SMART SPECIALISATION IN U.S. REGIONAL POLICY:

successes, setbacks and best practices

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Broadening innovation policy: New insights for cities and regions

Smart specialization in U.S. regional policy: successes, setbacks and best practices

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Background information

This paper was prepared as a background document for an OECD/EC high-level expert workshop on "Developing strategies for industrial transition" held on 15 October 2018 at the OECD Headquarters in Paris, France. It sets a basis for reflection and discussion. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the OECD or of its member countries, or of the European Union. The opinions expressed and arguments employed are those of the authors.

Broadening innovation policy: New insights for regions and cities

The workshop is part of a five-part workshop series in the context of an OECD/EC project on "Broadening innovation policy: New insights for regions and cities". The remaining workshops cover "Fostering innovation in less-developed/low-institutional capacity regions", "Building, embedding and reshaping global value chains", "Managing disruptive technologies", and "Experimental governance". The outcome of the workshops supports the work of the OECD Regional Development Policy Committee and its mandate to promote the design and implementation of policies that are adapted to the relevant territorial scales or geographies, and that focus on the main factors that sustain the competitive advantages of regions and cities. The seminars also support the Directorate-General for Regional and Urban Policy (DG REGIO) of the European Commission in their work in extending the tool of Research and Innovation Strategies for Smart Specialisation and innovation policy work for the post-2020 period, as well as to support broader discussion with stakeholders on the future direction of innovation policy in regions and cities.

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Citation: Wessner, C.W. and Howell, T. (2018), "Developing strategies for industrial transition", Background paper for an OECD/EC Workshop on 15 October 2018 within the workshop series "Broadening innovation policy: New insights for regions and cities", Paris.

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Executive summary

1. This paper discusses a number of US regional policy initiatives designed to address the need for industrial transition to areas offering opportunities for greater growth and employment. Much of the discussion focuses on the New York Nano-cluster which offers valuable policy lessons, first and foremost because it is represents a significant success, both in terms of employment and reputation, in a region that was left behind by globalization and other forces. Other cases demonstrate the need for long-term commitment and substantial resources while still others highlight the risks of globalization with promising clusters undermined by mercantilist action carried out with state support in policy and funding.

2. ***A Successful Industrial Transition***. The case of New York is an excellent example of the value of effective leadership, consistent commitment and broad cooperation to transform a region's industrial base by capitalizing on existing industrial and educational assets. A core lesson from the study of the New York cluster is the importance of investments in an educational institution open to an engagement with industry, one able to carry out applied research and train students to work with the new technologies of today and tomorrow. New York's ability to create a new institution specifically designed to address the opportunity of nano-technologies, with a focus on the needs of the semiconductor industry, was instrumental in transforming the region.

3. ***The Role of Intermediary Institutions***. Underpinning this effort was the ability to establish foundations that were not subject to the bureaucracy of state universities and thereby enabled the university to interact with companies competing in a rapidly evolving technological landscape. This was a crucial factor in the success of the NY nano-cluster and one extremely relevant to both American and European universities. Increasingly, the ability to reduce the cycle time for decisions and their execution can be seen as a key factor in a regions' competitiveness. These foundations, as well as other intermediary organizations charged with the regions development, played a crucial role in creating the educational and research capabilities needed to attract significant hi-tech manufacturing to the regions reviewed here.

4. ***Talent Creation***. This review of examples of US regional innovation policy underscores the importance of long-term investments-- at scale-- in both universities and the infrastructure needed to attract modern manufacturing. It also underscores the importance of institutions such as community colleges and universities in creating the talent, the skilled workforce required to capitalize on the new opportunities presented by modern manufacturing.

5. ***A Long Term Commitment***. An important finding across the various regions reviewed here is the need for long-term commitment and cooperation among multiple actors in the region to enable it to move collectively towards a common goal. An important if difficult lesson is that substantial time is required to develop new institutions, improve infrastructure and create a high tech work force even with the support of significant state and private sector resources. Another important lesson concerns the need for public private cooperation with a common vision of what is needed and both public and private contributions to achieve it.

6. ***Leadership***. Paradoxically, within a shared vision of regional progress, there is a need for entrepreneurial leadership, by civic entrepreneurs able to motivate public officials and university faculty to take new approaches with the goal of having new, and better outcomes.

7. ***Global Value Chains and Start-ups***. Many of the case studies described here underscore the important role of large corporations and their ability to connect the region to global value chains. Interestingly, overtime they can also be sources of innovative activity by small firms within the region. At the same time it is important to note that start up activity and the transformation of existing small firms requires focused policy support from within universities and the region, e.g., with incubators, mentoring, and the availability of repeated rounds of competitive awards for promising firms. Attention must also be directed to the need for a supportive policy framework and other factors that shape the ability of small firms to grow while remaining within the region. Too often there are complaints about what is not present, such as early stage finance, rather than systematic steps to correct gaps in a region's innovation ecosystem.

8. ***Learning from others*.** One of the strongest, and to some extent newest feature of innovation policies in the United States is a newfound willingness to learn from other countries in order to adopt and adapt best practice lessons to regional needs.

1. Introduction

9. A key factor in the industrialization and growth of the United States in the late 19th century was the development of institutions of higher education with a focus on practical applications. U.S. institutions of higher learning established with the explicit mission of fostering improvements in local industry and agriculture included private institutions such as the Rensselaer Polytechnic Institute (RPI, founded in 1824), the Massachusetts Institute of Technology (1861), Stanford University (1891) and, after the passage of the Morrill Land Grant Act of 1862, public universities established in many U.S. states.[1] U.S. universities facilitated the industrialization of the country, developing relevant curricula and educating generations of engineers, scientists and managers.[2] Engineering schools such as the U.S. Military Academy at West Point, RPI, and Union College produced engineers who built much of the infrastructure of the United States in the Nineteenth and early Twentieth Centuries.[3] In many cases, these institutions, and others founded more recently, have had a dramatic, positive effect on local economics, giving rise to transformational, technology-oriented industries substantial and increases in prosperity.[4]

[1] The Morrill Act mandate was to "teach such branches of learning as are related to agriculture and the mechanic arts … in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life."

[2] N. Rosenberg and R.R. Nelson, "American Universities and Technical Advance in Industry," *Research Policy* (1994); Christophe Lecuyer, "Patron and a Plan," in David Kaiser (Ed.), BECOMING MIT: MOMENTS OF DECISION (Cambridge, MA and London: The MIT Press, 2000). In 2004 alone, MIT produced 133 patents, launched 20 startup companies, and spent $1.2 billion on sponsored research. As of 1994, MIT's graduates had started over 4,000 companies, created 1.1 million jobs and generated global revenues of $252 billion. Presentation of David Daniel, University of Texas at Dallas, "Making the State Bigger; Current Texas University Initiatives," in National Research Council, Clustering for 21st Century's Prosperity: Summary of a Symposium (Charles W. Wessner; Rapporteur, Washington, D.C.: The National Academies Press, 2011).

[3] Frederick Randolf, *Curriculum: A History of the American Undergraduate Course of Study Since 1636* (San Francisco; Josey-Bass, 1977) p. 63.

[4] Private educational institutions like MIT and RPI and public land-grant universities embraced the promotion of economic development through the practical application of knowledge in many areas sometimes with spectacular results. After the Civil War, the United States experienced "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 as the Second Industrial Revolution." Alfred D. Chandler, *Scale and Scope: The Dynamics of Industrial Capitalization* (Cambridge, MA and London: Belknap Press of Harvard University, 1990) p. 62. U.S. universities—MIT in particular—played a central role in this process, furnishing companies like DuPont and GE with large numbers of researchers and engineers. MIT, which quickly developed into an economic engine, served as a model when California leaders founded Stanford University (1891)—originally as a bulwark against exploitation by Eastern business interests, but ultimately the institutional driving force behind the emergence of Silicon Valley. MIT's role as a driver of regional economic development inspired one of its graduates, North Carolina's Romeo Guest, to launch the initiative that eventually produced Research Triangle Park, centered on three North Carolina universities.

10. The rich history and economic contributions of practically-oriented universities in the U.S. has spawned many efforts to replicate such economic effects in geographic regions which are undeveloped or experiencing economic decline. New York's effort to establish industries based on nanotechnology (the manipulation of matter with at least one dimension sized at 1 to 100 nanometers) in its Capital Region, an economically stagnant area embracing the cities of Albany, Troy and Schenectady is one example of such an effort.[5] The success of this effort—at least to date—raises the question whether it offers lessons applicable to other states and regions. Given the high rate of failure for other attempts to create "new Silicon Valleys" in improbable locales, the question whether identifiable best practices can be gleaned from New York's experience is an important one.

11. The basic features of Silicon Valley, Boston's Route 128 and North Carolina's Research Triangle are readily apparent. Each area features a dense concentration of technology-intensive companies specializing in topical subjects such as microelectronics, software, and pharmaceuticals. The companies include major manufacturers as well as numerous supply chain and support firms. Each industrial concentration features one or more research universities offering curricula relevant to the needs of local companies, and which serve as a source of educated and trained manpower, spinoff companies and startups, new technologies and research infrastructure. These areas are more prosperous than the nation as a whole and offer jobs which feature levels of compensation which are much higher than the national average. Not surprisingly such specialized industrial concentrations—"industrial clusters"—have emerged as an important area of study by academics and policymakers.[6]

1.1. Innovation Clusters in Global Competition

12. In his 1890 book, PRINCIPLES OF ECONOMICS, Cambridge University economist Alfred Marshall introduced the concept of "industrial districts," which he characterized as concentrations of specialized industries in particular localities from which they derived advantages, including pools of skilled, specialized labor; supplier linkages yielding efficiencies due to proximity; and knowledge spillovers, including market intelligence, new designs and new applications—as Marshall expressed it, "secrets of trade are in the air." Marshall's work has been acknowledged and refined down to the present day as "cluster theory," with Michael Porter and others studying how "agglomerations" or clusters of similarly-specialized firms improve the management of modern value chains and spur innovation.[7] Dramatic examples of successful clusters include Silicon Valley, the Boston

[5] One nanometer is roughly equivalent to eight hydrogen atoms lined up side by side. A human hair is about 80,000 to 100,000 nanometers wide. "Nanotechnology" refers to any technology which operates below this size threshold, and includes semiconductor manufacturing, microfabrication, materials science, molecular biology and organic chemistry.

[6] "An industrial cluster is an agglomeration of companies, suppliers, service provides and associated institutions in a particular field. Often included are financial providers, educational institutions, and various levels of government. These entities are linked by externalities and complementarities of different types and are usually located near each other." World Bank, *Clusters for competitiveness: A Practical Guide and Policy Implications for Developing Cluster Initiatives* (February 2009), p. 1.

[7] In recent decades the role of universities to fostering high technology industry cluster has been developed into a formal model, the so-called "Triple Helix," which is widely referenced by economic development organizations and governments. A Triple Helix is a combination of university, industry and government organizations working, closely together, usually through hybrid

medical complex, as well as the network around Northwestern University in the US and globally the Cambridge complex, and Taiwan's Hsinchu Science Park.

13. Marshall based his work on industrial districts on the case of the city of Sheffield, which was the site of a concentration of specialty steelmakers and their suppliers and service providers. In his day only a handful, at most, of comparable specialized steelmaking clusters existed elsewhere in the world, and competition among them was limited by the distances separating their respective markets and by pervasive trade restrictions. In today's globalized economy, however, these factors are considerably less present. Clusters have multiplied around the world, and competition between them for markets, investment, skilled labor, and technology is intensifying. Government incentives deployed in Israel, Singapore, Germany, China or Ireland can induce a semiconductor company to build a manufacturing plant in one of those locations rather than Silicon Valley or elsewhere in the United States. Mercantilist trade policies can stifle promising clusters, and potentially limit innovation.[8] Korean and Taiwanese semiconductor makers have experienced a recent exodus of talent as China's government-backed semiconductor companies offer them levels of compensation that are multiples of their existing income.[9] In the decade after 2005 a highly successful concentration of light-emitting diode (LED) producers in Taiwan was devastated by a combination of Chinese talent-poaching, overinvestment and dumping.[10]

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intermediary entities, in which each party takes on same of the functions of the other parties without abandoning their primary role (for example, companies may engage in an educational role, training students and workers in research and manufacturing principles and skills.) Henry Etkowitz *The Triple Helix: University-Industry-Government Innovation in Action* (New York and London: Routledge, 2008); Laura I. Schultz, "Nanotechnology's Triple Helix; A Case Study of the University of Albany's College of Nanoscale Science and Engineering," *Journal of Technology Transfer* (2011).

[8] In 2011–12 an incipient cluster of photovoltaic manufacturers in Toledo, Ohio, was decimated by dumped PV panels manufactured by state backed firms on the other side of the world, in China's Hebei and Jiangxi Provinces. Competition for talent has emerged as another nexus of competition. (*See* below.)

[9] According to a 2016 Korean report, semiconductor companies in China were offering the "1–3–9 condition" to Korean semiconductor workers, meaning that they would pay each qualified worker nine times their annual salary for three years. "Korea Talent Moving to China for Better Conditions," *koreaBANG* (March 14, 2016). According to recent reports from Taiwan, China's HiSilicon, a semiconductor design house, had established a 100-person facility near Hsinchu Science Park which "recruits talent and conducts R&D in Taiwan, and then transfers the technology back to China. Taiwanese firms in the Hsinchu semiconductor cluster report that they frequently receive calls from Chinese headhunters looking for engineers. "They randomly call a number in the company and ask whoever picks up, 'are you an engineer?'" If one engineer is recruited, "he can easily take a dozen colleagues or an entire team." Elaine Huang, "Poaching Taiwanese Talent from the Inside," *Commonwealth Magazine* (June 7, 2013); "Pressure from China to Ease Semiconductor Restrictions," *China Post,* (November 1, 2015).

[10] Dumping in technology-oriented sectors usually reflects overcapacity and has the effect of depressing or destroying profitability over a long time frame, forcing companies lacking deep financial resources to defer or scale back research and investments, reduce employment levels, and in some cases exit the market. In the case of LEDs, for a number of years China targeted over 100 of Taiwan's leading LED experts for recruitment, offering them generous compensation packages to bring their process know-how to China to foster a Chinese LED industry. In 2010 the Chinese

14. In a global environment characterized by intensifying competition and mercantilist government policies and practices, even very promising clusters can wither or disappear. Some established U.S.-based high tech manufacturing industries have collapsed, and pioneering U.S. technological discoveries have been appropriated and exploited entirely outside of the United States.[11] The U.S. semiconductor industry released a white paper in 2009 reporting that, based on a survey of member companies, an increasing proportion of their new investments in manufacturing were being made outside the U.S., and numerous U.S. semiconductor makers were going "fabless"—exiting the manufacturing business altogether and outsourcing production of their designs to foundries generally based in Asia. The report observed that a significant part of U.S. firms' R&D activities—particularly process R&D and applied research—and investments would eventually "follow the fabs" and relocate to Asia.[12]

15. ***A successful industrial transition***. It is somewhat improbable, therefore, that in the face of the treads noted above, New York's Capital Region, embracing the cities of Albany, Schenectady and Troy, as well as a number of smaller cities and towns, has emerged as a "nanocluster"—a cluster focused on nanotechnology-based applied research and manufacturing, most notably, semiconductor fabrication. The Capital Region, like the rest of Upstate New York, has commonly been written off as part of the "rust belt," a region condemned to inevitable long-term economic decline by global forces beyond their ability to resist or affect. Yet in the past decade, driven by public and private investments in nanotechnology, the region has added manufacturing jobs at a rate that far outpaces the rest of New York State as well as the U.S. as a whole, and many of these jobs are well-compensated positions in high tech manufacturing firms. The successful emergence of "Tech Valley" confounds pessimistic conventional wisdom and is an encouraging case, one that offers valuable lessons for industrial transition in regions in the U.S. and elsewhere in the world.

LED manufacturer San′an Optoelectronics "uprooted a large number of engineers from the leading Taiwanese Company Epistas," an event covered in the Chinese media as the "108 Heroes Incident." "Chinese companies fight for [LED] talent is no longer a single episode. The extent of acquiring talent now covers upstream epiwafer manufacturers, midstream LED package manufacturers, and downstream lighting module manufacturers. Taiwanese employees have responded to Chinese companies' tactics by leaving behind Taiwanese companies...." "Taiwan LED Talents Exodus to China," *LED Inside* (November 11, 2013). In 2015 a Taiwanese report observed that "[w]ith massive support from the Chinese government, Chinese LED producers have bought large amounts of manufacturing equipment at nearly zero cost to them, resulting in overcapacity that has turned the global LED supply chains chaotic." "Buying Up the World," *Commonwealth Magazine* (December 13, 2015). In May 2016 Taiwanese banks were reportedly tightening LED industry credit, reflecting the reality that domestic LED makers had "been affected by the intense market competition from China." "Taiwanese Banks Tighten LED Industry Credit Policy," *LED Inside* (May 26, 2016).

[11] "Lost technologies" invented in the U.S. but mainly manufactured abroad include wafer steppers, laptop computers, solar cells, oxide ceramics, lithium-ion batteries, liquid crystal displays and many varieties of industrial robots. President's Council of Advisors on Science and Technology (PCAST), *Report to the President on Ensuring American Leadership in Advanced Manufacturing* (June 2011) pp. 4-5.

[12] Semiconductor Industry Association, *Maintaining America's Competitive Edge: Government Policies Affecting Semiconductor Industry R&D and Manufacturing Activity* (March 2009).

16. The region's success was not easy, or quick, nor is it complete. The effort to establish and sustain Tech Valley has had its share of setbacks, scandals, and disappointments. A 1999 effort to attract a semiconductor manufacturer to the Capital Region collapsed when a local town board rejected the proposal in the face of "environmentalist" opposition. A number of political and academic leaders closely associated with the development of Tech Valley have been prosecuted for corruption; some were exonerated, others convicted. Several promising initiatives have been scaled back or abandoned, including a consortium formed to facilitate the transition from 300mm to 450mm wafers in semiconductor manufacturing. While the region has succeeded in attracting investment by large, established companies, to date it has spawned only a handful of promising local nanotechnology-based startup companies.[13] High tech manufacturers lament a growing "skills shortage" in the region which may limit further economic growth. Despite these setbacks, the long term trend has showed continual upgrading of academic curricula and research infrastructure, growing levels of investment by industry and the State, and until very recently, substantial employment growth.

1.2. Evolution of Tech Valley—A Long Term Effort

17. Tech Valley is an outstanding example of policy continuity and commitment in purpose and investment. The success of the region is the product of a half century of policy initiatives and investments by the state government of New York and key local development organizations. The most significant milestones:

- 1959–75. Governor Nelson Rockefeller expanded the State University of New York (SUNY) system and worked to transform the SUNY system into a research powerhouse and engine of economic development over the opposition of entrenched educational interests.
- 1982–88. New York universities undertook research collaborations with semiconductor industry consortia such as the Semiconductor Research Corporation, including a determined but initially unsuccessful effort to attract Sematech, the U.S. semiconductor consortium, to Up-State New York.
- 1993. Governor Mario Cuomo inaugurated a Center for Advanced Technology (CAT) for thin film coatings at SUNY Albany, laying the foundation for what would ultimately become the College of Nanoscale Science and Engineering (CNSE or the NanoCollege).
- 1995. Governor George Pataki successfully forestalled an IBM plan to move its headquarters out of New York through tax and regulatory adjustments.
- 1997. IBM disclosed that it would build a $700 million 300mm wafer fabrication plant at its site in East Fishkill, NY, a project which developed into what was one of the largest single private investments in the history of the state. An important decisional factor was the proximity of university research infrastructure strongly supported by the state.
- 1998. In cooperation with IBM, New York policymakers launched an effort to create the world's only university-based 300mm semiconductor wafer fabrication

[13] "SUNY Poly Startups Created by Students Are Set to Launch," Albany *The Times Union* (July 1, 2017); "Why Upstate New York's Startups Struggle With Early Investment," *Albany Business Review* (March 16, 2015).

plant, to be used for university based research in support of the semiconductor industry.

- 1999–2001. Governor Pataki dramatically increased public outlays for university research, including a center of excellence for nanotechnology R&D at SUNY Albany. IBM and New York committed $100 million and $50 million, respectively, for the establishment of a commercial scale 300mm wafer fabrication facility for research purposes at SUNY Albany, the only such facility on a university campus anywhere in the world.
- 2002. Sematech announced it would establish a new research center at SUNY Albany, the first of a series of moves which culminated in Sematech's full migration from Texas to New York. Tokyo Electron (TEL), one of the world's leading makers of semiconductor manufacturing equipment, committed $200 million to research efforts at SUNY Albany, with the state contributing another $100 million.
- 2002. The Saratoga Economic Development Corporation (SEDC), a private county-level economic development organization, launched an effort to secure regulatory approval for semiconductor manufacturing at a promising site in Saratoga County's Luther Forest Park, ultimately winning approval in 2004.
- 2004. The College of Nanoscale Science and Engineering (CNSE) was established at SUNY Albany, an institution which now is recognized as the foremost institution for applied nanotechnology research in the world.
- 2005. To generate the talent needed for cutting edge manufacturing, Hudson Valley Community College (HVCC) began offering two-year degrees in semiconductor technology, the beginning of a broad effort by the region's community colleges to offer curricula and practical training in nanotechnology manufacturing.
- 2006. After a long courtship backed by very substantial incentives, Advanced Micro Devices (AMD) announced it would build a 300mm wafer fabrication facility at the SEDC's Luther Forest site.
- 2006–11. All of the infrastructure projects necessary to support semiconductor manufacturing in Luther Forest were successfully completed.
- 2009–11. GlobalFoundries, the corporate successor to AMD's semiconductor manufacturing business, built a 300mm wafer fabrication plant at the site, beginning commercial production in 2012, which was then the largest construction site in the country.
- 2014. GlobalFoundries and IBM disclosed a deal in which GlobalFoundries would acquire and operate IBM's semiconductor manufacturing facilities in East Fishkill while IBM continued to invest in semiconductor technology research.

18. ***An economic success***. The economic impact of the growth of nanotechnology in the Capital Region has been substantial, exceeding forecasts by a wide margin. The Albany/Troy/Schenectady area, which had seen a decline in manufacturing employment between 2001 and 2010 of 24.62%, experienced an increase of 20.89% between 2010 and

2014.[14] In 2014 the CEO of the Federal Reserve Board of New York noted the surge in manufacturing employment in the region—mainly associated with "computers and electronics"—and commented that "there are now more people employed in the Capital Region's manufacturing sector than before the recession. Not many places can say that, and this is certainly not true of the nation as a whole."[15]

19. The Albany NanoTech complex accounted for 3,391 local workers in 2016–17, including scientists, engineers, administrators, graduate students and company employees engaged in research projects, as well as food service, cleaning and maintenance. In 2015 GlobalFoundries employed 3,538 people at its Malta site and another 2,085 people at the former IBM fab in East Fishkill, a total of roughly 9,000 jobs directly attributable to research and production of nanotechnology. Depending on the multipliers used, indirect/induced jobs (such as construction, supply chain and local services in retail, hospitability, healthcare, banking and real state) approach the 60,000 to 80,000 range.

20. ***Global challenges***. Whether New York's nanotechnology success—including job growth—will prove enduring remains an open question. Like many clusters New York's "nanocluster" is heavily dependent upon one industry—semiconductors—and that industry is notoriously volatile and frequently destabilized by technological upheavals, government interventions, and the abrupt market entry and exit of major players. The government of China is currently mounting an effort, unprecedented in its sheer scale, to improve its competitive standing in the global semiconductor industry, creating significant risks and uncertainties, including the possibility of curtailed U.S. access to China's market—the world's largest—and of over-capacity and dumping.[16] Moreover, within New York, the policies which have contributed to success to date, such as large public investments and collaboration by many individual political units, may prove unsustainable.

1.3. Best Practices

21. The World Bank observed in 2009 that "industrial clusters often evolve spontaneously over decades, but that well-designed cluster initiatives can expedite the process and provide a much-needed initial platform on which to grow in output and sophistication.[17] It has proven challenging, however, to identify "best practices" in cluster initiatives, e.g., techniques recognized as superior to alternatives because if closely followed they consistently yield superior outcomes.[18] Many potential innovation clusters

[14] John Bacheller, "The Decline of Manufacturing in New York and the Rust Belt," *Policy by the Numbers* (October 4, 2016).

[15] William C. Dudley, "The National and Regional Economy," remarks at RPI, Troy, New York (October 7, 2014).

[16] Morgan Stanley, *Semiconductor -- China and Global -- Disruption Could Take Several Years -- But Could End Up Being Significant* (June 29, 2015); "Battle for Chip Supremacy," *Korea Times* (March 30, 2016); "Chips Down: China Aims to Boost Semiconductor as Trade War Looms," *CNBC* (April 20, 2018)

[17] World Bank, *Clusters for Competitiveness* (2009) op. cit., pp. 3-4.

[18] A recent Brookings study observes that "there are glaring gaps between the recognition that clusters play an important role in an economy that demands concentration and specialization and the practical ability to develop initiatives that help firms within clusters become more competitive and

fail.[19] While the success of Tech Valley is attributable, in part, to intrinsic advantages enjoyed by New York, a number of the practices and policies that contributed to the development of Tech Valley are arguably "best practices" which can be—and are being—adapted and used by other states and regions with realistic prospects for positive results.

22. ***Policy and investment continuity.*** While it may be obvious to observe that development strategies are more likely to succeed if they are implemented in a systematic and sustained manner over the long run, such continuity often proves elusive in democracies. In the U.S., state economic development efforts are frequently undercut by erratic changes in leadership and funding, reflecting the push and pull of divergent political views on the proper role of government in the economy. A 2015 op-ed in the *Detroit Free Press* lamented "Michigan's herky-jerky economic policy detours during the past 10 to 15 years" as successive governors reversed or scaled back their predecessors' initiatives:

> *If Michigan is ever to regain its long-lost status as one of the top U.S. states for economic growth, jobs and incomes, it must persuade investors from around the globe that it is a place with solid, consistent pro-growth economic policies. Not a grab bag of goodies for flavor-of-the-month industries or companies.*[20]

23. The continuity of New York's economic development policies has been extraordinary and is a factor underlying the success of Tech Valley. Over fifty years, all of New York's governors from Nelson Rockefeller down through Andrew Cuomo—Republican and Democrat—have shared a commitment to university-based innovation as a driver of economic development. That commitment has also been manifested in a bipartisan manner by the state's legislative leaders. This broad consensus has enabled a series of mutually-reinforcing state policies and sustained investments extending over a period of half a century. New York leaders' long-term commitment has enabled the flourishing of world class university research departments and research centers, the establishment of community colleges offering industry-relevant high tech training

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spur growth." Ryan Donahue, Joseph Parilla, and Brad McDearman, *Rethinking Cluster Initiatives* (Brookings Metropolitan Policy Program, July 2018) p. 2.

[19] Denis Gray, Eric Sundstrom, Louis G. Tomasky and Lindsey McGowan, "when Triple Helix Unravels: A Multi-Case Analysis of Failures in Industry-University Cooperative Research Centers," *SAGE Journals* (October 2011); Franz Todtling and Michaela Tripple, "One Size Fits All? Towards a Differentiated Regional Innovation Policy Approach," *Research Policy* (2005).

[20] Tom Walsh, "Michigan Needs to Stick to Coherent Economic Growth Plan," *Detroit Free Press* (March 28, 2015). The author recalled how in 1999 then-Governor John Engler launched a $1 billion initiative to establish a "life-sciences corridor" of medical and biotech innovation in Michigan. In 2003 then-Governor Jennifer Granholm transformed this initiative into a "technology tri-corridor" adding automotive technology and homeland security as themes, and created "Venture Michigan" to foster a local venture capital industry. In 2008 the state legislature supported the creation of major film incentives with the idea of making Michigan a center of movie-making. In 2010 Governor Rick Snyder, who openly disliked the film incentives, cut back the use of tax credits for economic development, a policy tool commonly used by his predecessors. *Ibid.* In 2016 a majority of state legislators tried to end funding for Venture Michigan and another venture fund created in 2011. "Report: Michigan at Crossroads in Diversifying Economy," *Crain's Detroit Business* (July 3, 2016).

programs and, ultimately, the creation of a high tech research and manufacturing cluster in the Capital Region.[21]

24. ***Global context.*** From a global perspective, stability of government financial support over the long run has been an important element in the success of innovation-based economic development. A generation or more of single-party rule—enabling continuity of public funding for industrialization and then research—was an important element in the emergence of countries like Japan, Taiwan and China as formidable high tech players. Significantly in this regard, Germany—a robust democracy characterized by periodic changes in governing parties and coalitions—has evolved a system which ensures stable, long-term public funding for basic and applied research, regardless of the party in power, and such fiscal stability is an important aspect of the success of the *Fraunhofer Gesellschaft*, whose thematic research institutes are a driving force behind Germany's numerous, thriving innovation clusters.[22]

25. ***Institutional mechanisms for stability.*** A number of U.S. states in addition to New York have developed mechanisms to ensure greater stability in public funding for innovation. One major example is Ohio's innovative Third Frontier program. It is predicated on periodic mandates by the state's voters to support amendments to the state constitution to ensure the state's authority to issue debt to support long-term investments in start-up and early stage technology companies.[23] The program combines an established institutional structure and a significant and predictable source of funding for innovation. Importantly it rests on a solid foundation of voter approval—in 2010 Ohio voters chose to extend the program by $700 million in a referendum which demonstrated "that voters are interested in funding high-tech jobs even while the state reels from the recession."[24] It has also shown considerable success. The Third Frontier program was instrumental in

[21] Governor Mario Cuomo succeeded Governor Hugh Carey in 1983 and "it would have been a relatively simple matter for the new governor to ignore politely the accomplishments of the Carey administration and begin afresh [but] to his great credit, Cuomo retained Carey's economic strategies intact [demonstrating] avoidance of ideology and a depoliticization of the policy process." Morton Schoolman and Alvin Magid (eds.) REINDUSTRIALIZING NEW YORK STATE: STRATEGIES, IMPLICATIONS, CHALLENGES (Albany NY: SUNY Press, 1986) p. 29. In 2015 the CEO of an Albany-based engineering firm commented that state government "is to be applauded, period. [Governor George] Pataki picked up where Mario left off. He made it as nonpartisan as I've seen an issue." Interview with Ray Rudolph, Chairman, CHA Companies (September 15, 2015).

[22] Since 1975 German federal and state funding for scientific research has been governed by the "Framework Agreement on Research Promotion (RV-Bo) under which funding ratios are assigned to the governmental units for universities and non-university research organizations like the Fraunhofer. Under ratios which have remained fixed for decades, the Fraunhofer gets 90 percent of its core funding (as distinct from its funding for contract research) from the federal government and 10 percent from the state. This arrangement cannot be modified without joint action by the various governmental units which generally share an aversion to reopening settled questions. Markus Winnes and Uwe Schimack, *National Report: Federal Republic of Germany* (TSER Project No. SOE1-CT96-1036, May 1999).

[23] The Third Frontier invests in university-based technologies being spun out into the commercial arena, early stage companies, seed and angel funds, and companies outside Ohio seeking to establish a presence in the state.

[24] Brian Duncan, Ohio venture partner for Arboretum Ventures, in "Ohio Voters Extend Third Frontier Program by $700M," *The Private Equity Analyst* (May 2010).

supporting the emergence of a biomedical cluster to Northeast Ohio centered on Case Western Reserve University, University Hospitals, and the Cleveland Clinic. The Third Frontier directed over $160 million to this effort between 2002 and 2007, enabling the region to attract substantial private sector investments.[25]

26. ***Entrepreneurial Foundations.*** In a number of states foundations and other philanthropic organizations have demonstrated the ability to channel significant funding to innovation-based economic development on a stable basis over a long time frame. Foundations are less vulnerable than governments to erratic changes in policy direction driven by the push and pull of government budget deliberations or the vagaries of electoral politics.

27. North Carolina's Research Triangle was originally capitalized largely through philanthropic contributions by wealthy and established state citizens. The individual who spearheaded this effort, banker Archie Davis, argued that more funds could be raised quickly by appeals to civic-minded state residents than through any for-profit scheme. Davis toured the state at his own expense advocating the creation of a university-supported research park and within several months had secured sufficient funding from 800 anonymous North Carolinians to buy the land for the park's site, which was then transferred to a non-profit Research Triangle Foundation. These funds also enabled the establishment of the Research Triangle Institute, which performed contract research for industry and government sponsors.[26] Davis "recognized that only by making the Research Triangle an entity for public service instead of for private gain would the park be successful in raising the needed development and operating capital."[27]

28. Similarly, in Ohio, many of the industrialists who drove the state's rapid development in the late 19th and early 20th centuries used their wealth to establish foundations – over 3,000 such entities currently exist. Ohio is "a region where the ghosts of once-great corporations live on in charitable foundations."[28] In responding to the latter-day economic crisis that saw Ohio sink into "Rust Belt" status, local foundations were able "to do something the area's patchwork of city government hasn't always been successful at," playing a key role in fostering economic development based on innovation and entrepreneurship. In February 2004 a coalition of Northeast Ohio foundations and companies formed the Fund for Our Economic Future, a fund which channeled resources to a few of the region's best economic development organizations, which used the funds to launch startups, foster cluster formations, recruit businesses from outside Ohio, and line up venture capital.[29] The fund estimates that since its creation it has been responsible for

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[25] "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).

[26] Fred M. Park, "Research Triangle Park: Turning Poor Dirt Into Pay Dirt," *Metro NC* (December 1999); Albert N. Link, *A Generosity of Spirit: The Early History of the Research Triangle Park* (Research Triangle Park: The Research Foundation of North Carolina, 1995).

[27] Christopher M. Cirillo, "Birth of an Idea: The Creation of Research Triangle Park and Its Sustained Economic Impact on the Research Triangle Area," *Urban Economics* (2013).

[28] "Philanthropy is Our Way of Life of Greater Clevelanders," Cleveland *The Plain Dealer* (December 26, 2010); http://www.clevelandfoundation.org/about/history.

[29] "Coalition Ready to Dip Into Pooled Funds to Boost NE Ohio Economy," Cleveland *The Plain Dealer* (July 27, 2004).

retaining or creating 33,900 jobs, adding $1.5 billion to payroll and attracting $8.4 billion in capital to northeast Ohio.[30]

29. ***Industrial transition built on the industrial legacy***. Old industrial regions sometimes experience virtually complete deindustrialization, with the disappearance not only of large manufacturers, but the collapse of associated supply chain firms that provided the big firms support and the out-migration of skilled workers.[31] In many U.S. states and regions, however, local leaders have found ways to leverage assets and skillsets from traditional industrial sectors to facilitate the emergence of new industries which are more technology-intensive and environmentally friendly. In the European Union this process is referred to as "industrial transition," which involves, among other things, "building on an existing industrial specialization and workforce skills to ensure a process of adaptation to new business opportunities through new technologies… ensuring the transition of regions to a low-carbon economy while defining new regional business models for local growth."[32] As New York Governor Andrew M. Cuomo expressed it,

> *The new economic clusters often build from that region's existing assets. For example, Rochester, which has a long history of engineering and academics coming from Kodak and the Xerox era, is now developing a cluster economy in the photonics area. Often the key to the future is updating the past.*[33]

30. Few other states enjoy an industrial foundation as deep as that of Upstate New York, and state policymakers were able to build upon that legacy of robust high tech firms despite considerable erosion of the broader industrial base. During the late Nineteenth and early- and mid-Twentieth Centuries several large, technology-based companies were established in northern and western New York, including General Electric, Corning, Eastman Kodak, and IBM—"a collection of now priceless economic resources."[34] These companies not only created tens of thousands of jobs requiring specialized skills, but provided major support for New York's education system and research centers and served as advocates for improvements in infrastructure and in science, math and engineering education at all levels. Although these firms have contracted substantially in the past half

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[30] "Fund for Our Economic Future Takes Aim at Regional Economic Growth," *Smart Business* (June 1, 2017).

[31] In the UK, de-industrialization in the 1980s saw the closure of large factories and the destruction of supply chains. "When the big factories closed, the supporting infrastructure decayed. Import dependency is the legacy… British manufacturing has downsized into workshops, as it loses its industrial districts." Center for Research on Socio-Cultural Change, *Rebalancing the Economy (or Buyer's Remorse)* (Working Paper No. 87, 2011) pp. 29-30.

[32] European Commission. *Pilot Action : Regions in Industrial Transition* (2017) <http://europa.eu/rapid/press-release_IP-17-5018_en.htm>

[33] "Rebuilding the Upstate Economy," *Huffington Post* (September 1, 2016)

[34] Morton Schoolman, "Solving the Dilemma of Statesmanship: Reindustrialization Through an Evolving Democratic Plan," in Morton Schoolman and Alvin Magid (eds.), REINDUSTRIALIZING NEW YORK STATE: STRATEGIES, IMPLICATIONS, CHALLENGES (Albany, NY: SUNY Press, 1986) p. 18.

century, a significant number of former workers and managers have played key roles in the development of Tech Valley.[35]

31. One firm in particular, IBM, played a key, even decisive role in enabling the creation of Tech Valley. IBM's early research made New York a center for nanotechnology R&D, and from 1963 onward it operated a wafer fabrication facility in East Fishkill, New York,. IBM engaged local universities in research projects and invested substantial sums in creating university research infrastructure. IBM also worked within the U.S. semiconductor industry to promote New York as a research and manufacturing location, and the early development of the NanoCollege was driven by IBM investments, research projects, and advocacy within the state.[36]

32. Other states offer similar examples of leveraging an old industrial legacy to create innovation-based industries of the future. In Ohio, for example, a comprehensive state effort to modernize and reinvigorate the economy was able to leverage previous industrial strengths. The local know-how and skills derived from these industrial sectors played a significant role in the evolution and expansion of new industries as exemplified in Table 1.[37]

Table 1. Expansion of new industries

Location	Existing Sector	New industries
Toledo	Glassmaking	Photovoltaics
Akron	Polymers for tires	Polymer-based biomaterials
Kent	LCD displays	Flexible electronics
Cleveland	Metal parts	Specialized medical devices
Cleveland	X-ray equipment	Biomedical imaging

33. In the Cleveland area, in the early 2000s, local metal companies confronted stagnant growth prospects with respect to their traditional mainstay businesses producing parts for the automotive and aerospace industries. The state's sustained effort to revitalize and grow its medical imaging industry created demand for a broad array of local manufacturers.[38] A number of these firms transitioned into medical devices, supported by

[35] "Ex-Plant Workers Find New Jobs to help-Hungry High Tech Sector," *Albany Business Review* (June 2, 2008).

[36] In retrospect, a defining moment in the development of Tech Valley occurred in 1995, when newly-inaugurated Governor George Pataki made an all-out effort to reverse a decision by IBM's senior management from moving the company's headquarters out of the state, a result which he achieved through a flurry of commitments that led IBM CEO Louis Gerstner to comment, "I've never seen a government move as fast as this one has in the past two weeks." "Big Blue to Stay in State, Build New Headquarters," *Watertown Daily Times* (February 17, 1995).

[37] An Hitachi Medical Systems executive observed in 2004 that "Northeast Ohio's long experience in diagnostic imaging has created a pool of workers familiar with the industry." "Imaging is everything in Local Medical Field," Cleveland *The Plain Dealer* (August 31, 2004).

[38] Reflecting Ohio's industrial legacy, virtually all of the parts and machinery required by biomedical manufacturers could be procured within the state, including crystals, robotics, electromechanical systems, gantry systems, coils and magnets, printed circuit boards and relevant software. SRI International, *Making an Impact* (2009) op. cit., p. 4.

curricula at local colleges.[39] A 2008 survey by the economic development organization Bio Enterprise concluded that the large number of manufacturers entering the medical business meant that Ohio had the second-largest number of FDA-registered companies among states in the Midwest.[40]

- ***Electrolizing Corp.***, a producer of metal coatings for the aerospace and automobile industries, developed TiMed, a color coating for titanium useable in surgical implants and medical instruments, areas in which color-coding reduced the risk of medical errors.
- ***Cleveland-based Swagelok Co.***, a producer of tube fittings, values and parts for fluid-based systems in the energy and chemical sectors, developed a computer-driven orbital welding system to make the extremely smooth tubing connections required in the biopharmaceutical sector (tight welds that do not catch organisms that could infect sterile, closed systems).
- The Cleveland–based arm of ***Precision Castparts***, a producer of forged aerospace fuel nozzles, developed an array of titanium and cobalt-chrome hip replacement implants.[41]

34. ***Overcoming impediments to regional approaches to economic development.*** In many U.S. states governmental powers are exercised by thousands of local jurisdictional subunits, including county, municipal, town and village governments as well as various special purpose authorities governing water, bridges, road maintenance and schools. According to the *2012 Census of Governments,* Illinois alone had 6,968 local governments; Pennsylvania, 4,905; Texas, 4,856; and California, 4,530. Even less-populated Kansas had 3,806 local governments.[42] Ohio has more local governments per square mile than nearly all other U.S. states, making and consolidating these jurisdictions—assuming the necessary political consensus to do so—is probably prohibited by state law.[43] Such dispersal of authority can lead to zero-sum competition between localities for resources to attract new businesses; higher levels of taxation; and stifling levels of regulation. A 2003 Brookings study observed that Pittsburgh alone had 418 local governmental units, and Philadelphia,

[39] In 2010, at the request of a local development organization, Cleveland's Cuyahoga Community College began offering classes in computer-controlled milling for the benefit of displaced workers from old-line manufacturing jobs seeking to find work in the medical device sector. "To Get Jobs, Areas Develop Industry Hubs in Emerging Fields," *USA Today* (June 6, 2011).

[40] "Small Manufacturers Try a New Line: Medical Devices a Growing market," Cleveland *The Plain Dealer*; "Manufacturers Shift Gears Into Growing Biomedical: Ailing Autos, Construction Push Companies Down a New Path," Cleveland *The Plain Dealer* (June 14, 2009).

[41] "Metal Industry Evolves: Companies Cash in on Burgeoning Bioscience Field," Cleveland *The Plain Dealer* (March 8, 2005).

[42] Richard Florida, "Does Having Lots of Local Governments Help or Hurt Economic Development?" *Citylab* (May 4, 2013).

[43] James Griffith, CEO of Timken Company, "Stimulating Manufacturing in Ohio: An Industry Perspective," in National Research Council, *Building the Ohio Innovation Economy: Summary of a Symposium* (Washington, D.C.: The National Academies Press, 2013).

442—extremes of fragmentation and internecine competition that Brookings linked directly to the state's economic malaise.[44]

35. New York's Capital Region faced similar challenges with balkanized governmental jurisdictions and institutions that were viewed by the business community as obstacles to regional economic growth. To address this proliferation of local authorities, in 1987 the Albany-Colonie Chamber of Commerce created the Center for Economic Growth (CEG) to spearhead the development and implementation of coherent strategies for regional development. CEG functioned as an advocacy group as well as a think tank and intelligence-gathering organization that committed resources to surveying and understanding successful innovation-based development initiatives in other parts of the U.S. and around the world. It promoted the use of the term "Tech Valley" to rebrand the Capital Region and to market it to high tech companies. Subsequently, CEG played a major role in breaking down parochial barriers to cooperation and forging coordinated regional initiatives able to attract state support.[45]

36. ***The key role of cooperative research facilities***. The importance to regional economies of a public-private research center capable of supporting prototyping, proof-of-concept and pilot manufacturing activity is not always fully appreciated. Such centers provide capabilities not otherwise available to start-ups and small businesses seeking to commercialize new technologies.[46] The centers themselves spin off new companies and train scientists, engineers and technicians who can move into jobs in local high tech manufacturing. The presence of a growing, skilled work force as well as sophisticated research facilities and services, acts as a draw for local investment by high tech companies from outside the region.

37. New York State's investments in nanotechnology research infrastructure are very likely unprecedented in sheer scale—$876 million between 2000 and 2009, and in 2010 a member of the CNSE faculty observed that the research facilities at CNSE were four times greater than the next largest microelectronics research center in Austin. In effect the state created research resources that semiconductor companies could not find elsewhere and could not afford to build themselves. The facilities included state-of-the-art pilot 300mm

[44] "The problem here is that Pennsylvania's fragmented state government and profusion of local jurisdictions probably spend more time working at cross-purposes than working together to compete in the global economy. Competitive regions move with alacrity to seize opportunities, mobilize coalitions, and organize resources to pursue common goals. They are flexible and fast. In Pennsylvania, by contrast, state departments often work in isolation, leading to bureaucratic overlap and mixed signals. Inconsistent and confusing state laws bog down concerted action." Brookings Institute's Center on Urban and Metropolitan Policy, Back to Prosperity. *A Competitive Agenda for Renewing Pennsylvania* (2003) p. 47.

[45] "The Argument for Regionalization," Albany *The Times Union* (April 11, 1993); "Tech Valley Image Has Winning Edge," Albany *The Times Union* (October 7, 1999); Michael Buser, "The Production of Space in Metropolitan Regions: A Lefebvrian Analysis of Governance and Spatial Change," *Planning Theory* (March 21, 2012) pp. 288-9.

[46] Nathan Rosenberg and Edward Steinmuller, "Engineering Knowledge," *Industrial and Corporate Change* (October 2013).

wafer fabrication facilities which enabled companies to try out new tools, materials and processes in an actual manufacturing environment.[47]

38. Cooperative research facilities need not approach the sheer scale of CNSE's nanotechnology resources to have a major regional impact. For example, in an attempt to resurrect a biomedical imaging industry that was eroding, in 2003 the state of Ohio created the Wright Center of Innovation in Biomedical Imaging at Ohio State University, providing $17 million from the Third Frontier program.[48] Most of the state funds were used to support state-of-the art scanning equipment and specialized facilities to protect the scanners from external disturbances and vibrations.[49] Industry partners could use the equipment in this facility to accelerate commercialization of new equipment and processes—"participants in this environment can further implementation of reimbursable procedures, develop new procedures for patient care, and conduct clinical trials toward use of biomarkers." A number of participating companies came from outside Ohio, just as CNSE drew industrial partners from outside New York. The Wright Center has intellectual property protections that "enable companies to bring their equipment to the Center, leverage the Center's expertise, and create new inventions in a user-friendly environment."[50]

39. A 2009 study of the Wright Center observed that "it is unusual for companies in the same industry to develop equipment in a common research center."[51] In fact, a number of recent studies have concluded that in the United States, the number and quality of intermediary facilities supporting the transition from basic research to prototyping, scale-up and manufacturing is inadequate. In part this reflects the closure or downsizing, over time, of numerous large-scale industrial applied research institutions, most notably Bell Labs,[52] although it is important to note there are active research laboratories supporting innovation in electronics, pharmaceuticals, aerospace and chemicals and of course in software and social media companies.[53] While some U.S. manufacturing companies,

[47] Micheal Tittnich, *et. al*., "A Year in the Life of an Immersion Lithography Alpha Tool at Albany Nano Tech," in Proceedings of SPIE, Vol. 6151, *Emerging Lithographic Technologies* (2006), pp. 1-3; Michael A. Fury and Alain Kaloyeros, "Metallization for Microelectronics Program at the University of Albany: Leveraging Long Term Mentor Relationship," *IEEE Explore* (1993).

[48] The Cleveland area had a legacy of leadership in medical imaging. Eugela-Electric Co. was established there in the early 1900s to manufacture X-ray equipment. Picker X-Ray, which became Philips Medical Systems, was founded in Cleveland in 1915, and later acquired Eugela-Electric. Ohio-Nuclear Inc., a maker of CT and MRI scanners, established manufacturing operations in the area in 1958, later becoming Technicare Inc. *Ibid*.

[49] Equipment included 3-Tesla, 7-Tesla and 8-Tesla MRI scanners built by Achieva and Philips Medical Systems. SRI International, *Making an Impact* (2009) op. cit., p. 5.

[50] SRI International, *Making an Impact* (2009) op. cit., pp. 6-7.

[51] SRI International, *Making an Impact* (2009) op. cit., p. 6.

[52] Roli Varma, "Changing Research Cultures in U.S. Industry," *Science, technology and Human Values* (Autumn 2000) p. 400.

[53] *See generally* Erich Bloch, "Seizing U.S. Research Strength," *Issues in Science and Technology* (Summer, 2003); An observer of this phenomena summarized it in 2000; "General Electric denoted the David Sarnoff Research Laboratory to SRI International, which General Electric acquired in its purchase of RCA. Regional telephone companies formed from the separate laboratory, and soon it was sold. Kodak acquired Sterling Drug and then sold. General Motors took over Hughes Aircraft, and DuPant acquired Conoco. General Electric aerospace merged into Martin Marietta which then

especially smaller firms, have fostered an internal culture that enables translational innovation, they are anomalies rather than the norm, and "their efforts often remain isolated and hard sustain."[54] The Obama Administration's establishment of the National Network for Manufacturing Innovation was an effort to address this problem of this "missing middle" in the U.S. economy.[55]

40. ***Partnerships with industry research consortia***. A number of US high tech industries have formed research consortia to share the cost and risks associated with R&D. Most of those entities partner with research universities or other research organizations such as the US National Laboratories. Participation in such industry consortia can work to the advantage of universities and the regions they are located, facilitating the building of working relationships with manufacturers which can play a role in those companies' future locational decisions.

41. For four decades New York policymakers and business and academic leaders have made a sustained effort to participate in major semiconductor research consortia. The state invested in industry-relevant R&D in local research universities which helped these institutions secure recognition by the industry's Semiconductor Research Corporation as entities "with clear capabilities and the required facilities" with which SRC would engage in research collaboration.[56] As noted, in 1987 New York narrowly lost a bid to become the site for Sematech, the industry-initiated consortium being formed to conduct collaborative R&D in semiconductor manufacturing.[57] Despite this setback New York maintained and intensified its outreach to the semiconductor industry, building a critical mass of microelectronics research infrastructure and expertise at SUNY Albany, an effort which culminated in Sematech's 2002 decision to establish its next research center at SUNY Albany, citing "the caliber of work already being done at SUNY Albany and the enthusiastic backing it had from the governor and the legislature."[58]

42. CNSE created numerous research consortia with semiconductor device, equipment and materials companies, arrangements that minimized the cost and risk associated with introducing new tools and processes. Sharing the costs of research, participating firms could test equipment and techniques in a neutral, "Switzerland-type" factory environment, developing and refining know-how and identifying and ironing out "bugs" in new-generation tools and processes before investing in their own manufacturing facilities. The NanoCollege features shared research facilities in which companies and CNSE staff

merged into Lockheed. Kodak transferred research from its central laboratory into operating divisions. Allied Signal, Armstrong World Industries, and W.R. Grace Completely eliminated corporate support for central research." Roli Varma, "Changing Research Cultures in U.S. Industry," Science, Technology and Human Values (Autumn 2000) p. 400.

[54] Suzanne Berger, *Making in America: From Innovation to Market* (Cambridge MA and London: MIT Press, 2013) p. 58.

[55] "National Network for Manufacturing Innovation: Frequently Asked Questions," http://manufacturing.gov/docs/numi_fan.pdf.

[56] Robert M. Burger, *Cooperative Research: The New Paradigm* (Durham, NC: Semiconductor Research Corporation, 2001) pp. 67-68.

[57] "Sematech Decision Tipped By Existing Building, State Aid," Albany *The Times Union* (January 7, 1988).

[58] "Albany No Longer a Secret in High Tech Chip World," *New York Times* (July 19, 2002).

collaborate as well as proprietary space rented by individual companies where the firms can take know-how and technology generated in the joint activity for refinement into their own proprietary products and industrial processes.

43. New York's longstanding investments in nanotechnology research, and the participation of the state's universities in semiconductor industry research consortia, played an important role in attracting semiconductor manufacturing to the Capital Region. Advanced Micro Devices (AMD), the corporate predecessor of GlobalFoundries, decided in 2006 to build a 300mm wafer fabrication facility in Lake Forest, reflecting the fact that it already had a substantial research presence in New York. In 2004 AMD entered into a collaboration with CNSE to conduct research at the NanoCollege on measuring performance of transistors for advance semiconductor devices.[59] In 2005 AMD was one of four semiconductor makers joining a seven-year, $600 million consortium with CNSE to pursue nanolithography as well as workforce development for advanced semiconductor production.[60] In the wake of AMD's choice of New York for its next manufacturing site, semiconductor industry analyst Len Jelinek observed that the probable factors underlying the choice were "the University at Albany's College of Nanoscale Science and Engineering as well as the proximity of IBM's plant in East Fishkill," and that "from an R&D perspective which is key in this industry, AMD's roots are quite strong in the New York area."[61]

44. ***Surmounting regulatory hurdles***. In East Asia high tech manufacturing facilities such as semiconductor fabrication plants are usually located in government-administered high-technology parks expressly created to support them.[62] Regulatory approvals, to the extent they are required at all, are usually straightforward, involve only a single decision making entity, and are unlikely to present impediments to investors. In the United States and Europe, however, the approval process may be sufficiently complex, and the opportunity for local opposition groups to halt a project realistic enough, that they

[59] AMD said that it chose CNSE as its university partner for this project because of its expertise and equipment. According to AMD's director of external research "this type of research hinges on having the right facility, and Albany NanoTech has kept critical combinations of infrastructure and expertise. By joining with Albany NanoTech, we've found a cost-effective way to stay on the cutting edge in this area of nanoscale research." "Advanced Micro Devices to Conduct Research at Albany NanoTech," *Albany Business Review* (November 9, 2004); "Shedding Light on a Minuscule Problem," Albany *The Times Union* (November 10, 2004).

[60] The project was the International Venture for Nanolithography (INVENT). "More Chips in the Tech Jackpot," Albany *The Times Union* (July 19, 2005).

[61] "Spinoff Businesses Likely to Follow," Schenectady *The Daily Gazette* (July 21, 2006). AMD was collaborating with IBM at East Fishkill on semiconductor design R&D. "IBM Lands Semiconductor Deal Worth Millions," Albany *The Times Union* (January 9, 2003).

[62] In 2002 local officials in Shanghai noted with satisfaction that government approvals for a water fabrications plant built by Semiconductor Manufacturing International Corporation (SMIC) in Shanghai's Pudong New Area had been expedited: "Because the review and approval links have been streamlined and government services are in place, the SMIC integrated circuit project that had a total investment in excess of $1.5 billion took only 13 months from the time work started to completion and being put is operation, setting a world record for the construction of a production line of that type." "China's WTO Accession Once Again Places Pudong Area At Forecourt Of Participating In International Cooperation," *Xinhua* (00:41 GMT, May 4, 2002)

constitute a deterrent to investment by manufacturers weighing alternative geographic options. New York has demonstrated at least one way to circumvent this problem.

45. As in many other U.S. states, New York's well intentioned zoning and environmental rules present challenges to economic development, confronting potential investors with approval and permitting requirements that can delay a project for months or even years. A regional economic development organization, the Saratoga Economic Development Corporation (SEDC) was able to avoid this trap with respect to Greenfield Semiconductor Manufacturing through "pre-permitting," enabling them to present investors with approved, "shovel-ready" sites. In 2002 SEDC filed the requisite zoning and environmental applications with respect to a generic 300mm semiconductor fabrication facility. Numerous public hearings were held to overcome local skepticism about safety, the environment and the impact of growth. To meet these concerns, local authorities conducted an exhaustive review of the legal and regulatory issues associated with establishment of a wafer fab. At the end of this process the necessary approvals were granted and the region's representatives could approach semiconductor makers with the assurance that the regulatory concerns that might deter investment had already been resolved.

46. ***A professional proposal for manufacturers***. Economic development strategies based on industrial recruitment require close coordination by economic development professionals to integrate various aspects of the regional outreach to manufacturers, including the availability of a suitable site, the economics of operating in the region, taxation, workforce issues, regulatory hurdles, available infrastructure, e.g., power and water, and financial incentives.[63] This effort ultimately requires development of sophisticated proposals that target the specific needs of individual manufacturers and demonstrate how the region fits those needs. RPI's president, George Low, observed in 1983 that New York lost out to Texas in the competition to be the site for the Microelectronics and Computer Technology Corporation (MCC) because Texas offered generous incentives, political support, and professionally prepared pitch presentations -- in contrast to New York's belated and haphazard effort.[64] New York offered a much better and nearly-successful bid in the 1987 competition for Sematech, again losing out to Austin, Texas.[65]

47. SEDC's pre-permitting exercise was one facet in a comprehensive and sustained effort to reach out to semiconductor manufacturers to invest in the Capital Region. SEDC, backed by a local utility, National Grid, spent several years identifying a good site for a semiconductor facility, settling on Luther Forest, in the towns of Malta and Stillwater, where engineering studies revealed that 60–200 feet of glacial sand deposits would protect a wafer fab from the kind of vibrations that could adversely affect semiconductor production. SEDC put together a large team of professionals with expertise in semiconductor manufacturing, which included the Austrian firm, M+W Zander, one of the world's principal companies building high tech manufacturing facilities. Hector Ruiz,

[63] See generally Nichola J. Lowe, "Beyond the Deal: Using Industrial Recruitment as a Tool for Manufacturing Development," *Economic Development Quarterly* XX(X) 1-13 (2012)

[64] Stuart W. Leslie, "Regional Disadvantage: Replicating Silicon Valley in New York's Capital Region," *Technology and Culture* (2001)

[65] "A Vigorous Effort," Syracuse *The Post Standard* (September 1, 1989); "Sematech Decision Tipped By Existing Building, State Aid," Albany *The Times Union* (January 7, 1988)

CEO of Advanced Micro Devices (AMD) at the time that company decided to build a plant in Luther Forest, commented that New York officials had put together "the most well-crafted economic development package he could recall seeing."[66]

48. Other states and regions have demonstrated the value of professional, fact-based outreach proposals to attract companies to a region. In 2008, "heavy hitting investors" proposed to invest $25 million in View Ray, a company that had developed promising new technologies in magnetic resonance medical imaging and image-guided gamma-ray treatment technology, but only if the company relocated from Gainesville, Florida, to Cleveland. The company agreed to the move, and to make 25 local hires. The investors were convinced by a pitch developed by three of Ohio's economic development organizations, Bio Enterprise, Team NEO and Bio Ohio, who cited Cleveland's advantages.[67] View Ray's CEO commented that

> *These regional entrepreneurial ecosystems [Austin and Research Triangle] have mainly benefitted from the spawning of startup founders in both regions as large corporations have relocated here … [I]ncumbent firms are a crucial source of entrepreneurial founders in both regions....*[68]

[66] "Tech Valley Vision Pays Off Big—Chip Maker AMD Hopes Rivals Will Also Build Plants in Region," Schenectady *The Daily Gazette* (June 24, 2006).

[67] The team's pitch was that northeast Ohio was the home of three of the world's leading makers of diagnostic imaging equipment, that the area's medical institutions were willing to work with innovative technology startups, and that the region offered deep technical and engineering talent to support medical imaging companies. "Investors Tip Biotech Firm Into Cleveland," Cleveland *The Plain Dealer* (February 26, 2008).

[68] Elsie Echeverri-Carroll, Maryann Feldman, David Gibson, Nichola Lowe and Michael oden, *A Tale of Two Innovative Entrepreneurial Regions: The Research Triangle and Austin* (University of Texas at Austin and University of North Carolina at Chapel Hill, March 15, 2015) pp. 7-8.

2. Growing Challenges

49. ***International trade and investment***. The progressive liberalization of foreign trade and investment that has occurred during the past half century has been, on balance, beneficial to innovation-based economic development, opening up foreign market opportunities and enabling states and regions to benefit from foreign direct investment and technology transfer. The New York nanocluster is no exception, where investments by the sovereign wealth fund of Abu Dhabi as well as foreign manufacturers such as Tokyo Electron have proven crucially important. The Capital Region's principal semiconductor firm, GlobalFoundries, serves global markets and operates in Asia and Europe as well as North America. However, global competitive forces can also detrimentally affect regional economic development efforts, and state and regional, and even national governments have relatively few policy tools available enabling a direct response.[69]

50. ***An American setback***. An example of how a successful cluster can be disrupted by international trade developments beyond its control is offered by the experience of city of Toledo, Ohio, which a decade ago was the site of a growing and thriving innovation cluster based on photovoltaic (PV) research and manufacturing. The cluster drew upon Toledo's industrial legacy of glassmaking and the pioneering inventions and entrepreneurial initiatives of a local "glass genius," Harold McMaster.[70] McMaster, holder of over 100 patents, founded a company, which, less than a decade after his death in 2003, emerged as the largest producer of photovoltaic modules in the world, First Solar.[71]

51. The University of Toledo (UT) drove the formation of a photovoltaic cluster in the Toledo area. UT engaged in research collaborations with McMaster which enabled the startup of other local photovoltaics producers, including Glass Tech Solar, Xunlight and Solar Fields LLS. UT recruited eminent solar researchers.[72] It established a School of Solar and Advanced Renewable Energy, training students in clean energy science and technology.[73] It set up a Clean and Alternative Energy Incubator, to assist green energy

[69] Thomas R. Howell, "The Multilateral Trading System and Transnational Competition in Advanced Technologies: The Limits of Existing Disciplines," and *The Innovation Imperative: National Innovation Strategies in the International Economy* (VINNOVA / National Academies, 2009).

[70] "Toledo Finds the Energy to Reinvent Itself," *Wall Street Journal* (December 18, 2007).

[71] McMaster, who held a combined Masters Degree from Ohio State University in physics, mathematics and astronomy, became the first research physicist ever employed by Libby Owens Glass in Toledo, in 1939. He led the development of curved tempered glass for use in the automobile industry. Beginning in 1984, McMaster and some of his colleagues formed several companies to develop glass-based technologies that could be used to convert solar rays into electricity. One of these, Solar Cells emerged as the industry leader in thin-film photovoltaics. In 1990 McMaster sold Solar Cells to investors who renamed it First Solar, and began manufacturing operations in the Toledo area in 2004. "Harold McMaster, 1916-2003: Investor Became a Philanthropist," Toledo *The Blade* (August 26, 2003); "Sun Burn I: Area Courted Solar Energy With Research," Toledo *The Free Press* (July 19, 2012).

[72] "Toledo Reinvents Itself as a Solar Power Innovator," *USA Today* (June 15, 2010).

[73] "UT Creates School of Solar and Advanced Renewable Energy" (Press Release, April 15, 2009).

startups, offering competitive awards and business support.[74] UT established a university-government-industry partnership, the Wright Center for Photovoltaics Innovation and Commercialization, to accelerate the transfer of technology from university laboratories to commercial applications. UT's President, Lloyd Jacobs, said in 2011 that in the field of 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."[75]

52. The state of Ohio also provided extensive support to the emerging Toledo Solar Cluster. Between 2003 and 2008 the Third Frontier program invested over $39 million in the photovoltaic research base as well as in individual solar companies.[76] Ohio Advanced Energy, a business group comprised of local renewable energy companies, worked with state officials to develop the Ohio Advanced Energy Portfolio Standard, a requirement that at least 25 percent of the state's electricity be generated by renewable and clean energy by 2025.[77] A 2009 survey of the Toledo photovoltaic cluster by SRI International gave the following verdict:

> *While still an emerging industry globally, the PV sector continues to gain momentum in Ohio. The cluster is anchored by First Solar and Toledo-area PV startups on the verge of commercialization and production. The University of Toledo's new faculty hires, capital investments, entrepreneurial support programs, creation of PV startups, and the attraction of large Federal research grants provides a complimentary dynamism to developments in the private sector. OTF has encouraged critical research partnerships and cross-sectoral relationships, e.g., bringing together researchers from UT and PV companies, PV module manufacturers with downstream users of PV products, pre-seed/seed funds with UT and "Launch" incubator companies, and so on.*[78]

53. At the same time that Toledo's photovoltaic cluster was emerging, the government of China was promoting the development of an indigenous PV industry, not to serve markets in China—which at the time made little use of solar energy—but for export to Europe and North America.[79] China acquired PV technology by buying manufacturing

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[74] *Making an Impact Assessing the Benefits of Ohio's Investment in Technology-Based Economic Development Programs* (SRI International, 2009).

[75] "Solar Incubator Spreads Wings, UT Program Adds Firms, Broadens Its Research," Toledo *The Blade* (July 3, 2011).

[76] Investments included a $2 million grant to enable UT to establish the Center for Photovoltaics and Hydrogen, involving research collaborations with local PV companies; an $18.6 million grant to UT in 2017 to help it start the Center for Photovoltaics Innovation and Commercialization; and $15 million invested in Rocket Ventures, an entity providing financial support to entrepreneurs in northeast Ohio to support commercialization. SRI International, *Making an Impact* (2009) op. cit.

[77] Norman Johnston, "The Toledo, Ohio Solar Cluster" in National Research Council, *The Future of Photovoltaic Manufacturing in the United States: Summary of Two Symposia* (Washington, D.C.: The National Academies Press, 2011).

[78] SRI International, *Making an Impact* (2009) op. cit., pp. 39-40.

[79] European Photovoltaic Industry Association (EPIA), *Global Market Outlook for Photovoltaics Until 2013* (April 2009); "China's Photovoltaic Industry: Exporting on the Cheap," *Energy Tribune* (April 2009).

equipment on the international market and by securing expertise from abroad, while local governments provided substantial backing for PV manufacturing firms within their jurisdictions.[80] State-owned banks reportedly provided $18 *billion* in loans on concessional terms to Chinese solar makers.[81] China's solar power production capacity expanded by over ten fold between 2007 and 2012, aking China the largest producer of solar panels in the world, accounting for about one-third of global PV shipments By 2011 the global PV equipment market was characterized by massive overcapacity, and producers "complained that solar [equipment] prices have been negatively affected by China flooding the world market with solar panels priced below production costs."[82] The global industry experienced what one observer characterized as "PV Armageddon."[83] Solar-panel prices fell by nearly 90 percent between 2007 and 2017.[84] In 2011 a group of US solar panel manufacturers filed on antidumping actions against Chinese PV makers, complaining that

> *We believe Suntech [a Chinese PV maker] 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.*[85]

54. By 2012, a global shakeout of PV manufacturers was under way, and Toledo-based solar firms were in difficulty. Toledo's Xunlight Corporation was reportedly making interest-only payments on state loans that were required to include principal payments and in 2016, Xunlight went into Chapter 7 liquidation.[86] In November 2012 it was reported that the State of Ohio might not be able to recover loans made to Toledo's Willard & Kelsey Solar Group, which reported growing "bills, legal challenges, and financial troubles."[87] The company went bankrupt in 2013.[88] In 2017 First Solar laid off 450 workers at its solar plant in Perrysburg, a Toledo Suburb, and dropped plans to introduce its Series 5 generation of panels, which represented an incremental improvement over its Series 4 line. A solar industry analyst observed that "a small vibration back in China can cause an avalanche in

[80] Xia Yu, *The Role and Incentives of Chinese Local Governments in Solar PV Overinvestment* (MA Thesis, University of Texas at Austin, May 2013).

[81] "Suntech, Owing Millions, Faces a Takeover," *New York Times* (March 13, 2013).

[82] "Sun Burn 2: Global Changes Slow Solar Growth," Toledo *Free Press* (July 26, 2012); "Lights Go Out for Most PV Cell Makers," *Joong-An Daily Online* (June 12, 2012); Alan Meick, *China's Wind and Solar Sectors: Trends in Developing, Manufacturing and Energy Policy* (March 9, 2015).

[83] "PV Armageddon: The Rapid Market Swings Concealed Major Efficiency Gains," *Printed Circuit Design and Fab* (April 2012).

[84] "When Solar Panels Become Job Killers," *New York Times* (April 8, 2017).

[85] "Chines Solar Firm Suntech Defaults on Bonds Payment," *Houston Examiner* (March 19, 2013).

[86] "Tentative Settlement Reached With Failed Toledo Solar-Panel Manufacturer Xunlight," Toledo *The Blade* (April 20, 2018).

[87] "Local Solar Firm Awash in Debts," Toledo *The Blade* (November 12, 2012).

[88] For a list of bankrupt and closed solar energy companies, see "The Mercifully Short List of Fallen Solar Companies: 2015 Edition," *Greentech Media* (December 1, 2015).

prices around the world." As of 2017 China accounted for two-thirds of the world's solar production capacity.[89]

55. U.S. trade policy is administrated by the Federal government, and state and local authorities have no direct policy responses available to counter dumping. U.S. makers of solar panels ultimately secured antidumping, duties of about 30 percent on imports of Chinese solar panels, and in 2018, President Trump imposed an additional tariff of 25 percent. These measures came too late to save companies like Xunlight and Willard & Kelsey, and their effectiveness may be limited as solar panel suppliers based in other countries (such as India) increase their penetration of the U.S. market.[90] This experience underscores the limitations of U.S. trade remedies in responding to market disruptions from state-backed companies abroad. Antidumping cases take a long time to prepare and litigate, often 1-2 years, during which time the dumping can continue causing substantial economic harm to businesses relying on private investors and with debts to service. Moreover, the relief available is prospective only, and the antidumping laws generally do not result in payment of damages to injured companies.

56. While each situation involving major foreign market distortions is unique, in the past the U.S. government has demonstrated, often *in extremis*, that it will intervene with sweeping policy measures to prevent the destruction of a U.S. industry considered essential to security and national economic well-being. Thus in the 1980s the Reagan administration, facing the imminent destruction of the U.S. semiconductor industry, implemented economic sanctions that resulted in a comprehensive trade agreement with Japan to end dumping worldwide and open the Japanese market. Separately, at the industry's request, the Sematech research consortium was created, a government industry partnership with shared costs to restore U.S. competitiveness in semiconductor manufacturing[91]. Both policy measures were criticized as interventionist, yet both succeeded, with Sematech eventually becoming an international consortium.[92] While these measures were controversial at the time and remain exceptional, they nonetheless demonstrate what can be achieved when the federal government concludes that a fundamental national economic interest is at stake. This case also underscores the risks posed to a rules based trading system which is unable or unwilling to address the challenges inherent in state capitalism and mercantile trading policies.

57. ***The challenge of university-industry linkages***. In advanced industrial countries, the most important—and intractable—impediments to innovations in the near-absence or inadequacy of linkages between university-based scientific and engineering research and private industry, creating gaps which limit the potential economic impact of path-breaking

[89] "When Solar Panels Became Job Killers," *New York Times* (April 8, 2017); "Donald Trump May Be the Only Hope for Struggling US Solar Manufacturers," Greentech Media (April 21, 2017).

[90] "U.S. imposes 25 Percent Import Tariff on Solar Cells and Modules from China," *Mercomindia* (August 13, 2018).

[91] Defense Science Board, *Task Force on Semiconductor Dependency* (November 30, 1986); Larry D. Browning and Judy C. Shetler, Sematech: Saving the U.S. Semiconductor Industry (College Station, TX; Texas A&M University Press, 2000).

[92] National Research Council, Charles W. Wessner (ed) *Securing the Future: Regional and National Programs to Support the Semiconductor Industry* (Washington, D.C.: The National Academies Press, 2003)

research. The weakness of such links has been lamented in countries with excellent science research bases but lagging performance in innovation, including Canada,[93] France[94] and the United Kingdom.[95] In these countries, historically academia and industry tended to regard each other with suspicion if not distain. According to one account, the U.K.'s foremost electronics research group of the 20th Century used to toast their discoveries with the cry "And may it never be of use!"[96] Conversely, countries which have established strong publicly-funded institutional and social mechanisms for inducing university-industry collaboration, such as Germany and Taiwan, have better recent records of innovation.

58. In the United States university-industry research collaboration has been integral to US economic development, an orientation dramatically enhanced by the impact of the Bayh-Dole Act of 1980, which created a presumption that government grants or contracts to researchers or businesses would usually allow patent rights to be retained by grantees or contractors. In the wake of this legislation many U.S. universities established technology transfer offices to commercialize university research discoveries.[97] These facilities and a changing university culture have contributed to the creation of a number of successful industrial clusters around research universities and the stimulation of local economic growth.[98]

59. The convening, interdisciplinary role which U.S. universities can play with respect to development of new industries is demonstrated by two research centers seeking to integrate separate industries and disciplines in the emerging field of flexible electronics—electronic devices that can be bent, rolled or folded without losing functionality:

- ***Sonoco Institute of Packaging Design & Graphics.*** The Sonoco Institute was founded at South Carolina's Clemson University in 2009 to develop innovative packaging technologies, including printed electronic "smart" packaging which is capable of interacting with retail environments. Clemson has a long history and curriculum featuring packaging technology as well as close relationships with the printing industry and its supply chains. It has been working with industry parties to commercialize technologies involving printing of conductive inks with electronics applications. The physical site features diverse analytic equipment and

[93] Independent Panel on Federal Support to Research and Development, *Innovation Canada: A Call to Action* (2011) ("Jenkins Report").

[94] Blanka Vavakova, "Reconceptualizing Innovation Policy: The Case of France," *Technovation* (2006).

[95] Andrea Mina, David Connell and Alan Hughes, *Models of Technology Development in Intermediate Research Organizations* (Cambridge University Center for Business Research, Working Paper No. 396, December 2009).

[96] Salutation at a dinner held for the Rutherford team of Cavendish Laboratory, Cambridge University, cited in Brian Oakley and Kevin Owen, *Alvey: Britain's Strategic Computing Industry* (Cambridge MA: The MIT Press, 1989) p. 267.

[97] "Innovation's Golden Game," *The Economist* (December 12, 2002).

[98] Naomi Hausman, "University Innovation and Local Economic Growth and Entrepreneurship," (Harvard Center for Economic Studies, CES-12-10, June, 2012); "Stewards of Invention: CU's Technology Transfer Office Helps Ideas Become Companies," Boulder *The Daily Camera* (June 19, 2006).

expertise to develop and test new products and processes, as well as training programs.[99]

- ***Center for the Advancement of Printed Electronics (CAPE)***. CAPE, based at Western Michigan University (WMU) is a collaboration with industry to develop materials for use in fabricating flexible electronics devices using printing processes. CAPE draws on WMU's legacy of innovation in paper and printing and on cross-departmental faculty competencies. It features five pilot manufacturing facilities including various printing systems. Industry partners include Corning, Amway, Neenah Paper Inc. and Daetwyler R&D.[100]

- ***Georgia Tech Center for Organic Photonics and Electronics (COPE)***. COPE was founded in 2003 at Georgia Tech to develop flexible organic photonic and electronic devices and materials for applications in telecommunications, information technologies, defense and energy. It has numerous U.S. and European industrial partners including Solvay and Boeing. Its research center transfers technology to industry and in some cases commercializes technology through the formation of start-up companies.[101]

60. ***Innovation culture and start-ups***. Numerous studies of Silicon Valley cite its innovation culture as a key factor underlying its success.[102] It is a region in which most successful firms began as local start-ups, and Stanford University long fostered a "start-up culture" in which it is "almost an unwritten rule that you have to start a company to be a successful professor."[103] Attitudes toward entrepreneurial failure are benign—"not only was risk-taking glorified but failure was socially acceptable … the list of individuals who failed, even repeatedly, only to succeed later was well known within the region."[104] The acceptability of failure is powerfully reinforced by the Chapter 11 bankruptcy laws in the U.S. which limit the penalties of failure and allow for the relatively rapid redeployment of intellectual capital with limited personal penalties.

61. Start-ups, not recruitment of established companies from other regions, underlie the success of Silicon Valley and Boston, which spawned entirely new companies such as Hewlett-Packard, Intel, Google, Apple, Reddit, Dropbox, and Facebook. Incumbent firms, even highly successful technology-oriented companies, "are not the hyper wealth-creation engines that drive places like Silicon Valley and create millionaires who turn around and

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[99] The Institute's website cites its extensive equipment resources and states that "if you have a substrate, ink, plate, anilox, doctor blade, mounting tape, screening, process, technique, etc., ... that you'd like to test, but don't have access to a press (or press time) contact us to arrange a print trial today." http://www.clemson.edu/centers-institutes/sonoco-institute/services/index.html.

[100] http://www.wmich.edu/chemical-paper.

[101] http://www.cope.gtech.edu/?q=research.

[102] Timothy J. Sturgeon, "How Silicon Valley Came to Be," in Martin Kenney (ed.) *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region* (Stanford University Press, 2000); Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge MA: Harvard University Press, 1994).

[103] "Upstarts and Rabble Rousers … Stanford Fetes 4 Decades of Computer Science," *San Francisco Chronicle* (March 20, 2006).

[104] Saxenian, *Regional Advantage* (1994) op. cit., pp. 38-39.

sink their earnings back into the economy."[105] For this reason the relative success of a given innovation cluster is commonly benchmarked, in part, by reference to the number of successful startups it has spawned.

62. One of the perceived shortcomings of the New York Tech Valley effort is the fact that it has been heavily weighted toward recruiting established companies from outside the region and that—to date—it has generated relatively few local startups, none of which have yet achieved significant scale.[106] In Boston and Silicon Valley, such new firms have eventually become the greatest sources of wealth generation and employment. A rejoinder is that a number of successful high tech clusters, such as Research Triangle and Austin, Texas began with the recruitment of large established firms and that these companies created on environment in which startups eventually flourished—but only after significant passage of time.[107] Whatever the relative merits of these two perspectives, as with other older industrialized states, upstate New York is not a region in which successful high tech startups are common but current trends are encouraging.[108]

63. ***The promise of Illinois***. Other regions in the U.S. are more than encouraging. Policymakers in Illinois have long grappled with the paradox that it is richly endowed with world-class universities, major companies and research institutions including the Argonne National Laboratories, but "we just haven't seen enough companies starting here."[109] One local critic faults the state's reliance on a "big company strategy" seeking to recruit large established firms."[110] The University of Illinois has one of the largest research budgets in the country, and the state is the site of the first creation of stem cells from adult cells

[105] "Finding Funding to Stay Hot," Albany *The Times Union* (October 2013)

[106] It is premature to conclude that Tech Valley will not become seedbed for nanotechnology-based startups. In 2017 it was noted that "with little fanfare SUNY Poly [the NanoCollege] slowly but surely… [is] becoming a hot spot for clean energy and biotech startups that could be the Teslas of the future." "SUNY Poly Startups Created by Students Are Set to Launch," Albany *The Times Union* (July 1, 2017). Promising nanotechnology - based startups include BessTech, which uses silicon nanostructures to increase the storage power of lithium-ion batteries; HocusLocus, which is commercializing a nanoscale RNA switching mechanism with medical applications; Glauconix, which has developed nanoscale artificial eye tissue for drug screening and prevention and treatment of glaucoma; and ThermoAura, developer of a nanoscale solid-state thermoelectric material that converts heat to electricity. "High Tech Firm Opens Up New Facility in Colonie," Saratoga Springs *the Saratogian* (December 9, 2017); "Bess Tech Draws in Venture Capital," Albany *The Times Union* (May 14, 2015).

[107] Elsie Echevarri-Carroll, Mary Ann Feldman, David Gibran, Nichola Lowe and Michael Oden, *A Tale of Two Innovative Entrepreneurial Regions: The Research Triangle and Austin* (University of Texas at Austin and University of North Carolina at Chapel Hill, March 15, 2015).

[108] Stuart W. Leslie, "Regional Disadvantage: Replicating Silicon Valley in New York's Capital Region," *Technology and Culture* (2001)

[109] Former Provost of Northwestern University Lawrence Dumas, cited in Thomas O'Halloran, "Disruptive Environments Trust Seed Discovery and Promote Translation," in National Research Council, *Building the Illinois Innovation Economy; Summary of a Symposium* (Washington, D.C.: The National Academies Press, 2013).

[110] Presentation of David Miller, head of the Illinois Biotechnology Industry Organizations ((iBIO), "Early Stage Finance and Support in Illinois," National Research Council, *Building the Illinois Innovation Economy* (2013) op. cit.

(Argonne Lab, 2003) and the first planted biotechnology field in the world (1987). However, homegrown biotechnology companies and startups have migrated to other regions.[111] A number of observers fault the local innovation culture. In the Midwest, for entrepreneurs, "failure is not okay, you are ostracized, and you have huge problems with your next funding."[112] A business professor at Northwestern University recalls his experience at a party in Chicago where he found "the usual conversation about real estate and banking." Asked how big his company was, he said that he had just started it and times were difficult. At that point the conversation stopped and the conversation returned to real estate. He recalls "I knew what was in their minds. He's between jobs."[113]

64. Illinois has implemented numerous initiatives to foster local entrepreneurialism, recognizing that changing cultural attitudes is extremely challenging. The state legislature created the Illinois Science and Technology Commission (ISTC) to promote innovation, attract early stage financing, and foster public-private partnerships for R&D and Innovation.[114] Northwestern University's International Institute for Nanotechnology has launched startups to commercialize nanotechnologies developed at Northwestern.[115] The University of Illinois offers curricula designed to foster entrepreneurialism, including business plan competitions, funding for proof of concept, and a residential dormitory having 130 students from different fields of study who are interested in becoming entrepreneurs. The University of Chicago's New Venture Challenge program has been recognized as the number one university accelerator in the country, and its Innovation Fund invests in local startups. Such initiatives appear to be moving the needle. *Forbes* observed in 2018 that Illinois universities were transforming the startup landscape:

> *Ten years ago Chicago was not a major player in the startup ecosystem. Now it's one of the most important cities in tech. In fact the overall Illinois rate of startup growth is 68.85%, and Chicago itself has been consistently ranked first for VC returns. It's been named alongside Boston, Los Angeles and Austin as one of the country's best startup cities [reflecting] one of the most innovation-driven higher education systems across the U.S.*[116]

65. ***Clustering vs. dispersion***. From the time of Alfred Marshall's observations down to our own, the economic advantages of cluster formation have been evident. However, by their nature, clusters entail the dense concentration of industrial and research sites in specific geographic locations. In situations involving public investments, where some

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[111] "Magazine Ranks Illinois Top State for Biotechnology," Champagne-Urbana *The News-Gazette* (July 23, 2005); "Fertile Ground for a Biotech Hub," *Daily Herald* (March 8, 2001); "Region's R&D Spending Plummets," Crystal Lake *The Northwest Herald* (March 3, 2013).

[112] Former Mayor of Bloomington, Indiana, cited in National Research Council, *Building the Illinois Innovation Economy* (2013) op. cit.

[113] Robert Wolcott, "Driving Entrepreneurship in Illinois," in National Research Council, *Building the Illinois Innovation Economy* (2013) op. cit.

[114] Mark Harris, "Illinois Science and Technology Coalition," in National Research Council, *Building the Illinois Innovation Economy* (2013) op. cit.

[115] "What the Giant of Teeny-Tiny is up to Now," *Crain's Chicago Business Review* (October 13, 2012).

[116] "How Illinois Universities Power the Chicago Startup Ecosystem," *Forbes* (February 26, 2018).

regions are perceived to be receiving far more than their "share" can result in political pressures and ultimately, the operation of powerful centrifugal forces on a cluster. In the New York case, the fact that the Capital Region was seen to have received more than its share of state research investments for a number of years under Governor Pataki was undoubtedly a factor underlying Governor Andrew Cuomo's decision to apply the Albany model across Upstate New York. That move was widely seen as politically astute and perhaps even essential, but its application has experienced mixed results and raised questions about the state's commitment to the Albany Nanocluster.[117] A key challenge for policy makers is to maintain support for repeated investments in a thriving cluster even though those investments are essential for the cluster to continue to grow, or even survive.

[117] "Has 'Tech Valley' Peaked?" Albany *The Times Union* (November 11, 2013); "One Troubled Tech Park in Malta," Schenectady *The Daily Gazette* (April 6, 2014); "Billions at Stake in Tech Arms Race as Luther Forest Flounders," *Albany Business Review* (October 18, 2013).

3. The Federal Aspect

66. Although Federal agencies and local Congressional offices made valuable contributions to the development of Tech Valley, the New York nanocluster was primarily a placed–based initiative, created without large scale central goverment funding. While the U.S. federal government has over 200 programs addressing various aspects of regional development, until recently there was "no federal policy on clusters." With exceptions in the fields of defense and health, the federal research bureaucracy, which is highly decentralized, normally distributes an large number of relatively small grants and research contracts across the economy. However, under the Obama Administration, efforts were made to coordinate federal policies and initiatives were put in place to foster regional innovation clusters.

- ***Economic Development Administration (EDA)***. The EDA, an arm of the Department of Commerce, implements programs to assist economically distressed regions. It supports the University Center (UC) program, which marshals the resources available in colleges and universities to support regional economic development strategies in distressed areas. It also supports cluster-focused proof-of-concept and commercialization programs as well as early stage seed capital funds.[118] Despite considerable impact, the EDA's developments resources remain tightly constrained given the scope of its responsibility and the needs of the country's regions.
- ***Manufacturing USA***. Manufacturing USA, previously known as the National Network for Manufacturing Innovation (NNMI) is a network of federally-funded research institutes operating as public-university-private partnerships focusing as the development of manufacturing technologies. Fifteen institutes have been created, specializing in technologies such as additive manufacturing, composite materials, regenerative medicine and digital manufacturing. Eight of the institutes are administered by the Department of Defense, six by the Department of Energy, and one by the Department of Commerce. The objective of the institutes is to solve generic industrial problems, with shared facilities and cooperative research, train domestic workers in new areas of manufacturing, and demonstrate new technologies and while reducing the costs and risks associated with their commercial use.

[118] http://www.eda.gov/programs/eda-programs.

4. Lessons for Europe

67. It may seem presumptuous to conclude that U.S. state and regional innovation initiatives offer lessons to Europe, given the latter's renowned universities, centuries-old traditions of scientific discovery and invention, and superb public research laboratories. British universities, for example, are among the global leaders in many scientific disciplines, British researchers are the most productive and efficient in the world in terms of output per researcher and per unit of research spending, and in pre-clinical and clinical health, three of the top five universities in the world are British, including number one, Oxford. Universities in continental Europe have been closely collaborating with local industries over a much longer time frame than has been case in the United States. German universities were sites of "serious research and scholarship long before their British and American counterparts," and at the end of the Nineteenth Century German institutions were providing "the best technical and scientific training in the world and were seen as a model for U.S. universities." The world-renowned *Fraunhofer-Gesellschaft*, which provides innovation–based research for industry, is used as a model today for innovation initiatives in many other countries, including the recently established Manufacturing USA Institutes, which are explicit attempts to replicate the Fraunhofer model in the U.S. That said, the U.S. experience can still offer perspectives that may be useful in a European context.

68. ***Curriculum***. US research universities have an unparalleled record of rapidly introducing new curricula relevant to emerging industries, effectively accelerating their development. Over a century ago, U.S. universities' reaction to the advent of new electricity-based industries was "virtually instantaneous," with MIT initiating curricula in electrical engineering in 1882, the same year Thomas Edison's demonstration project for electric lighting at the Pearl Street Station in New York first became operational.[119] The spectacular growth of the US semiconductor industry in the 1960s was driven by the rapidly-evolving curriculum of Stanford's Department of Electrical Engineering, which introduced coursework in the design and fabrication of integrated circuits soon after the first such devices were created in 1961, and which subsequently drew on the leading engineers in Silicon Valley to instruct faculty and students on the latest developments in the discipline. American prominance of the computer software industry was "overwhelmingly due to the remarkable speed with which university faculties were able to develop and to introduce an entirely new academic curriculum in computer science beginning in the late 1950s."[120] SUNY Albany's introduction of curricula and entire degree programs in the emerging field of applied nanotechnology is a recent manifestation of this longstanding US tradition of practically-oriented research and instruction.

69. ***Entrepreneurialism***. Broader lessons from the United States, may be drawn from the proliferation of entrepreneurial innovative start-ups, which is generally acknowledged as an area of European weakness. Reporting on a recent Franco-German initiative to find start-ups across the European Union, *Reuters* observed that

[119] Cornell followed in 1883. Rosenberg and Nelson, "American Universities" (1994) op.cit.

[120] Nathan Rosenberg, "America's Entrepreneurial Universities," in David M. Hart, *The Emergence of Entrepreneurial Policy: Governance, Start-ups and Growth in the U.S. Knowledge Economy* (Cambridge: Cambridge University Press, 2003).

> *Europe has long been seen as a laggard in developing new technologies compared with the United States, which has a strong venture capital industry funding Silicon Valley start-ups. The more risk-averse culture in Europe has also been cited as an obstacle to creating a "European Google," partly because failure can carry more stigma than it does across the Atlantic.*[121]

70. Europe's risk averse culture is arguably reinforced by punitive bankruptcy laws and compounded by less openness to new technologies among public officials and, to some degree, the public at large. A major gap in the European innovation system has been the reluctance of many universities to engage with industry and quickly adapt curricular to the needs of industry.[122]

71. Upstate New York is not Silicon Valley. Its development of a nanotechnology cluster has not—to date—seen the emergence of significant numbers of start-up companies. However development of the cluster offers some salient examples of "entrepreneurial" actions, a term that applies not only to the launch of new companies but a mindset that perceives opportunities and acts on them, accepting the risk of failure.[123] At SUNY Albany, a physics professor, Alain Kaloyeros, demonstrated a unique ability to forge productive research partnerships between academia and industry. Similarly two economic development professionals in Saratoga County, Ken Green and Jack Kelley, undertook a seemingly quixotic, decade-long quest to attract a semiconductor manufacturer to the Capital Region, one that ultimately achieved great success. Crucially state institutions did not stifle these "bottom-up" initiatives, but supported what we call "civic entrepreneurs" -- Kaloyeros was backed by the SUNY administration and a succession of governors, and Green and Kelly by regional development organizations, local companies, a utility (National Grid) the Empire State Development Corporation (a state institution) as well as senior New York political leaders.[124]

72. As a professor at SUNY and later as head of the College of Nanoscale Science and Engineering, Kaloyeros displayed a genius for putting together research collaborations between high tech companies and his university, which may reflect the influence of an early mentor, a senior engineer from IBM.[125] As his powers and responsibilities grew, he established a number of not-for-profit intermediary organizations (501-C3 corporations) to function as interfaces between the university and companies. These foundations provided

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[121] "France, Germany Push for EU Funding for Technology Start-ups," *Reuters* (May 27, 2018)

[122] It should be noted that some European universities manifest an entrepreneurial culture producing start-ups at a significant rate, including Cambridge, the Catholic University of Leuven, TUM in Munich, Aalto in Helsinki and Chalmers in Gothenberg, among others.

[123] See Enterprising Oxford: Supporting Entrepreneurial Connectivity <http://www.ship.ox.ac.uk/what-does-it-mean-to-be-entrepreneurial>

[124] "Bruno, Others Did Hard Work for Nanotech," Schenectady *The Daily Gazette* (May 12, 2012); "Nano's Seeds Planted Long Ago," Albany *The Times Union* (October 3, 2011); "Seed Cash for Tech Valley," Albany *The Times Union* (February 23, 1999).

[125] Kaloyeros and his mentor, IBM's Michael Fury, describe the nature of the close research collaboration between the university and private companies -- and the benefits for each party -- in an academic monograph originally published in 1993. Michael A. Fury and Alian E. Kaloyeros, "Metallization for Microelectronics Program at the University of Albany: Leveraging a Long-Term Mentor Relationship," *Higher Education* (February 2011), pp.193-208.

flexibility and speed, key requirements of companies at the technological frontier, and qualities that eased private sector concerns about entering into relationships with academic institutions.[126] Despite what some viewed as an abrasive personality and overly freewheeling style, his university accorded him "running room" in which to run his projects and. the state provided his efforts with substantial financial backing aided by his derct relationship with the states leadership. Using his foundations, "he cut through red tape like no one else."[127] The net result was the creation of the world's first college of applied nanotechnology and the establishment of large-scale research collaborations with many of world's leading semiconductor producers.[128]

73. At the same time, it is apparent that at some indeterminate point, the institutional checks and balances on Kaloyeros had eroded to the point that he was operating as a "one-man band, a lone ranger," with most state officials in the dark as to his operations.[129] In 2011, for example, oversight of the SUNY Research Foundation by the Office of the State Comptroller was eliminated, on the grounds that review of large contracts by state auditors caused delays in state economic development projects. [130] By 2015 some of Kaloyeros' colleagues were expressing alarm over the degree of power he was able to exert over the state's investments, coupled with his idiosyncratic behavior.[131] When he was indicted in 2016, state officials stepped in to increase oversight and transparency with respect to the SUNY institutions that had supported Kaloyeros' efforts while seeking to maintain momentum with respect to ongoing and prospective CNSE projects.[132] This effort involves striking a careful balance between allowing institutional flexibility to enable talented and entrepreneurial individuals to drive promising public-private development initiatives and maintaining the institutional checks required to ensure transparency and protect the integrity of government. This is a challenge not unfamiliar to European policymakers, and the Kaloyeros case offers lessons with respect to both poles in the perennial tension between entrepreneurialism and oversight.

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[126] Corporate partners sought a "more corporate presence relating to potential industry partners than the persona of an academic institution could provide." Key factors in the success of the foundations was their were the responsiveness and ability to execute with the speed and effectiveness required by the semiconductor industry. The establishment of such intermediaries demonstrated to companies that SUNY Albany understood these imperatives. The intermediaries were created in conjunction with the SUNY Research Foundation which did not have university-type rules governing subjects such as faculty tenure and human resources policies. Robert W. Wagner, *Academic Entrepreneurialism and New York's Centers of Excellence Policy* (2017)

[127] "Bid - Rigging Trial Begins for State University of New York Official," *Reuters* (June 18, 2018).

[128] These achievements endure, notwithstanding Kaloyeros' resignation and eventual conviction on federal bid-rigging charges in 2018.

[129] The terms were used by Kaloyeros' defense attorney during his trial. "Bid-Rigging Trial Begins for Ex-State Official," *Reuters* (June 18, 2018).

[130] "Restore DiNapoli's Oversight … Legislature Shouldn't Have Limited Comptroller's Authority Over Contracts," *The Buffalo News* (April 12, 2012).

[131] "Alain Kaloyeros, Powerful Centerpiece of Buffalo Billion, Could Become a Household Word," *Gotham Gazette* (September 29, 2015).

[132] "SUNY Poly Settles Law, Tries to Clear Kaloyeros Hangover," *Politico* (March 27, 2017); "SUNY Poly Units Review," Albany *The Times Union* (November 18, 2016).

74. Kaloyeros' successes and travails have tended to overshadow the fact that the Tech Valley effort was driven by the initiative of many individuals, most of them relatively obscure, pursuing a shared vision of knowledge-based economic development. As noted, the successful effort to attract a semiconductor wafer fabrication plant to the Capital Region was spearheaded by the Saratoga Economic Development Corporation (SEDC), a small entity with several employees operating out of extremely modest quarters. These individuals -- primarily Ken Green and Jack Kelley -- educated themselves with respect to the fundamentals of semiconductor manufacturing, built a knowledge base, secured necessary local regulatory approvals, and reached out to Silicon Valley with ultimate success. Significantly, this effort was not superseded, taken over or suppressed, but rather was supported and reinforced at every step of the way by private firms, other economic development organizations and various arms of the state government.

75. ***New York's "Smart Specialization"***. In tacit recognition of the potential value of "bottom up" local development initiatives, in 2011 New York established a new competitive system for allocating state economic development funds via Regional Economic Development Councils (REDC). The state was divided into regions which were tasked with preparing their own regional development plans and submitting annual bids to the state for funding for promising projects. The selection of winning projects was undertaken by the governor, the Empire State Development Corporation (ESD) and the governor's budget division, working as a team.[133] The rationale underlying this arrangement was that local leaders closely familiar with local conditions and potential could generate potentially transformative proposals that could be brought to the attention of the state's economic development organizations, rather than relying on pet projects put forward by individual legislators.[134] One state official involved in the creation of the REDCs said that the new regime created a greater likelihood that good ideas bubbling up from the local level would be recognized and reinforced by the state. While it is perhaps premature to judge the new development arrangements, there are already enough success stories that the REDCs are being touted as "a national model."[135] The parallels with the Smart Specialization concept are of course striking.

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[133] "ESD Team Reviews EDC Funding Proposals," Massena *Daily Courier - Observer* (September 13, 2014); "The Recipe for NY's Success," Albany *The Times Union* (January 13, 2011)

[134] In 2011 Julie Shimer, the Chairperson of Empire State Development, said that the REDCs were screening mechanisms for the ESD. In terms of developing meritorious projects, "[D]espite its best efforts making those decisions from Albany [is] always difficult. It's hard to have all the information on the ground and hear from all the stakeholders…[G]etting the regional input is very important. Certainly all the state agencies did the best job they can with the information they have, and I think that what's going to happen now is, we'll have much higher quality information and we'll be able to compare these proposals." "How to Fix NY's Business Climate--It Starts with Regional Community-Based Planning, Says Development Corps Chairwomen, Syracuse The Post-Star (August 18, 2011)".

[135] "No More Bad Old Days--Legislators Should Give Up Their Wish to Dole Out the State's Development Cash," *The Buffalo News* (February 4, 2017); "Another Voice: Regional Counsels -- Economic Progress Under Threat from the State Senate," *The Buffalo News* (February 28, 2017); "Empire State Development Approves $46 Million for OCEDC's STAMP Plan," *The Daily News* (August 18, 2016).

5. Conclusion

76. A final observation about New York's creation of the Albany nanocluster is that from the outset, state policymakers carefully studied successful innovation clusters in other regions and countries, and familiarized themselves with current academic thinking on the subject.[136] They believed that "best practices" existed and could be adopted and adapted, while recognizing the caveat that "what works in one region may not necessarily work in another region". They also appreciated that any cluster strategy should be "built on that region's assets, institutions and advantages."[137] Importantly, this strategy included close cooperation with industry and a desire to address its needs. In this sense, their approach is quite consistent with the Smart Specialization concept now being adopted in Europe and elsewhere. At the same time, New York's challenges of maintaining investment at scale, backed by sustained commitment, and buttressed by regional cooperation are also likely to be encountered by the regions that seek to follow the precepts of the Smart Specialization strategy. In all cases, efforts will need to be made to strengthen a rules based trading regime that enables multiple centers of growth and, crucially, the innovation they engender.

[136] F. Michael Tucker, "The Rise of Tech Valley," *Economic Development Journal* (Fall 2008); Stuart W. Leslie, and Robert H. Kargon, "Selling Silicon Valley: Frederick Terman's Model for Regional Advantage," *Business History Review* (Winter 1996).

[137] New York Governor Andrew Cuomo, "Rebuilding the Upstate Economy," *Huffington Post* (September 1, 2016).