 1998.

[21] George Eggers, a North Carolina civil rights activist who later headed the North Carolina Fund, recalled in a 1990 oral history interview that "you know, I think [Sanford's] supporting John Kennedy was an act of courage…and it later turned out to have very practical results in my judgment. I think the Research Triangle Park succeeds today because Terry Sanford supported John Kennedy. In other words, I think the Federal government brought the facilities to Research Park that would not necessarily have come if Terry's support of John Kennedy and later Luther Hodges going to Washington, because Terry supported Kennedy started in motion a string of events that ended up with that HEW agency coming to the Research Triangle Park and making it financially feasible. Southern Oral History Program, "Oral History Interview with George Esser," Interview L-0035, June-August, 1990.

[22] Park, "Poor Dirt into Pay Dirt," op. cit., p. 5.

[23] Doug Campbell, "High Tech Down South," *Region Focus* Summer 2005, p. 39.

[24] Michael E. Porter, *Research Triangle,* Washington, DC: Council on Competitiveness, p. 44.

[25] Ibid. p. 40.

[26] Albert N. Link, *From Seed to Harvest: The Growth of Research Triangle Park,* Research Triangle Park: Research Triangle Foundation, 2002, p. 37.

that before the Park, North Carolina had been a very poor state, with one of the lowest per capita income levels in the U.S.:

> *Since this Research Triangle Park was created, primarily because of it, we have gone up…among the states in per capita income…The success of this Park, and the way we have worked on it together, has emboldened us in North Carolina. We now believe we can do big things.*[27]

THE BOARD OF SCIENCE AND TECHNOLOGY

In 1961, Governor Sanford gathered 39 scientists from the three Universities of the Triangle to provide advice on how to help the state meet the challenge posed by scientific change, solve the problems of local industry, and remake the state into a center of science and innovation.[28] This group consulted with scientists invited from other states, and ultimately concluded that the key need was more financial support for scientific research. In 1963, the state General Assembly created the Board of Science and Technology to encourage scientific, engineering, and industrial research applications within the state. The Board initially operated as a grant dispensing entity modeled on the National Science Foundation, operating the first competitive state research grants programs in the U.S. The Board's grants programs were directed at "the best [local] university ideas" and represented a "pipeline for the commercialization of academic discoveries." Between 1963 and 1969, the Board reviewed 339 proposals and funded 110, leading to 116 follow-on grants from other sources.[29]

Over the following decades, through a number of governmental reorganizations, the Board proposed and acted as an advocate for a significant number of what have become the "state's core institutional infrastructure organizations," including the Microelectronics Center of North Carolina (MCNC), the North Carolina Biotechnology Center, and the North Carolina School of Science and Mathematics. In 2000, the Board instituted the "innovation index" to benchmark North Carolina's innovation-related performance relative to other states. In 2006, it promulgated the Roadmap for Nanotechnology in North Carolina's 21st Century Economy to foster nanotech-based economic development in the state.[30] In 2006, it successfully proposed the provision of matching state grants to small businesses in North Carolina that

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[27]Ibid. pp. 33-34.
[28]This group became the Governor's Science Advisory Committee, one of the first organizations of its kind in the country.
[29]John Hardin and Maryann Feldman, "North Carolina's Board of Science and Technology: A Model for Guiding Technology-Based Economic Development in the South", in D. P. Gillerman, and P. A. Coclanis, eds., *Way Forward: Building a Globally Competitive South,* Chapel Hill: Global Research Institute, 2011, pp. 120-121.
[30]"Utah Firm Picks Triad—210 Jobs Expected at Whitsett Plant," *Winston-Salem Journal,* August 10, 2006.

succeed in wining federal Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) grants.[31]

DEEPENING UNIVERSITY-INDUSTRY COLLABORATION

In 1974, Archie Davis, serving as President of the Research Triangle Foundation, began advocating a physical presence by the three research universities within the Park. In 1975, the Triangle Universities Center for Advanced Studies, Inc. (TUCASI), a non-profit corporation, was founded on a 120-acre tract within the Park.[32] This "park within an park," virtually unique in science parks in the U.S. and abroad, subsequently came to house a number of other organizations including the Microelectronics Center for North Carolina, the North Carolina Biotechnology Center, and the National Institute of Statistical Sciences.[33]

NORTH CAROLINA—RECRUITING A BIOTECHNOLOGY INDUSTRY

North Carolina Research Triangle Park (RTP) is the foremost U.S. example of a successful innovation cluster established through a state recruitment effort seeking to attract established high-tech companies from other states.[34] North Carolina's more recent success in establishing biotechnology clusters demonstrates the continuing viability of out-of-state recruitment as a development strategy in innovation-based, technology-intensive industries. By some key metrics, the state ranks third nationwide (after only Massachusetts and California) in the life sciences and ranks number one in terms of concentration of clinical trial research support firms. Life sciences firms with significant operations in the state include Pfizer, Novartis, Biogen-Idec, NovoNordisk, and Merck. Significantly, in contrast to other prominent life science states, few of North Carolina's biopharma manufacturers have local origins—nearly 85 percent were "nonlocal," and many "of them were actively recruited from Europe, Japan and other U.S. locations."[35]

In 1984, North Carolina's General Assembly established the North Carolina Biotechnology Center (NCBT), the world's first government-sponsored economic development organization in the fledgling field of biotechnology. The

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[31]"N.C. Behind Grant Plan—State May Match Funds Given to Firms by Feds," *Winston-Salem Journal* October 6*,* 2005. John Hardin and Maryann Feldman, "North Carolina's Board of Science and Technology: A Model for Guiding Technology-Based Economic Development in the South," op. cit., pp. 120-121

[32]Leyden and Link, "Collective Entrepreneurship," op. cit. p. 7.

[33]Albert N. Link and John T. Scott, "The Growth of Research Triangle Park" at the National Academy of Sciences STEP Collaborative Conference on "Policies to Promote Entrepreneurship in a Knowledge-Based Economy: Best Practice from the U.S. and the U.K. September 18-19, 2010, p. 5.

[34]The development of the Research Triangle Park is summarized in the Annex to this report.

[35]Ibid. p. 11.

establishment of the NCBT was the beginning of a phenomenally successful effort by the state to achieve a leading position in this field. By 2012, North Carolina led all other states in job growth rates in the biosciences, recording a 23.5 percent increase in jobs since 2001. Total job gains in biotechnology during the period—12,000—were exceeded only by three much larger states, California, Texas, and Florida.[36]

As was the case with respect to RTP, North Carolina has approached industrial recruiting in the life sciences over a long time horizon. The North Carolina Biotechnology Center spearheads the comprehensive study of hundreds of prospective biotech company recruits, gathering data and information gleaned informally at conferences and industry events in order to gain advanced knowledge of plans by companies to establish new facilities. The North Carolina Department of Commerce works with "local practitioners" in communities to educate them with respect to the nuances of the biopharma industry" and the available local resources that can be deployed in outreach efforts to biopharma firms. BioNetwork, a consortium of community colleges that provide biopharma training, is engaged in the early phases of recruitment deals and can highlight the state's advantages in the workforce area as well as identify and seek to address skills gaps. The three state development organizations work together as a team, often seeking to shift emphasis away from incentives sought by companies to the states intrinsic locational advantage.[37]

Dr. Charles Hamner, who has been characterized as the "biofather" of North Carolina's biotech industry, ran the North Carolina Biotechnology Center for a 14-year period beginning in 1987.[38] During his tenure the NCBC directed $50 million to the state's universities, created a $26 million venture capital fund investing in local biotech startups (which helped attract an additional $400 million of private venture funds), recruited ten biotech companies to the state, and raised funds to establish the NCBC's headquarters in Research Triangle Park, which became a "networking hub for area biotech executives."[39] In an interview at the time of his retirement, he observed that "thirty-five other states have biotechnology initiatives, but no other state has nearly as holistic an approach as we do."[40]

NCBC is providing support for intellectual exchange networks that foster research and information sharing in order to promote industry-university

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[36]Battelle Technology Partnership Practice,*2012 Evidence and Opportunity: Impacts of the Biosciences in North Carolina,* January 2013, pg. ES-2.

[37]Ibid. p. 112-113. North Carolina has used traditional incentives as well in the competition for biopharma jobs. In 2004, the state legislative approved a package of $36 million in incentives to persuade Merck & Co. to locate a $300 million vaccine plant in Durham, N.C. *Site Selection,* January 2004.

[38]*WARLtechwire,* "Just Call Charles Hamner the 'Biofather' of Biotech in NC," November 18, 2011.

[39]"Head of NC Biotechnology Center Steps Down: Hamner Helped Shape Industry," *The News and Observer,* September 27, 2001.

[40]"Bold Vision of Biotech's Future: A Chat with Charles Hamner," *The News and Observer,* May 14, 2001.

collaborations. Intellectual Exchange Groups (IEGs) can be launched by interested groups and individuals in the life sciences fields with participants drawn from universities, businesses and other constituencies. NCBC funds cover the cost of meeting expenses. These groups meet four times a year. Thematic IEGs have been formed in North Carolina in bioprocessing, plant molecular biology, smaller eukaryotes, chromatography, next generation sequencing, immunology, and other areas.[41]

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[41]NCBC, "Intellectual Exchange Groups," <*http://www.ncbiotech.org/business-commercialization/connect-with-colleagues/intellectual-exchange-groups*>.