SUSTAINABLE DYNAMISM: A Regional Economic Development Strategy of Continuous Reinvention

Volume I: Implementing a Strategy

Sustainable Dynamism

A new approach to economic development, and its potential to generate continuous growth in regional per capita income and GDP, is predicated on a regional economy's ability to exploit successive waves of new technologies and innovations by fostering an economic environment conducive to entrepreneurial activity and new firm formation that will produce a sustainable process whereby new products and services are continually introduced into the market.

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SUSTAINABLE DYNAMISM:
A Regional Economic Development Strategy of Continuous Reinvention

VOLUME I:
Implementing a Strategy

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FOREWORD

This is Volume I of a two-volume research report on the implementation of the recommendations of ***Benchmarking Growth in Demand-Driven Labor Markets.***[1] It presents a general framework for implementing a strategy of fostering an economic environment conducive to entrepreneurial activity and new firm formation that will produce a sustainable process, whereby new products and services are continually introduced into the market. In addition, the critical role of workforce development policies and programs are addressed. To that end, this volume lays out specific programs and strategies, and puts them within the context of recent work done on technology transfer and Connecticut's future economic prospects. It lays out a formal context for constructing a framework for a growth and development strategy. It then provides an operational definition of sustainable dynamism, which is grounded in the idea that such a set of economic conditions would characterize a region where innovation itself is its "leading product". The birth and evolution of four science cities suggests a framework, within a workforce investment context, for implementing a set of policies that would put Connecticut's regional economies on track to achieving sustainable dynamism.

A more formalized development of the ideas that serve as the basis for the strategies is presented in Volume II. In addition to providing that framework, Volume II contains references for further research and lays out the background, development, and formal framework for the implementation strategies presented here in Volume I. The focus in Volume II is on the development of economic growth theory, the current emphasis on technological change as endogenous to the growth and development process, and the implications for the programs and policies recommended in Volume I.

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[1] McPherron, Patrick, "Benchmarking Growth In Demand-Driven Labor Markets – 2006" OCCASIONAL PAPER (December 2006) Office of Research, Connecticut Department of Labor: Wethersfield, CT.

EXECUTIVE SUMMARY

Innovate or Relocate! So declares *Benchmarking Growth in Demand-Driven Labor Markets.*[2] The upshot is that a regional economy that has lost the ability to re-invent itself will stagnate, and stagnation is just the transition period from growth to decline. This is the specter that confronts Connecticut's future if fundamental changes in the trajectory of the State's economy are not addressed. Outlining a strategy for changing the current trajectory is the motivation for the development of this follow-up to the benchmarking report.

Four broad strategies are suggested for the kind of economic development that could maintain the State's high per capita ranking into the next generation:

1. Invest in education, from pre-school to post-secondary.
2. Invest in improvements to Connecticut's transportation systems.
3. Increase the supply of affordable housing.
4. Foster a workforce for Connecticut's high demand, high skill, and high growth careers, such as those in healthcare, finance, engineering, and teaching.

This report presents a general framework for implementing a strategy of fostering an economic environment conducive to entrepreneurial activity and new firm formation that will produce a sustainable process whereby new products and services are continually introduced into the market. The key to this process is *innovation*; the bridge between invention and the development and introduction of new products into the market. A regional economy characterized by such a virtuous cycle of dynamic activity would be in a critical position to re-invent itself, and thus constantly adapt its export base to changes in the growth and mix of national and global demand. As the title of this paper suggests, such a region would have attained *sustained dynamism*.

In lieu of the Connecticut technology transfer report, completed by Innovation Associates (IA) in October 2004[3] for the Technology Transfer and Commercialization Advisory Board of the Governor's Competitiveness Council, it may seem to the reader that this report is an exercise in "reinventing the wheel." While the technology transfer report and the current report both concentrated on the lessons that could be learned from successful science cities, the approaches by the two reports are complementary. The very extensive, and well-researched, coverage of the nature of the "science cities" investigated in the technology transfer report concentrated on the current, and recent, developments in the studied university-based economic growth centers. In its approach, the technology transfer report focused on the current, and recent past, entities, policies and programs that have characterized the successes of the example university-based centers studied by IA (i.e., a cross-sectional—*point-in-time*—view), whereas the current report focuses on the birth, motivation, development and evolution, and current life cycle stage of the four case-study science cities (i.e., a history and development—*over time*—view).

To provide the context for a clearly formulated strategy, it is helpful to briefly review developments in growth theory in the post-World War II (WW II) era. The development of economic growth theory in the post-WW II era can be partitioned into three historical periods:

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[2] McPherron, Patrick, *Benchmarking Growth In Demand-Driven Labor Markets – 2006* OCCASIONAL PAPER (December 2006) Office of Research, Connecticut Department of Labor: Wethersfield, CT, p. iii.
[3] Innovation Associates, Inc., *Report to the Connecticut Technology Transfer and Commercialization Advisory Board of the Governor's Competitiveness Council* (October 2004).

(1.) Technology as Exogenous: The Solow Model, (2.) Technology as Endogenous: The Romer-Lucas Model, and (3.) the Entrepreneurial Economy. Central to the approach presented here is the treatment of technology and knowledge by each of the three growth paradigms, and their implications about the changing role of the entrepreneur and the exploitation of knowledge for the development and introduction of new products and services into the market. In a regional economy whose economic future is predicated on an economic base driven by industries characterized by the early states of the product/technology life cycle, the process of recognizing new opportunities and then commercializing those perceived opportunities by starting a new firm is particularly important. Thus, the entrepreneurial economy that is emerging in North America and Europe has a new role for entrepreneurship. Rather than imposing an efficiency burden on the economy, a critical feature of the Solow economy, entrepreneurship serves as an engine of growth by providing a vital conduit for the spillover and commercialization of knowledge and new ideas.

Central to the new knowledge economy is the re-emergence of spatial proximity as a critical factor. This is a consequence of the spatial constraint in the diffusion of knowledge. Why is geographic proximity so important for the transmission of knowledge, and especially tacit knowledge? Localization theories suggest that face-to-face interaction and nonverbal communication facilitate the transmission of ideas and intuition that cannot be communicated through codified instructions. At the heart of understanding the critical importance of spatial proximity in the transfer of knowledge lays the distinction between *information* and *knowledge*. While information is often context-free, tacit knowledge is often derived from specific contexts. Thus, in order to access knowledge and participate in the generation of new ideas, local proximity is significantly more cost-effective than trying to attain the same knowledge across distance.

With the rise of the knowledge-based economy, there is now a new, and expanded, concept of the "economic base." It arises out of the *third wave* of economic development policies and is based on the *strategic management of places*. Instead of the economic base being predicated on an industry, a product or set of products, or a specific technology, this new approach views the "product" as the continuous introduction of new products and innovations. The regional economy's "product" or "economic base" is its ability to continually re-invent itself. It exports new products and innovations to the nation and the world as an on-going process. Thus, the new emphasis: *entrepreneurship and regional development*. This new approach to economic development, and its potential ability to generate continuous growth in regional per capita income and GDP, is predicated on the regional economy's ability to exploit successive waves of new technologies and innovations that generate an ongoing process of introducing new products and services into the market.

How does a region tap into the above dynamic? A recently emerging answer to that question is: a "*science city*." But what is a science city? What comprises a science city has no standardized set of criteria. Science parks apparently do not make science cities.[4] Throwing several high-tech businesses together in one place to share streets, sewers, and Internet connections does not produce the social, financial, economic, and other support systems that foster an ecology conducive to triggering a process of sustained innovation that can support the ongoing

[4] Wallston, Scott, *Do Science Parks Generate Regional Economic Growth?* (March 2004) AEI-Brookings Joint Center: Washington.

introduction of new products and innovations into the market by tapping into the externalities generated by inter-firm networks and knowledge spillovers.

In order to translate the above ideas into concrete examples of regions that based their success on some form of the science city paradigm, four of the most well known centers of high-tech industry clusters were studied. Of course, the two most famous science cities, Silicon Valley and Boston-Route 128, were followed from their birth to the present. In addition, Metro Washington and Research Triangle Park were also studied.

In the birth and development of Research Triangle Park, when the initial meetings got under way to discuss the idea of a research park, the group did not look to Silicon Valley or Boston-Route 128 for guidance, as there was a folk wisdom that Route 128 and Stanford Research Park were not planned, but rather just happened, so there was no clear path to follow. This, of course, was a myth. Though there are certainly unique aspects to the rise of each one of the four science cities that cannot be transplanted to another region, there are many important features that each one shared, and can in fact be used to guide economic developers and policymakers in their own efforts to build science cities as a path to creating a dynamic regional economy. Six common characteristics appear to have been shared by the four studied science cities. They are not intended to be exhaustive. Instead, they do seem to have played a significant role in the birth and evolution of the science-based clusters that currently define these four regions. These six common characteristics are:

- The region faced a problem or crisis.
- An individual, or group of individuals, took the lead in trying to solve the problem or crisis.
- A local institution, or institutions, played a critical role in generating regional economic renewal.
- The region pursued an economic development strategy based on technology transfer and science-based growth (i.e., a knowledge economy).
- The region developed an ecology that fostered entrepreneurial activity.
- In the initial stages, regional inter-firm networks developed along the social network type of industry cluster.

What Has All This Got to Do with Connecticut? In the PowerPoint presentation of *Benchmarking Growth in Demand-Driven Labor Markets*, Point B, in Slide 7 ("Macro Effect on Local Economy") states:

> Excess supply of unemployed or underemployed labor in a region implies a demand for **entrepreneurs**!

That is what it all has to do with Connecticut. Connecticut has a shortage of science-based entrepreneurial activity! One thing that three of the four science cities had in common was their response to crisis in their regional economies.[5] Once the one or two industries that served as their economic base matured and declined, adopted a new generation of technology, or moved its

[5] Of course, the fourth, Silicon Valley rose up out of a "Greenfield;" that is, the Silicon Valley "science city" economy supplanted the agriculturally based economy that existed before it in Santa Clara County.

routine/standardized stages of production to lower-cost locations,[6] the regions were faced with abandoned plant and equipment (i.e., *derelict capital*), declines in per capita income and GDP, and ultimately population loss. In each case, their labor markets were suddenly confronted with an excess supply of labor and out-migration. But, as the above citation indicates, this implied that there was also an *excess demand* for entrepreneurs. A strong common thread running through the successful responses to crises by the above studied science cities is the building of their economic regeneration on an entrepreneurial-based foundation, fueled by science-based growth. The framework for science-based growth is Etzkowitz's *Triple Helix Model*: the university-industry-government nexus.

Connecticut's crisis was sparked by the end of the Cold War, when the State's economies[7] were faced with the collapse of the market for their principal export: defense goods. On the heels of this shock to the export base, another export mainstay, insurance services, was shifting its back-office functions out of Hartford to lower-cost regions, such as Omaha and Des Moines, as the industry began a massive re-structuring. The State's export base was shattered. As of 2006, no new economic driver has replaced the loss of defense-related manufacturing employment and the jobs at the more routine/standardized stages of insurance services production.[8] Consequently, save the securities, commodities, contracts industry (NAICS 523)[9] centered in Fairfield County, which is a satellite of, and benefits from, the New York City economy, Connecticut's economic fortunes are tied to coattail effects of the movements in the U.S. economy. Such an economy cannot "take its own economic fate in its hands," but instead is dependent on externally generated economic fortunes.

Further, Innovation Associates, in their report to the Technology Transfer and Commercialization Advisory Board pointed out that Connecticut had some drawbacks in its ability to foster technology transfer and commercialization, and an entrepreneurial climate, inside and outside its universities. Statewide infrastructure to support technology start-ups and entrepreneurial development in Connecticut appeared to be weaker than in some comparable states. Connecticut lacked comparable availability of start-up capital including pre-seed/seed capital funds and angel capital networks, networking of universities, industries, entrepreneurs, investors, and infrastructure including incubators and research parks in and around the universities. In addition, save some very recent developments at Yale University, the major universities do not have the depth and breath of entrepreneurial activities seen in several model universities, including a range of entrepreneurial courses, business competitions, mentoring programs, and networks.

To address the above concerns, three science cities are identified for Connecticut: one emerging and two potential. One science city is already in the process of developing in New Haven around Yale University. The remaining two identified centers have potential, but are not yet in the development stage. Hartford, around an expanded RPI-Hartford Campus, the UConn-Downtown Campus, and Capital Community College is the first potential science city. Storrs, centered

[6] In the case of Metro Washington, it was a sudden, tectonic shift in Federal policy that resulted in an abrupt excess supply of highly skilled labor.
[7] The use of the plural is intentional. There are, at least, three economies that are partially or wholly in the State.
[8] This is not to dismiss, or ignore, the casino jobs created by the tribal nations in New London County, but the leisure/tourism industry, for the most part, is not based on highly skilled, highly paid labor inputs to produce its "product." Most of the jobs created are semi- to low-skilled.
[9] Dyer, Lincoln, *Connecticut's Investment Employment Rising*, CONNECTICUT ECONOMIC DIGEST (March 2007) 12:3.

around the UConn Main Campus and a soon-to-be-constructed Mansfield-Storrs town center, is the other. In addition, UConn and RPI-Hartford could consider developing coop programs, such as those at the University of Cincinnati and Northeastern University in Boston.

Workforce investment and labor market information (LMI) play a critical role in meeting the challenges of Connecticut's economic future. The Worker Profiling and Re-Employment Program and the *Workforce Investment Act* are two workforce-based programs that can contribute significantly to an entrepreneurship-based strategy by using the workforce development pipeline as a resource for identifying potential entrepreneurs. Labor market resources can also play a critical role in assessing the performance of these strategies. LMI databases are an indispensable resource in the quantitative assessment and tracking of entrepreneurial and science-based economic development strategies.

Two existing programs already provide potential vehicles for fostering a workforce investment-based entrepreneurship strategy within a larger economic development framework: *Self-Employment Assistance* (SEA) under the Worker Profiling and Re-Employment Program and *Micro-Enterprise* through Individual Training Accounts (ITA) under the *Workforce Investment Act.* They provide two distinct paths to producing the needed supply of entrepreneurs in the State's economy. From the workforce development standpoint, tapping into the potential of existing programs could be the key to connecting workforce development to entrepreneurial activity and knowledge-based economic development. The SEA program under the Worker Profiling and Re-Employment program and the ITA's under the *Workforce Investment Act* (WIA) are programs and resources that could be more fully exploited to foster entrepreneurship and knowledge-based growth. Further, utilizing the potential for fostering the creation of micro-enterprise through SEA and ITA's could complement, and have potential synergies with, existing funding/early stage financing and training programs currently offered by Connecticut Innovations (CI) and the Connecticut Development Authority (CDA). In addition, there are private venture capital groups in Connecticut such as the Connecticut Venture Group,[10] which is a voluntary professional organization whose purpose is to connect leading venture investment professionals with high growth emerging companies, that could work in conjunction with the workforce development programs.

Implementing the above workforce-based entrepreneurial/micro-enterprise strategies would be within the stated goals of the State's 2005-2007 Workforce Investment Plan,[11] which does include entrepreneurship as a cornerstone in its economic development strategy. Four aspects of producing and retaining talent are presented:

1. Generating talent (building and fortifying the educational pipeline)
2. Sustaining talent (back-filling key skilled occupational shortage areas and retraining older workers for emerging jobs)
3. Advancing talent (addressing both sides of Connecticut's dual economy)
4. Using talent (***increasing academic R&D and "entrepreneurism" in Connecticut***)

[10] Their website can be accessed at: **http://www.cvg.org/entrepreneurzone.asp**
[11] State of Connecticut, STRATEGIC TWO-YEAR STATE WORKFORCE INVESTMENT PLAN FOR TITLE I OF THE WORKFORCE INVESTMENT ACT OF 1998 (WORKFORCE INVESTMENT SYSTEMS) AND THE WAGNER-PEYSER ACT for the Period of July 1, 2005 to June 30, 2007, p. 3.

Aspect 4, "using talent" is at the heart of the two-sided coin idea articulated in *Benchmarking Demand-Driven Growth*. That is, an excess supply of skilled labor implies an excess demand for entrepreneurs. Nevertheless, in practice, Connecticut's workforce programs have largely neglected the entrepreneurship option. Yet, it potentially could be an important policy tool for retaining unemployed, or underemployed, high-skilled workers and for creating new jobs. An important step toward achieving that goal is to provide the opportunity for highly skilled talent in Connecticut's labor force to pursue the entrepreneurship avenue not only as a means to re-employment, and thus "using talent," but to eventually get to the point where this utilized talent becomes a source of further job creation as their business start-ups expand. Further, the entrepreneurship outlet offers a way to keep an excess supply of highly skilled labor from out-migrating from the State, draining it of a critical economic resource. In the face of massive Federal layoffs, entrepreneurial opportunities were critical to tapping into the excess supply of high-skilled workers for first-generation start-ups in the development of the Biotech and Information and Communications Technology (ICT) clusters in the Metro Washington economy.

In *A Talent-Based Strategy to Keep Connecticut Competitive in the 21st Century*, Connecticut's Office of Workforce Competitiveness (OWC)[12] identifies three priorities in advancing a 21st century talent pipeline: (1.) Growing Talent, (2.) Using Talent, and (3.) Enriching Talent. To that end, State organizations are directed toward three corresponding areas of focus: (1.) Focus on 21st Century Careers, (2.) Focus on Business Innovation Services, and (3.) Focus on Workforce Investment. As in the WIP, "Using Talent" is one of the major action steps identified in the OWC report that the Governor and General Assembly have worked together on in the 2005 and 2006 legislative sessions.[13] The report notes that:

> Connecticut is also slipping in the utilization of its research and development base to support innovation.[14]

Finally, the important role of labor market information in assessing and tracking the progress of workforce-based entrepreneurial/knowledge-based policies and programs has been highlighted. Particularly, LMI databases are critical resources in the development of quantitative assessments and tracking of entrepreneurial and science-based economic development strategies. A good model to follow in the development of quantitative evaluation methods is that of the Advanced Technology Program of the U.S. Department of Commerce. The Advanced Technology Program has developed a set of evaluation criteria that uses data from the Quarterly Census of Employment and Wages (QCEW) database.

[12] Office of Workforce Competitiveness, "A Talent-Based Strategy to Keep Connecticut Competitive in the 21st Century", State of Connecticut (February 2007), p. 3.
[13] Ibid., p.10.
[14] Ibid., p.10.

I. INTRODUCTION AND PLAN OF APPROACH

Innovate or Relocate! So declares *Benchmarking Growth in Demand-Driven Labor Markets.* The upshot is that a regional economy that has lost the ability to re-invent itself will stagnate, and stagnation is just the transition period from growth to decline. This is the specter that confronts Connecticut's future if fundamental changes in the trajectory of the State's economy are not addressed. Outlining a strategy for changing the current trajectory is the motivation for the development of this follow-up to the benchmarking report. The report concludes that:

> The analysis indicates that Connecticut's level of creative market forces declined earlier and more sharply than similar measures for the U.S. If people "vote with their feet" and locate in an area where they can maximize expectations of future well being, then Connecticut can expect difficulty competing for young, educated workers with states experiencing more robust development. Attracting and retaining firms capable of generating wealth from outside the State requires improvements in education, transportation, availability of affordable housing, and investments in industries that have a strategic advantage in the world economy. Sustaining the State's ranking in per capita income into the next generation is not possible without an increase in the real returns of preschool through college education, particularly in developing the creative skills commonly associated with entrepreneurs and innovators. A review of the literature shows other states already increasing their investment levels not only to improve education, but also to improve the transportation infrastructure, to lower crime rates and to provide affordable housing.[1]

Four broad strategies are suggested for the kind of economic development that could maintain the State's high per capita ranking into the next generation:

1. Invest in education, from pre-school to post-secondary.
2. Invest in improvements to Connecticut's transportation systems.
3. Increase the supply of affordable housing.
4. Foster a workforce for Connecticut's high demand, high skill, and high growth careers, such as those in healthcare, finance, engineering, and teaching.

The challenge at hand is to develop and implement the necessary steps to translate the required remedial measures, as suggested by *Benchmarking Growth in Demand-Driven Labor Markets*, into specific policy actions. To that end, the focus of this strategy is based on the recent resurgence of interest in the regional economy, the role of entrepreneurial activity, and new firm formation, in generating local and regional economic growth and development as an ongoing process. Specifically: What are the policies and programs needed to foster the conditions that put a local/regional economy on the path to sustained innovation and re-invention? Critical to achieving such success is for the local/regional economy to tap into a locally available knowledge base and to create the environment needed for success, including facilitating access to early stage capital financing that encourages a high start-up rate of entrepreneurial-type, higher-risk firms that exploit science- and technology-based knowledge to introduce new products and

[1] McPherron, Patrick, "Benchmarking Growth In Demand-Driven Labor Markets – 2006" OCCASIONAL PAPER (December 2006) Office of Research, Connecticut Department of Labor: Wethersfield, CT, p. iii.

services into the market and to develop new process innovations for producing and distributing goods and services.

In the short to intermediate run (approximately two to five years), this implies a concentration of public policy efforts on establishing, or supporting, research and development (R&D) centers at, or within geographic proximity of, academic institutions engaged in fields of applied science and technology. In addition, public policy should encourage private, corporate R&D efforts to locate in spatial proximity to established, and emerging, or potential, academic research centers to take advantage of clustering, network economies, and knowledge spillovers (such as tacit information externalities). Further, cooperative education programs between research universities and new start-ups, as well as existing firms, should be instituted to not only provide the conduit for the transition from local college study to career at a local employer (or self-employment as a local start-up firm) of skilled workers and entrepreneurs, but, equally as important, to maintain the academic-business link to facilitate a sustainable dynamic; that is, to sustain an ongoing pipeline bringing new products and services to the market through research and innovation in local academic R&D labs.

In the long run (a decade or more), this implies a focus on insuring a locally/ regionally based, highly skilled labor supply. The specific policy focus to this end should be concentrated on targeting resources to grades K through 12 and, in particular, pre-school programs for disadvantaged children to significantly increase their odds of academic success. In a world of "footloose" capital and the need to constantly re-invent itself, a highly skilled labor force that is being continually replenished is the single-most critical asset for a region's economic viability.

From both the short and long run perspectives, three other policy initiatives are critical to Connecticut's efforts to ensure economic growth and vitality. The first two are specifically addressed by *Benchmarking Growth in Demand-Driven Labor Markets*: affordable housing and upgrading and expanding the transportation infrastructure (particularly the recommendations of the Transportation Strategy Board). In addition, a third challenge is also critical to Connecticut's economic future: low cost and reliable energy. Currently, the State is not competitive in this critical factor input to an R&D- and information-intensive economy.

To that end, this report presents a general framework for implementing a strategy of fostering an economic environment conducive to entrepreneurial activity and new firm formation that will produce a sustainable process whereby new products and services are continually introduced into the market. The key to this process is *Innovation* – the bridge between invention and the development and introduction of new products into the market.[2] A regional economy characterized by such a virtuous cycle of dynamic activity would be in a critical position to re-invent itself, and thus constantly adapt its export base to changes in the growth and mix of national and global demand. As the title of this paper suggests, such a region would have attained *sustained dynamism*.

The next section puts this report in context with recent work done on technology transfer and Connecticut's future economic prospects. Section III lays out a formal context for constructing a framework for a growth and development strategy. Section IV provides an operational definition of *sustainable dynamism*, which is grounded in the idea that such a set of economic conditions

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[2] Freeman, Chris and Luc Soete, THE ECONOMICS OF INDUSTRIAL INNOVATION (1997, 1999) MIT Press: Cambridge, Ch. 8, p. 200.

would characterize a region where *innovation* itself is its "leading product." The birth and evolution of four science cities, examined in Section V, suggests a framework, within a workforce investment context, for implementing a set of policies that would put Connecticut's regional economies on track to achieving sustainable dynamism. Section VI provides some concluding remarks.

II. REINVENTING THE WHEEL? The Connecticut Technology Transfer Report and the Current Findings

In lieu of the Connecticut technology transfer report, completed by Innovation Associates in October 2004 for the Technology Transfer and Commercialization Advisory Board of the Governor's Competitiveness Council,[3] it may seem that this report is an exercise in "reinventing the wheel." However, the very extensive and well-researched coverage of the nature of the "science cities"[4] investigated in the technology transfer report concentrated on the current, and recent, developments in these university-based economic growth centers. As such, it provided a snapshot, or point-in-time view, of those examples. Thus, this approach captured these university-based economies in their current stage of development. The results of the four case studies reported here (in Section IV) are based on a "motion-picture," or over-time, perspective as opposed to a "snapshot," or point-in-time, view. Each one of the science cities studied in the current report is followed from its beginnings to the present, providing a brief historical sketch, including the origins (as well as antecedent events that motivated the founding of each science city), evolution and transformation (including response to crises), and finally the current stage of the life cycle. The approach in this study asked and then sought to answer the question: How did the four case-study science cities get to their current, successful stage of development? Thus, the approaches by the two reports are complementary; the technology transfer report focused on the current, and recent past, entities, policies and programs that have characterized the successes of the example university-based centers (i.e., a cross-sectional—point-in-time—view), whereas the current report focuses on the birth, motivation, development and evolution, and current life cycle stage of the four case-studies (i.e., a history and development—over time—view). In addition, the current report focuses on the importance of spatial proximity in the transfer of technology at its early stages of development. Spatial proximity is a critical factor in creating an ecology that fosters invention and innovation, which plays a pivotal role in the birth and development of knowledge-based clusters.

Section A, below, summarizes some of the major findings and recommendations of the technology transfer report, and Section B explains how the current study complements the work previously done in the technology transfer report.

A. FINDINGS AND RECOMMENDATIONS OF THE TECHNOLOGY TRANSFER REPORT

The Technology Transfer and Commercialization Advisory Board of the Governor's Competitiveness Council contracted Innovation Associates (IA) to help it: (a) identify best practices employed by universities for causing effective, efficient and timely transfer of

[3] Innovation Associates, Inc., *Report to the Connecticut Technology Transfer and Commercialization Advisory Board of the Governor's Competitiveness Council* (October 2004)
[4] The definition and concept of a "science city" is explored in depth in Section IV.

technology and commercialization, and (b) articulate related recommended actions for consideration by the private, public and educational sectors. To this end IA, in conjunction with the Technology Transfer and Commercialization Advisory

Board, identified and selected 10 university-based models for study. The models selected were those that demonstrated significant technology transfer outcomes, exhibited qualities similar to Connecticut's universities, and focused on clusters targeted by Connecticut, particularly life sciences and information technology/software. Specifically, the study focused on those models that had similar disciplines and R&D expenditures as the major public university in the State, the University of Connecticut (UConn), and the major private university, Yale University, as well as other factors discussed more thoroughly in the report's introduction.

In addition, some models were sought that were particularly innovative or had exemplary qualities tied to commercialization such as strong university-industry collaboration, entrepreneurial programs, incubators or research parks, seed/pre-seed initiatives, and innovation centers. IA conducted on-site visits to most of the models. The exemplary universities selected were:

- Carnegie Mellon University (CMU),
- Georgia Institute of Technology (Georgia Tech),
- Massachusetts Institute of Technology (MIT),
- Purdue University (Purdue),
- Stanford University (Stanford),
- University of California, San Diego (UCSD),
- University of Pennsylvania (Penn),
- University of Wisconsin-Madison (UWM),
- Washington University (WU), and
- Cambridge University, United Kingdom (Cambridge).

The summary of lessons that follow were drawn from on-site and telephone interviews with technology transfer directors. In some cases, directors of entrepreneurial programs, sponsored research, incubators, and research parks at the 10 universities were also interviewed. In many cases, directors of associated programs such as innovation centers and seed capital programs also were interviewed.

IA's recommendations were based on successful initiatives from university-centered examples. Their recommendations were intended to leverage the strengths of Connecticut's resources and build on existing infrastructure. Those resources mainly involve Connecticut's university research. IA also pointed out that, in addition to infrastructure in and around its universities, the "infrastructure" in Connecticut, in part, involves activities by organizations such as Connecticut Innovations (CI), Connecticut Technology Council (CTC), CURE, Connecticut Venture Group (CVG), Connecticut Economic Resource Center (CERC), and others that provide a base upon which to build future initiatives. Since IA did not conduct a formal assessment or evaluation of Connecticut's strengths and weaknesses, they drew from interviews with top officials at UConn and Yale, heads of organizations such as CI, CTC, CURE, CVG, and individual Advisory Board members including high-level representatives of major corporations, venture capital firms, and government. IA also drew from previous work conducted by Battelle, Ashland, and others.

The report notes Connecticut's impressive science and technology resources that include Yale and UConn as well as major research corporations, strong financial and insurance companies, and manufacturing industries. In addition, smaller universities and community colleges have an increasing interest in playing a role in technology-based economic development, particularly ***regarding entrepreneurial and workforce development.*** Yale's impressive track record in technology transfer and commercialization place it in the top quartile of new and active licenses. Its R&D expenditures are among the top in the country and it is one of the highest recipients of Federal funding, particularly NIH funding. President Levin of Yale has set into motion local economic development initiatives and has shown support for technology development in and around the University. UConn's technology transfer and commercialization activities are relatively new and growing stronger. UConn also has started a strategic process to target its research strengths that, if carried forward, should lead to a stronger R&D base that provides the pipeline for commercialization. In addition to Yale and UConn, IA cited a then-recent survey which revealed that several other Connecticut universities and community colleges were conducting activities with industry; some were engaging in technology transfer, some had entrepreneurship programs, and many had faculty who provided consulting to industry.

At the time of the report, Connecticut's industries represented the top 16 patenting organizations in the State. These corporations represent an enormous resource for the State and their role in creating new enterprises is essential to the State's ability to sustain and grow a technology-based economy. Therefore, it is critical for the State to involve corporations in development and implementation of technology strategies as well as support and facilitate R&D activities in these corporations. This support includes stimulating university-industry collaboration, facilitating technology transfer that is mutually beneficial to all participating parties, and building an infrastructure conducive to attracting and retaining entrepreneurs and high wage employees, including improvement of the inner cities. Attracting and retaining R&D industries also involves supplying those industries, now and in the future, with an educated workforce. Although workforce development was not part of this study, strong support for education from K-12 to vocational education and associate degree programs to graduate scientific and engineering programs, is the pillar of R&D corporate attraction and retention. Recommendations from studies being conducted by the Office of Workforce Competitiveness go hand-in-hand with recommendations from this study on technology transfer and commercialization.

IA then pointed out that Connecticut had some drawbacks in its ability to foster technology transfer and commercialization, and an entrepreneurial climate, inside and outside its universities. Statewide infrastructure to support technology start-ups and entrepreneurial development in Connecticut appeared to be weaker than in some comparable states. Connecticut lacked comparable availability of start-up capital including pre-seed/seed capital funds and angel capital networks, networking of universities, industries, entrepreneurs, investors, and infrastructure including incubators and research parks in and around the universities. In addition, the major universities do not have the depth and breath of entrepreneurial activities seen in several model universities, including a range of entrepreneurial courses, business competitions, mentoring programs, and networks.

These activities in model universities add value to technology transfer efforts, particularly aimed at launching start-ups. Moreover, major universities in Connecticut are at a disadvantage in creating and retaining start-ups, and executing licenses to local firms, "*because environments around the universities, while vastly improving, are not yet at the point of being attractive to many entrepreneurs.*"[5] This was compounded by the unavailability of local early stage capital, and incubation and commercial space, which was not yet comparable to that found in and around model universities. In addition to weaker entrepreneurial foci, major Connecticut universities did not involve corporations to the same extent as several model universities or to promote the same type of corporate friendly environment. In addition, Connecticut lacked a major focal point for its technology transfer and commercialization activities. As IA noted, many states have developed innovation centers or similar initiatives, often affiliated with universities that provide a focus for their technology transfer activities. These centers usually combine many of the technology transfer components now lacking in the State – funds to attract academic stars, pre-seed/seed capital, business assistance, mentoring, networking, and linkages to service providers. An innovation center focused on a major cluster could provide a rallying point for the State. In addition, pre-seed/seed capital funds targeted to university technology transfer activities, as well as enhanced entrepreneurship programs and infrastructure might boost start-ups. IA also suggested that university strategies to target R&D strengths and more actively involve the private sector also could facilitate sponsored research and commercialization activities.

IA presented their recommendations in three major groups:

a) State policy makers and statewide organizations,
b) Private sector, and
c) Universities.

However, many of these recommendations were relevant to more than one group. The recommendations were not necessarily presented in order of importance within each group. They are as follows:[6]

STATE POLICYMAKERS/STATEWIDE ORGANIZATIONS

- Develop an action plan and engage bipartisan support for the plan
- Initiate aggressive courting of Federal funds to support targeted initiatives
- Explore development of an innovation center
- Increase seed and "pre-seed" capital
- Enhance angel capital networks
- Pro-actively court venture capitalists
- Enhance networking capacity
- Celebrate entrepreneurial success
- Educate policy makers to "talk the talk" and "walk the walk"
- Create permanent Technology Transfer Advisory Board

[5] Innovation Associates, Inc., "Report to the Connecticut Technology Transfer and Commercialization Advisory Board of the Governor's Competitiveness Council" (October 2004), p 137.
[6] For a detailed discussion of each one of the recommendations, see IA's report to The Technology Transfer and Commercialization Advisory Board, of the Governor's Competitiveness Council pp. 138-147.

- Enhance transportation infrastructure and revitalization efforts in New Haven

PRIVATE SECTOR

- Improve understanding by Connecticut industry
- Enhance industry's role on university advisory committees
- Test a pilot technology donation program
- Increase corporate endowment of university chairs
- Augment mentoring
- Structure sponsored research to promote desired R&D direction

UNIVERSITIES

- Identify and target strategic areas for aggressive R&D development at UConn
- Encourage collaborative R&D between Yale and UConn and regional universities
- Assess and implement means to increase and retain start-ups
- Champion the universities' entrepreneurial successes
- Enhance entrepreneurial development activities at UConn and Yale
- Institute an entrepreneurship "Boot Camp"
- Implement "It's Time to Come Home" campaign
- Enhance incubation capacity at UConn and Yale
- Conduct feasibility study for a UConn Research Park
- Increase support for Yale Science Park
- Assess rewards and incentives at major universities
- Identify and market a single point of entry for industry at UConn
- Mine alumni rosters for potential angels and mentors
- Create a centralized research database for UConn
- Increase promotion of technology transfer at UConn
- Provide tech transfer assistance to small universities and colleges

B. THE CURRENT FINDINGS: A Complement to the Technology Transfer Study

The findings and recommendations of the technology transfer report summarized in Part A clearly show what features those successful, university-based economic development centers seem to share. The Innovation Associates report offers some valuable recommendations on how the State's resources could be focused on developing centers of entrepreneurship, innovation, and technology transfer in order to foster knowledge-based economic development. However, some questions about the nature of these successful university-based economic development models are still left unanswered. How did these successful university-based centers of entrepreneurship and innovation come about? How did they get to the stage of development in which IA considered them a model? What are their origins? A fully functioning, and successful, knowledge-based, dynamic regional economy does not just drop out of the sky one day. There was a path that it followed from its inception to its birth, to its evolution and development to a successful, dynamic economy that is capable of continuous creation of wealth and jobs. Some of this path was thought out and planned; some was the result of unforeseen events beyond anybody's control, such as luck and serendipity, or shifts in national and international economic forces beyond the boundaries of the local and regional economy.

In addition to the focus on the birth, development, and life cycle features of university-centered technology transfer as an engine of regional economic growth, the current report also focuses on the critical role that spatial proximity plays in the transfer of knowledge and innovation.

What follows seeks to answer the questions concerning how successful science cities come about, and to highlight the importance of the spatial component to any knowledge-based mechanism as a driver of regional economic growth and development. As such, it is hoped that this report will be not only the follow-up to *Benchmarking Growth in Demand-Driven Labor Markets*, but also a complement to the technology transfer report.

III. A FORMAL CONTEXT FOR A GROWTH AND DEVELOPMENT STRATEGY

This section develops the formal context for implementing the policies and programs that will address the issues and challenges identified in *Benchmarking Growth in Demand-Driven Labor Markets*. The first step to developing a framework is to briefly review developments in growth theory in the Post-World War II (WW II) era. Following Audretsch, Keibach, and Lehmann (2006), the discussion below partitions the Post-WW II era into three historical periods: (1.) Technology as Exogenous: The Solow Model, (2.) Technology as Endogenous: The Romer-Lucas Model, and (3.) the Entrepreneurial Economy.[7] Central to the approach presented here is the treatment of technology and knowledge by each of the three growth paradigms and their implications about the changing role of the entrepreneur and the exploitation of knowledge for the development and introduction of new products and services into the market. Before proceeding, it seems appropriate to provide precise definitions of the terms "technology" and "innovation."

> ***Technology*** is defined as:
> The sets of *production, organization, information,* and *communications blueprints*, which are available to all firms, and which mediate the relationship between the input factors employed and the output produced.[8]
>
> ***Innovation*** is defined as:
> …the adoption and implementation of new production techniques and technologies.[9]

[7] This approach follows Audretsch, David B., Max C. Keilbach, and Erik E. Lehmann, ENTREPRENEURSHIP AND ECONOMIC GROWTH (2006) Oxford University Press: New York, Ch. 2.
[8] McCann, Philip, URBAN AND REGIONAL ECONOMICS (2001) Oxford University Press: New York, p. 222.
[9] McCann, p. 222.

The initial motivation for the development of growth theory after WW II was the neoclassical response to the Harrod-Domar growth model developed in the 1930's.[10] The Harrod-Domar model is briefly summarized below (for a more rigorous and detailed presentation of the Harrod-Domar model, see Volume II of this report).

According to the Harrod-Domar model there are three critical concepts related to growth:[11]

1. *Warranted growth* – the rate of output growth at which firms believe they have the correct amount of capital and therefore do not increase or decrease investment, given expectations of future demand.
2. *Natural rate of growth* – The rate at which the labor force expands; a larger labor force generally means a larger aggregate output.
3. *Actual growth* – The actual aggregate output change.

There are two possible problems that are observed in the economy: First, the relationship between the actual and natural (population) growth rates can cause disparities between the two, as factors that determine actual growth are separate from those that determine natural growth. Factors such as birth control, culture, and general tastes determine the natural growth rate. However, other affects such as the marginal propensities to save and consume influence actual output. There is no guarantee that an economy will achieve sufficient output growth to sustain full employment in a context of population growth.

The second problem identified in the model is the relationship between actual and warranted growth. If it is expected that output will grow, investment will increase to meet the extra demand. The problem arises when actual growth either exceeds or falls short of warranted growth expectations. A vicious cycle can be created where the difference is exaggerated by attempts to meet the actual demand, causing economic instability.

The Harrod-Domar model was initially created to help analyze the business cycle; however, it was later adapted to explain economic growth. Its implications were that growth depends on the quantity of labor and capital, and that more investment leads to capital accumulation, which generates economic growth. The model also had implications for developing countries. Labor is in plentiful supply in these countries, but physical capital is not; the result is slow economic progress. Developing countries do not have sufficient average incomes to enable high rates of saving, and therefore accumulation of the capital stock through investment is low.

Major conclusions:

- Economic growth depends on policies to increase saving (investment), and using that investment more efficiently through technological advances.
- An economy does not find full employment and stable growth rates naturally, similar to Keynesian Theory.

[10] The Neoclassical growth models presented in this section, and sections III-V and VII of Volume II, are predicated on the concept of the ***Production Function***. Those not familiar with this concept can refer to Appendix A, and Section I, of Volume II, for a brief introduction to this idea.

[11] This summary is based on the entry appearing in the online encyclopedia, Wikipedia, Harrod, R. F. (1939), An Essay in Dynamic Theory, ECONOMIC JOURNAL, Vol. 49, No. 1 and Domar, D. (1946), Capital Expansion, Rate of Growth and Employment, ECONOMETRICA, Vol. 14.

Thus, equilibrium in the Harrod-Domar model is a *razor-edge* equilibrium. If the economy deviates in any direction, the result is instability.

A. TECHNOLOGY AS EXOGENOUS: The Solow Economy[12]

The first period of the post-WW II era can be characterized as the "Solow Economy." Robert Solow's 1956 article was largely addressed to the pessimism about full employment growth built into the Harrod-Domar growth model (see above). Solow's work changed the approach that economists took to study growth. From that point on, the production-function model has been the basis for explaining the determinants of economic growth. The production-function approach relates measures representing two fundamental factors of production:

1. Physical Capital
2. Unskilled Labor[13]

These two fundamental factor inputs were used as the basis for explaining variations in growth rates over time in a single country, or across countries in a cross-sectional context. The *unexplained residual*, which typically accounted for a large share of the unexplained variance in growth rates, was attributed to ***technological change.***[14] Solow acknowledged that technical change contributed to economic growth, but in terms of the formal model, it was considered "manna from heaven."

Since the mid-1950's, research into the causes of growth have been based on the neoclassical formulation and has led to the development of various forms of the production function. Many such models assume that technological advance is embodied in new capital. Much of the empirical work has been guided by the ***growth-accounting*** framework, which is implicit in the neoclassical model, and econometrically links two factor inputs, *physical capital* and *labor*, to growth rates. Guided by the Solow growth model, economic growth policy, in many instances, sought to encourage investment in physical capital as the key to generating economic growth and increases in labor productivity.

Within the regional context, as far as accounting for technological change, the growth-accounting framework states that the growth in regional output, over time, is the sum of the rates of growth of the factor inputs (capital and labor), weighted according to their relative contributions to the economy, plus the level of technology. In growth-accounting terms, the level of technology represents the contributions to regional growth that cannot be accounted for simply by changes in the optimally combined stocks of capital and labor. This unaccounted for contribution is the *Solow Residual*, discussed above, which is also referred to as the *Growth of Total* (or *Multifactor*) *Productivity*.

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[12] The remainder of this section is based on Audretsch, David B., Max C. Keilbach, and Erik E. Lehmann, ENTREPRENEURSHIP AND ECONOMIC GROWTH (2006) Oxford University Press: New York, Chapter 2, and McCann, Philip, URBAN AND REGIONAL ECONOMICS (2001) Oxford University Press, Chapter 6, R.M. Solow (1956) A Contribution to the Theory of Economic Growth, QUARTERLY JOURNAL OF ECONOMICS. Vol. 70 (1) pp. 65-94, and Solow, R.M. (1987) GROWTH THEORY: An Exposition, Oxford University Press: N.Y.

[13] Economists refer to a labor-input that is composed of one type only such as unskilled as "homogenous."

[14] For a more detailed and rigorous presentation on the Solow Growth Model, Section IV, Volume II.

B. LIMITATIONS OF THE SOLOW MODEL

Within the growth-accounting framework, neoclassical regional growth depends on changes in the regional factor stocks and the level of regional technology. If factors are mobile, then there can be no systematic, long-run differences in the growth rates of factors across regions. Observed growth differences due to differences in regional stocks can only be short-run or, at most, medium-term adjustments to a Pareto-efficient factor allocation (i.e., allocative efficiency). However, the growth-accounting approach does suggest that different regions may have longer-term differences in their growth rates based on systematic differences in their levels of technology. Importantly, technological differences may be related to geography, particularly since there is a general consensus that, in reality, the application of new technology across all firms, industries, and regions is not an instantaneous process, as is assumed in the perfect competition model.

Also contrary to the perfect competition model, the cumulative diffusion of technology over time tends to exhibit an S-shaped form, where ***technology diffusion*** is defined as the time taken for a particular invention or innovation to be adopted across all firms, sectors, or regions.[15] The process is such that the rate of technology diffusion is initially very low, although it is gradually increasing. After a while, the rate of technology diffusion reaches its maximum, after which it begins to slow. Eventually, a given generation of technology will have been spread throughout all firms, sectors, and regions, such that the rate of additional technology diffusion approaches zero.

The central assumptions of the neoclassical model imply that in an environment of perfectly competitive markets and factor mobility, the level of technology will be disbursed through all sectors and all regions in the economy instantaneously. Consequently, there will be no systematic long-run differences in technology across regions and the growth benefits of new technology will be maximized across all regions. This, of course, contradicts the results implied by the theory of agglomeration, which suggests that growth possibilities may vary across regions based on persistent differences in the spatial distribution of human capital.[16]

There have been some relatively recent analytical developments in production-function analysis that attempt to reconcile localized growth with neoclassical competitive market conditions. These various developments are generally subsumed under the heading of *New Growth Theory* or *Endogenous Growth Theory*. These theories are introduced below in the next section, and in more detail in Volume II of this report.

C. TECHNOLOGY AS ENDOGENOUS: The Romer-Lucas Economy

First proposed by Romer in 1986, with a follow-up in 1987[17], ***Endogenous Growth Theory*** maintained the orthodox neoclassical growth-accounting framework, but dispensed with the need for an exogenous technology residual. Romer's two models are summarized as follows:

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[15] McCann, p. 224.
[16] McCann, p. 225-26.
[17] Romer, P. M., Increasing Returns and Long-Run Growth, JOURNAL OF POLITICAL ECONOMY (1986) (94): 1002-37 and Growth Based on Increasing Returns Due to Specialization, AMERICAN ECONOMIC REVIEW (1987) (77.2): 56-62.

1. The first approach (1986) assumes that increasing specialization increases output and, as such, output is defined as a function of the number of *specialized capital goods*, rather than simply as an aggregate capital stock.
2. In the second approach (1987), the source of endogenous growth: is the *stock of knowledge*.

Both of Romer's models conclude that the portion of output growth that would be considered as the technology residual in the neoclassical model can be attributed entirely to *capital acquisition.* In terms of Romer's first model, the *specialized capital stock*, knowledge growth is assumed to increase with the number of units of *specialized capital goods*. In terms of Romer's second model, the *stock of knowledge*, it is assumed that knowledge increases with the level of *capital inputs*.

In 1988, Lucas[18] also proposed an endogenous growth model based on knowledge inputs. However, unlike Romer's focus on firm-specific capital, Lucas's model is based on the *level of human capital*. According to the Lucas model, the portion of output attributed to the technology residual in the neoclassical growth model should actually be attributed entirely to labor through human capital acquisition. Both the Romer and Lucas endogenous growth models are treated in much more detail in Volume II of this report. The neoclassical model's focus on capital and labor as the primary explicit factors of production, and the general exclusion or trivialization of the role of knowledge, was not limited to macroeconomic growth theory. The most widely accepted theories of regional and international trade were based on capital and labor, and frequently land as well. In fact, trade theory was the first instance where empirical research revealed the inadequacy of the three traditional arguments in the production function, as formulated within the neoclassical model, in explaining observed economic phenomena.[19] According to Heckscher-Ohlin theory, the proportion of production factors determines trade structure; that is, a country, or a region, with an abundance of physical capital, relative to labor, will tend toward the export of capital-intensive goods. However, the findings of Wassily Leontief for the U.S. economy contradicted the prediction of Heckscher-Ohlin. This finding is known as the *Leontief Paradox.* Leontief found that the U.S. *exported* labor-intensive goods, implying that the U.S. had the comparative advantage in (unskilled) labor-intensive goods, and *not* capital-intensive goods.[20]

In an effort to resolve the Loentief Paradox, economists began shifting the perspective of the model from an exclusive focus on the factor inputs of capital and labor to including extensions based on various aspects of knowledge: *human capital and skilled labor*, and *technology*. The neo-technology theories focused on the role of R&D and the creation of new economic knowledge in shaping the comparative advantage and flows of foreign direct investment. Gruber, Mehta, and Vernon (1967) suggested that R&D expenditures reflect a temporary comparative advantage resulting from products and production techniques that have not yet been adopted by foreign competitors. Recently, Gomory and Baumol (2003) took this further and introduced the ideas of *acquired comparative advantage* and the ability for a region or nation to maintain that

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[18] Lucas, R. E., *On the Mechanics of Economic Development*, JOURNAL OF MONETARY ECONOMICS (1988) (22): 3-42.
[19] Audretsch et al, pp. 16-17.
[20] Leontief, Wassily, and reprinted in Leontief, Wassily, INPUT/OUTPUT ECONOMICS, 2nd Ed. (1986) W.W. Norton: New York, Ch. 2.

acquired comparative advantage: *retainability*. The relatively high R&D component, and successful retainability, give firms in the developed world their acquired comparative advantage.

The human skills hypothesis extended the Heckscher-Ohlin theory by including *human capital* as a third factor of production. It was found that regions and countries with a labor force that had a relatively high level of human capital tended to export human capital-intensive goods; that is, countries and regions with an abundance of skilled labor tended to export skill-intensive goods.

As trade theory began to incorporate input factors reflecting knowledge, technology, R&D, skills, and human capital into more realistic models, growth theory, as pointed out above, also began including various representations of knowledge as an explicit, and even endogenous, factor input generating growth. When Romer (1986) and Lucas (1988) formally introduced knowledge into macroeconomic growth models, their criticism of Solow's growth model was not based on the neoclassical production function itself, but with what they thought he had omitted from that model: knowledge. Romer, Lucas, and others argued that knowledge was an important factor of production, along with the other traditional factor inputs: capital, labor, and land. Further, because it was endogenously determined as a result of externalities and spillovers, it was particularly crucial[21].

However, in the most prevalent model found in the literature of technological change, firms exist exogenously and then engage in the pursuit of new economic knowledge as an input to the process of generating innovative activity. The most decisive input in the knowledge production function is new economic knowledge.

Since Griliches (1979), there have been a number of empirical studies done to test the knowledge production function. These studies all confronted numerous measurement issues surrounding the challenges to quantifying knowledge inputs and innovative output. Some solutions for measuring innovative output included counting the number of patented inventions, new product introductions, the share of sales accounted for by new products, productivity growth, and export performance[22].

Proxies were developed for firm specific investments in new economic knowledge, which included such measurements as R&D expenditures and human capital as key inputs that yield a high innovative output.

Cohen and Levinthal (1989) found that firms that had developed the capacity to adapt new technology and ideas developed in other firms were those that made firm-specific investments in knowledge and R&D expenditures, which gave them the capacity to absorb external knowledge. This key insight implied that by investing in R&D, firms could develop the absorptive capacity to appropriate at least some of the returns accruing to investments in new knowledge made external to the firm. This insight into the empirical evidence strengthened the assumption underlying the knowledge production-function model.

The evidence supporting the link between knowledge inputs and innovative output appears to become stronger as the unit of aggregation becomes larger. At the industry level, the link between R&D and innovative output, as measured by number of patents, or new product innovations, shows that those industries that are the most R&D intensive, such as computers,

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21 Audretsch, et al (2006), p. 18.
22 Ibid., p.18.

instruments, and pharmaceuticals, are the most innovative. Also, much of the industrial organization literature has shown that innovation tends to take place in industries with capital-intensive firms such as the chemical industry, pharmaceuticals, and instruments.[23] Thus, empirical evidence and theoretical models supported the view that, as in the Solow economy, large-scale firms would have at least as much advantage over small firms in a knowledge economy[24] This seemed especially true when it came to the scale of investment in R&D required, certainly in absolute terms, to reap the returns from knowledge-generated product innovation.

A fundamental implication emerging from the models of endogenous growth was that higher economic growth rates could be obtained through knowledge investments. This focused policy on university research, technology investments, and promoting human capital investment in the 1990's.

D. THE ENTREPRENEURIAL ECONOMY

The recent emergence of entrepreneurship was first identified in job reallocation studies. In 1981, Birch first revealed the importance of the role of small firms in job creation in his long-term study of U.S. job generation. However, Birch's study overstated the importance of smaller firms in the creation of jobs, and in their landmark research *Job Creation and Destruction* in 1996, Davis, Haltiwanger, and Schuh corrected for the size class, or regression-to-the-mean, fallacy inherent in Birch's results. While their quantitative results differed from those of Birch (i.e., small firms *do not* create *most* of the new jobs in the economy), they did find that small firms accounted for more than their share of new employment in the U.S. manufacturing sector between 1972 and 1988[25]. The reversal of the trend from large enterprises to the re-emergence of small firms was not limited to the U.S. A similar trend was found in Europe as well. As mounting empirical evidence revealed the re-emergence of entrepreneurship as a significant trend in the economy, researchers and economists began searching for explanations and developing theories to account for this phenomenon. Audretsch et al. (2006) report six hypotheses that formed the basis for early explanations.[26]

1. Technological change had reduced the extent of scale economies in manufacturing.
2. Increased globalization had rendered markets more volatile as a result of competition from a greater number of foreign rivals.
3. The changing composition of the labor force toward a greater participation of women, immigrants, and young and old workers, may be more conducive to smaller, rather than larger, enterprises due to the greater premium placed on work flexibility.
4. A proliferation of the trend in consumer tastes away from standardized, mass-produced goods toward stylized and personalized products facilitates small niche producers.
5. Deregulation and privatization facilitate the entry of new and small firms into markets that were previously protected and inaccessible.

[23] Freeman, Chris and Luc Soete, THE ECONOMICS OF INDUSTRIAL INNOVATION (1997, 1999) MIT Press: Cambridge, Ch. 4.
[24] Audretsch et al (2006), p.19
[25] Ibid., pp. 24-25 and Davis, Haltiwanger, and Schuh (1996) pp. 62-64.
[26] The six hypotheses reported by Audretsch et al. (2006, p. 26) were developed by Brock and Evans (1989).

6. The increased importance of innovation in high wage countries has reduced the relative importance of large-scale production and, thus, fostered the importance of entrepreneurial activity.

Confronted with lower cost competition in foreign locations, large-scale producers in high cost locations lost their competitiveness. Producers in high cost locations have four options, apart from doing nothing and losing global market share[27]:

1. Reduce wages and other production costs sufficiently to compete with low cost foreign producers.
2. Substitute equipment and technology for labor to increase productivity.
3. Shift production out of the high-cost location and into a low-cost location.
4. Outsource the production of inputs to third-party firms, typically located in lower-cost locations.

Pressed to maintain competitiveness in traditional low- and moderate-technology industries, where economic activity can be easily transferred across geographic space to access lower production costs, large corporations throughout the OECD countries deployed two strategic responses: First, offset greater wage differentials between North America and Europe and low-cost locations by increasing productivity through substitution of technology and capital for labor. Second, locate new plants and establishments in a lower-cost location through outward foreign direct investment, outsourcing, or both.

Much of the policy debate responding to job displacement resulting from the latest round of globalization has revolved around a perceived trade-off between maintaining higher wages but at the expense of greater unemployment, or higher levels of employment, but with lower wages. Audretsch et al. (2006) argue that there is an alternative. This alternative involves shifting economic activity out of the traditional industries where the high-cost regions and countries of North America and Europe have lost the competitive advantage into those industries where the comparative advantage is compatible with both high wages *and* high levels of employment: *knowledge-based economic activity.*

This has implications for the regional economy. As long as corporations were physically tied to their regional location by substantial sunk costs, such as capital investment, the competitiveness of a region was identical to the competitiveness of the corporations located in that region. The re-globalization process[28] has not only reduced the degree to which the traditional factor inputs of capital and labor are sunk, but also shifted the comparative advantage in the high wage countries of North America and Europe towards knowledge-based economic activity, while corporations in traditional industries have shifted production to lower cost locations. The response of planners

[27] Ibid., p.26.

[28] The term "re-globalization" is used here rather than globalization. The world economy has reached this point before. World trade increased dramatically from the last half of the 19th Century to the early part of the 20th Century. It all ended abruptly in 1914 [although the U.S. benefited from 1914 to 1917 (when it entered the War), as it traded with both, the nations of the Allied and Central powers]. Trade recovered after World War I, but once again, was ended. This time by the retaliatory tariffs implemented by nations as a misguided response to the fall in commodity and agricultural prices throughout the last half of the 1920's leading up to the Great Depression. For instance, see Sachs, Jeffery and Andrew Warner, *Economic Reform and the Process of Global Integration* (1995) BROOKINGS PAPERS ON ECONOMIC ACTIVITY.

and policymakers has been the development of the *strategic management of regions*. Since regions, unlike corporations, cannot change the location of production, the focus has been on the development and enhancement of those factors of production that cannot be transferred across geographic space at low cost. The principal factors of focus have been knowledge and ideas.

The question still remains as to why a shift to a knowledge-based economy should imply a more pronounced role for entrepreneurship. It is particularly perplexing given that the evidence indicates that new economic knowledge is conceptually and econometrically linked to investments in human capital, university research, and R&D, and that they are essential ingredients into firm innovation. In fact, Acs and Audretsch (1990) and Freeman and Soete (1997, 1999) showed that innovative U.S. firms tend to be arge corporations. At first glance, this would seem to confirm the conventional interpretation of the knowledge production-function model. However, in the most innovative industries, it was large firms (500 or more employees) that contributed the most innovations in some industries, but smaller firms that contributed the most in other industries. For instance, small firms accounted for most of the innovations in computers and process-control industries; however, large firms produced more innovations in pharmaceutical and aircraft industries.[29]

However, standardized measures of innovation paint a different picture When innovation *rates* are compared (e.g., per 1,000 employees) rather than the total numbers, it turns out that smaller firms in manufacturing have a higher rate of innovation than larger firms.[30] Where do small firms with little or no R&D get the knowledge inputs? A clue from the new economic geography literature is that these knowledge spillovers come from other, third party firms or research institutions, such as universities, that may be located within spatial proximity. What are the mechanisms that translate the spillovers from the R&D labs of universities and large corporations to the small firms that commercialize that knowledge? Audretsch et al (2006) identify at least two channels reported in the literature; both of these spillover mechanisms involve the appropriation of new knowledge[31]:

1. Firms develop the capacity to adapt new technology and ideas developed in other firms and are therefore able to appropriate some of the returns accruing to investments made in new knowledge made externally. Small firms are too constrained by size to make sufficient investments in generating new knowledge instead, they must access knowledge essential for innovation by way of networks, linkages, and other types of spillover conduits.
2. Another view proposes inverting the model of the knowledge production of the function. The conventional approach assumes that the firm exists exogenously and then, if large, undertakes the necessary investments, or if small, engages in strategic alliances, to endogenously create the knowledge required to innovate. The "inverted" model assumes that knowledge is exogenous. New and potentially valuable knowledge does not exist abstractly "in the firm;" it is embodied in people, either in individuals or in groups or teams of individuals.

[29] Audretsch et al (2006), p. 29 and Freeman and Soete (1997, 1999), Ch. 9.
[30] However, caution must be exercised in inferring this result to non-manufacturing. Also, although their conclusions are based on earlier research, Freeman and Soete point out some qualifications to this result (Ch. 9).
[31] Audretsch (2006), p. 30.

Such new knowledge is inherently uncertain, asymmetric, and involves high transaction costs (Arrow, 1962). Because of the fundamental characteristics inherent in new ideas, what one individual thinks is a potentially valuable idea may not be valued so highly by the decision-makers of his or her firm. Such divergences in the valuation of new ideas are even more likely to result if the new knowledge is not compatible with the firm's core competence or consistent with the firm's technological trajectory. A divergence in the valuation of an idea between an individual worker, or team of knowledge workers, and the decision-making hierarchy of an incumbent firm forces the individual knowledge worker, or team of knowledge workers, to either ignore the idea and redirect their activities and work in a direction more compatible with the organization's goals, or appropriate the value of the new idea within an organizational context outside the framework of the incumbent firm by leaving that organization and starting a new firm.[32]

TABLE 1: Three Stages in an Industry's Life Cycle

STAGE	VOLUME	RISK/UNCERTAINTY	CHARATERISTICS
Early Exploratory Stage	Low	High degree of uncertainty due to limited experience	• Supply of a new product of a relatively primitive design • Manufactured on comparatively specialized machinery • Marketed through a variety of exploratory techniques
Intermediate Development Stage	Growing rapidly	High, but declining, degree of uncertainty (Uncertainty gives way to risk)	• More refined manufacturing techniques • Market definition is sharpened • Output grows rapidly in response to: o Newly recognized applications o Unsatisfied market demands
Mature Stage	High, but slow, or no, growth	More predictable	• Management, manufacturing, and marketing reach advanced degree of refinement. • Markets grow at a more regular and predictable rate. • Established supplier/customer connections buffer changes and protect market shares. • Innovations are fewer and incremental.

SOURCE: Audretsch et al. (2006), p. 31-32 and Williamson (1975), p. 122.

[32] A dramatic example of such an outcome is discussed below. When confronted with just such a dilemma, the "Traitorous Eight" left Schockly Semiconductor and founded Fairchild Semiconductor.

Why would an incumbent firm be resistant to deviating from its core competence or strategic trajectory? Audretsch et al (2006) suggest that the answer lies in the industry-product life cycle. As an industry evolves over its life cycle, the cost of radical innovation tends to increase relative to the cost of incremental innovation and imitation. Thus, diminishing returns to radical innovative activity set in. This is not the case for incremental innovation, and especially, imitation. An implication is that it requires an increasing amount of R&D effort to generate a given amount of innovative activity as an industry matures over its life cycle. To see this, it will be helpful to briefly look at the implications of the idea of an "industry-product life cycle."

The *Industry Life-Cycle Theory* (Vernon, 1966) typically links trade and foreign direct investment with the stage of the life cycle, with no direct implications about radical versus incremental innovations, and few implications for entrepreneurship. However, Audretsch et al. (2006, p. 31) argue that a different interpretation of the life cycle framework suggests that the relative importance of radical versus incremental innovations is shaped by the industry life cycle. There are many versions of the industry life cycle. One suggested by Williamson is depicted in Table 1.

Though not stated explicitly by Vernon (1966) or Williamson (1975), Audretsch et al. (2006, p.32) connect the role of R&D with the industry life cycle and observe that it is not constant over the industry life cycle. In the early stages of the life cycle, R&D tends to be highly productive so that there are increasing returns to R&D. This would be the "Early Exploratory Stage" in Table 1. In fact, radical innovation tends to spawn new industries. In addition, the costs of radical innovation tend to be relatively high, while the costs of incremental innovation and imitation tend to be relatively low. Because innovation in newly emerging industries tends to be more radical and less incremental, it is more costly to diffuse it across geographic space for economic application in lower-cost locations. As discussed above, as an industry evolves over the life cycle to the "Intermediate Development Stage," the cost of radical innovation tends to increase relative to the cost of incremental innovation and imitation.

As an industry progresses to the "Mature Stage," the amount of R&D effort to generate a given amount of innovative activity increases while the amount of R&D expenditures to transfer new technology to lower-cost locations decreases, and innovation activity tends to become less radical and more incremental. Thus, information generated by R&D in mature industries can be transferred to lower-cost locations for economic commercialization.

The comparative advantage of the high cost location demands innovative activity in the early stages of the life cycle, specifically the "Early Exploratory Stage." Innovative activity at this stage is characterized by radical innovation, which is, by its nature, more involved in creating and developing new technological trajectories rather than following along existing technological lines. Re-globalization has changed the economic geography by shifting the comparative advantage of the developed countries away from the capital factor input toward the knowledge factor input. The implication is that the comparative advantage of developed countries is increasingly found in economic activity that is directed toward the early stages of the product-industry life cycle (the "Early Exploratory Stage" in Table 1), where new ideas play a predominant role and little has been standardized in the industry.

In a regional economy whose economic future is predicated on an economic base driven by industries characterized by the early stages of the product-technology life cycle, the process of recognizing new opportunities and then commercializing those perceived opportunities by starting a new firm is particularly important. Thus, the entrepreneurial economy that is emerging in North America and Europe has a new role for entrepreneurship, where entrepreneurship serves as an engine of growth by providing a vital conduit for the spillover and commercialization of knowledge and new ideas.

E. THE SPATIAL CONTEXT

The resumption and acceleration of globalization after the collapse of the Soviet-Russian Empire and the telecommunications revolution have brought two largely unanticipated developments: one in *economic geography*, and the other in *organizational form*.

Changes in economic geography were brought about by the re-emergence of regions and spatial proximity as playing important roles in economic activity. In addition, entrepreneurship has re-emerged as a significant organizational form generating innovation and economic growth. That innovative activity has become more important over time is not surprising. What was less anticipated, even though it had been unfolding for decades (but just below the radar-screens of many observers), is that much of the innovative activity that has been associated with high tech entrepreneurship is located in innovative regional clusters, such as Silicon Valley, Route 128, and Research Triangle Park. These innovative clusters have been around, evolving and re-inventing themselves for decades—long before the recent re-emergence of the so-called global economy.[33] Nevertheless, one of the apparent paradoxes of the latest round of globalization is the re-emergence of location (or the belated recognition of location) as a spatial platform for the efficient organization of economic activity. An important factor driving this recognition (or re-emergence, depending on one's viewpoint) of the importance of spatial proximity is the shift of the competitive advantage of high wage countries and regions to knowledge. Knowledge spillover is a key mechanism in models of endogenous growth. However, until the changes in the world economy, induced by the demise of the USSR and the end of the Cold War, the spatial dimension was not fully appreciated, or recognized. For instance, Krugman (1991) and others argue that knowledge externalities are so important and forceful that there is no compelling reason for a geographic boundary to limit the extent of the spillover. Thus, there was something missing in theories of knowledge spillover, or knowledge externalities. Hence, they failed to explain the re-emergence of location as a platform for harnessing knowledge and generating innovative activity.

The missing piece hinged on explanations or theories of localization which explain why the value of economic knowledge tends to decline as it is transmitted across geographic space; that is, the theory of localization of knowledge spillovers. Foray (2006)[34] and Audretsch and Feldman (1996) draw a distinction between *knowledge* and *information*.

> ***Information*** has a singular meaning and interpretation. It can be codified at low cost and the transactions costs are trivial. In contrast, ***knowledge*** is vague, difficult to codify, and often only serendipitously recognized. Even though the marginal cost of transmitting information across geographic space has been rendered trivial by the telecommunications

[33] The generation of research programs that spawned, especially Route 128 and Silicon Valley, grew out of the War Department's (later the Defense Department) weapons-systems and communications R&D needs in World War II, and the subsequent Cold War, and later, its sidebar, the Space Race.

[34] Foray (2006), pp. 5-6 and Chapter 4 for discussions of the implications of the distinction between information and knowledge.

> revolution, the marginal cost of transmitting knowledge, and especially, tacit knowledge, rises significantly with distance.[35]

Why is geographic proximity so important for the transmission of knowledge, especially tacit knowledge? Localization theories suggest that face-to-face interaction and nonverbal communication facilitate the transmission of ideas and intuition that cannot be communicated through codified instructions. While information is often context-free, tacit knowledge is often derived from specific contexts. Thus, in order to access knowledge and participate in the generation of new ideas, local proximity is significantly more cost-effective than trying to attain the same knowledge across distance. Audretsch et al. (2006) recount what is a nice summary of the above ideas by Glaser et al. (1992):

> Intellectual breakthroughs must cross hallways and streets more easily than oceans and continents[36]

F. INNOVATION AND ECONOMIES OF SCALE: Keynesian and Post-Keynesian Perspectives on Growth[37]

For the purposes of this report, the focus of the Keynesian/post-Keynesian view of growth is on Verdoorn's Law and cumulative growth***. Verdoorn's Law*** states that there is a positive relationship between the growth rate in labor productivity and growth in output. As output growth increases, *dynamic economies of scale* in production are engendered via "learning by doing" effects, both by labor (Arrow, 1962) and of capital due to its increased accumulation associated with easy credit availability conditions under an economic environment of expanding output.

Keynesian and post-Keynesian approaches to regional growth differ fundamentally from neoclassical models in their basic assumptions. Specifically, Keynesian/post-Keynesian growth models do not require the assumption that factor inputs are paid according to their marginal products, and they do not require the assumption that production exhibits constant returns to scale with respect to the factor inputs. However, similar to models of endogenous growth, these models imply that there is no particular long-run rate of growth towards which a region is expected to converge. Therefore, the actual regional growth rates will depend on the extent of economies, or diseconomies of agglomeration. Nevertheless, in terms of regional growth, Keynesian/post-Keynesian and neoclassical models can be shown to produce largely equivalent results. Thus, the interpretation of empirical observations of regional development can be shown to be consistent with either approach[38]. The purpose of introducing the Keynesian/post-Keynesian approach here is to draw on its focus on dynamic economies of scale and their link to innovation.

G. A NOTE ON ECONOMIC GROWTH vs. ECONOMIC DEVELOPMENT

Before proceeding to the discussion on sustainable dynamism, this section concludes with a brief discussion on the delineation between growth and development. The distinction is an important one and it is addressed in *Benchmarking Growth in Demand-Driven Labor Markets*. The

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[35] Audretsch (2006), p. 22.
[36] Audretsch (2006), p. 23.
[37] This section draws on McCann (2001), p. 235 and 238.
[38] McCann (2001), p. 238.

Benchmarking report states: "To develop and implement a 'boutique' economic plan requires an understanding of the difference between increasing production by simply increasing employment in existing facilities and developing the productive capacity of each worker." The latter is economic development. The report then reproduces a passage from a report by the Corporation for Enterprise Development that makes the distinction between economic growth and economic development:

> Economic development is frequently equated with economic growth, but in our view, the terms refer to different things. First, development is both a prerequisite to and a result of growth. Development, moreover, is a qualitative change, which entails changes in the structure of the economy including innovations in institutions, behavior, and technology. Growth, on the other hand, is a quantitative change in the scale of the economy – in terms of measures of investment, output, jobs, consumption, income, and others. Hence, development is prior to growth in the sense that growth cannot continue long without the sort of innovations and structural changes implicit in development. But growth, in turn, will drive new changes in the economy, causing new products and firms to be created as well as countless small incremental innovations.[39]

The *Benchmarking* report then goes on to define a region's ***economic growth*** as the change in real output per unit of the labor force and ***economic development*** as the change in real output per unit of employed labor. Therefore, it is possible to have economic growth without development and development without growth. The implementation strategy proposed here suggests that once an economic ecology that fosters sustained dynamism is implemented and put in place, the changes in the structure of the economy, which characterizes *economic development*, will have been set in motion. This then would set the stage for the subsequent change in the scale of the economy (i.e., economic growth) which, in turn, would facilitate further development, and so on.

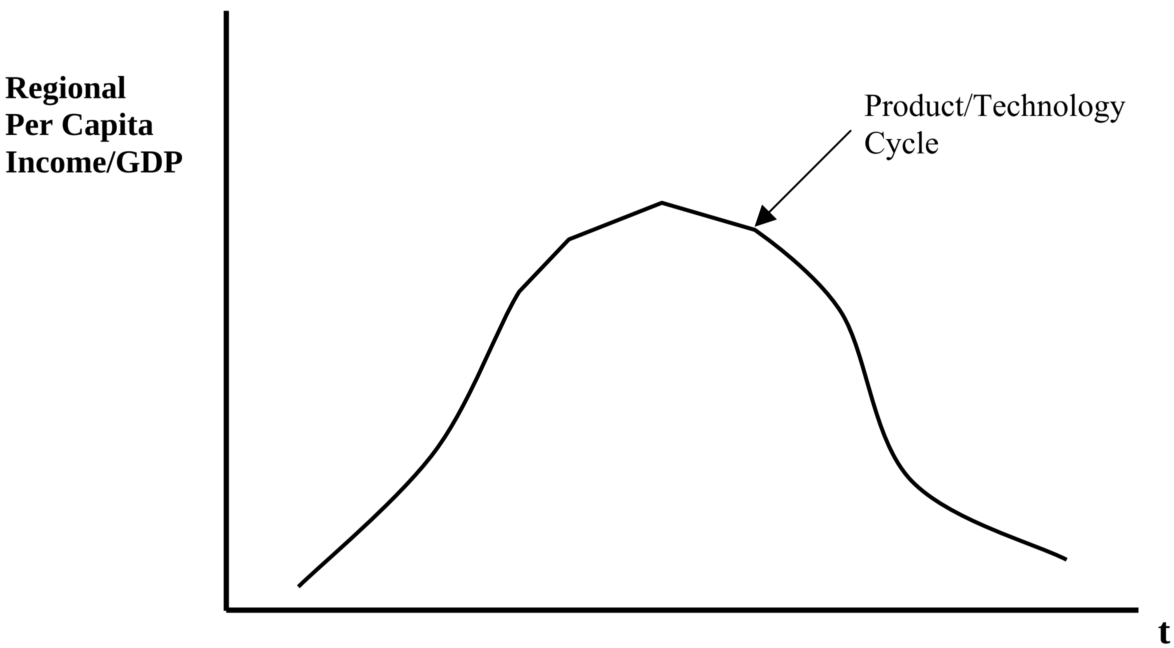
IV. SUSTAINABLE DYNAMISM: Innovation as a Region's "Leading Product"

Traditional regional and urban economic theory and economic development practice focused on the importance of the local economic base. Growth in per capita regional GDP and income were tied to the regional economy's exporting goods and services (particularly goods) to the rest of the nation and world, which would bring income back into the local area and, via employment and income multiplier effects, generate growth in the local-market oriented industries such as retail trade and consumer services. However, historically, in many instances, the economic base of a region would be dominated by a single industry/technology, which would tie the local economy's fate to that industry/technology's life cycle. Once the industry/technology matured and declined, the region's decline would follow as resources were reallocated away from those regions whose economic fortunes were tied to "sunset" industries and technologies to regions with higher rates of return whose economic bases were grounded in "sunrise" industries or technologies, or both. Further, even if the industry itself is not in decline, due to recent trade agreements, the introduction of broadband technology, and re-globalization, many U.S. regions have found themselves locked into the "wrong" stage in the production process, as various

[39] Schweke, W., Brian Dabson and Carl Rist (1996). "Improving Your Business Climate A Guide to Smarter Public Investments in Economic Development," CFED, ISBN 1-883187-10-9, Washington, DC.

activities are outsourced, either on-shore or off-shore, or facilities are outright moved to another region, or overseas. With a region's loss of jobs and income, and therefore the subsequent loss of the ability to support local-market oriented industries, the inevitable population decline would follow. Two archetypical regional economies characterized by this dynamic are Detroit and Pittsburgh. Graph 1 illustrates this idea with a stylized representation of the product/technology cycle. On the upward-sloping side of the curve, regional per capita income and GDP are increasing in the early phases of the development and diffusion of a new industry or technology (as the life cycle moves from the R&D to the standardized production phase). At some point, regional per capita income and GDP peak, and then stagnate or decline, as the industry/technology matures, and then moves to its declining phase (when the standardized production stage is moved out of the originating region and there is no new industry or technology to rejuvenate the regional economic base).

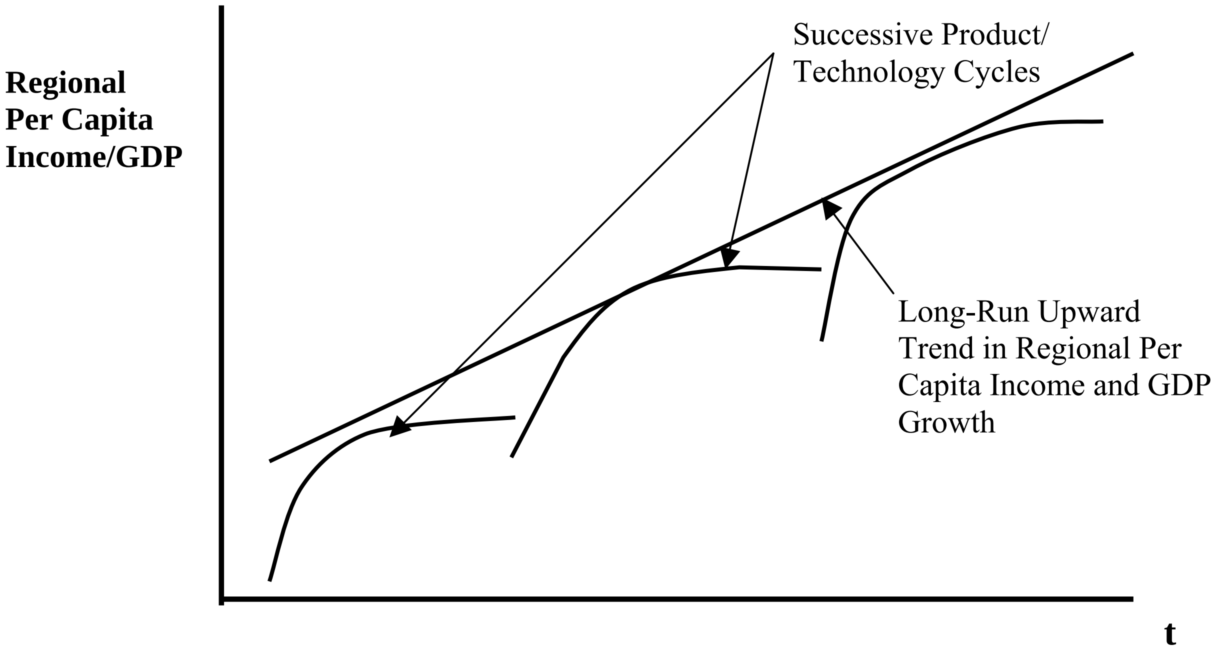
GRAPH 1: Regional Per Capita Income/GDP and the Product/Technology Cycle



However, there is now a new, and expanded, concept of the "economic base." It arises out of the *Third Wave* of economic development policies and is based on the *strategic management of places*. Instead of the economic base being predicated on an industry, a product, or set of products, or a specific technology, this new approach views the "product" as the continuous introduction of new products and innovations. The regional economy's product, or economic base, is its ability to continually re-invent itself. It exports new products and innovations to the nation and the world as an ongoing process. Thus, the new emphasis: entrepreneurship and regional development. This new approach to economic development, and its potential ability to generate continuous growth in regional per capita income and GDP, is illustrated in Graph 2.

As depicted in Graph 2, as the regional economy continually introduces new products and innovations into the market, it jumps to successively higher product/technology cycles, which generates long-run growth in regional per capita income and GDP.

GRAPH 2: Regional Per Capita Income/GDP and Continuous Innovation



How does a region tap into the dynamic depicted in Graph 2? A recently emerging answer to that question is: a **Science City**. What is a science city? What comprises a science city has no standardized set of criteria. Science parks apparently *do not* make science cities.[40] Throwing several high-tech businesses together in one place to share streets, sewers, and Internet connections does not produce the social, financial, economic, and other support systems that foster an ecology conducive to triggering a process of sustained innovation that can support the ongoing introduction of new products and innovations into the market by tapping into the externalities generated by inter-firm networks and knowledge spillovers.

A. ECONOMIC DEVELOPMENT AND THE ROLE OF "SCIENCE CITIES"

Etzkowitz sought to provide an answer to this question at the "Science Cities National Workshop" held in York (UK) in September 2005. In *Making Science Cities,*[41] he introduced a "Triple Helix" model of *university-industry-government* relations and science-based regional economic growth. His triple helix model arose out of his archival and interview-based research on the birth and evolution of the two prototypical U.S. science cities: Route 128 and Silicon Valley – one built on a "Brownfield" (Boston-Route 128), and the other on a "Greenfield" (Silicon Valley in Santa Clara County).

Both of these regions had three characteristics in common:

1. Universities with research capacity in fields with conjoint practical and theoretical relevance.

[40] Wallston, Scott, *Do Science Parks Generate Regional Economic Growth?* (March 2004) AEI-Brookings Joint Center: Washington
[41] Etzkowitz, Henry, *Making Science Cities: The "Triple Helix" of Regional Growth and Renewal* (September 23, 2005) Keynote Address to Science Cities National Workshop: York, U.K.

2. Faculties and administrators interested in using these scientific and technical resources to develop the local region.
3. Collaborative efforts among university, industry, and government to implement this strategy.

Etzkowitz argues that the emergence of *polyvalent research fields* with simultaneous theoretical, technological, and commercial potential provides a substrate for the growth of science-based clusters.[42] Once it was recognized that knowledge is imbued with multiple attributes, this then encouraged the multiple roles of academics and their involvement in biotechnology firms and of industrial researchers in academic pursuits. Etzkowitz[43] identifies two distinct paths through which knowledge can develop: *univalent knowledge* and *polyvalent knowledge*. Univalent knowledge follows a sequence from basic to applied research typically carried out in different time periods, at different sites, and by different persons. The emergence of polyvalent knowledge called forth the concept of *translational research* (a fuzzier notion than applied research) and an activity that is closely associated with fundamental investigation and likely to be conducted in tandem.

The Triple Helix Model

Etzkowitz's triple helix model, derived from the Boston regional organizing experience in the 1930's and 40's, comprises three basic elements[44]:

1. There is a more prominent role for the university in innovation.
2. There is a movement toward collaborative relationships among the three major institutional spheres in which innovation policy is increasingly an outcome of interaction among university, industry, and government.
3. Finally, in addition to fulfilling their traditional functions, each institutional sphere also 'takes the role of the other' operating on a y-axis of their new role as well as an x-axis of their traditional function.

Thus, each sphere takes on one or more roles of the others. *Academia* is a source of firm formation in addition to its traditional role as a provider of trained persons and research; *Government* helps to support the new developments through changes in the regulatory environment, tax incentives and provision of public venture capital and; *Industry* takes the role of the university in developing training and research, often at the same high level as universities The model was expanded through analysis of areas where the role of one sphere in innovation either predominated or was lacking. When one or more of the spheres is out of balance with the others, then innovation is impeded. It was found, for instance, that too much, or too little, government intervention impeded innovation.

So What Makes a "Science City"?

The discussion begins with the Boston region's response to a grave economic crisis in the early 20th century in which it lost much of its economic base. Nevertheless, the region's academic base remained strong and even grew, in part because of support from outside the region as its

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[42] Viale and Etzkowitz theme paper for the 5th Triple Helix conference. www.triple.helix5.com
[43] Etzkowitz (2005), p. 2.
[44] Ibid., p. 18.

universities were viewed as a national resource. For example, during the financial crisis that MIT experienced after World War I, help came from George Eastman, of Kodak, who viewed MIT as a significant resource of people and ideas for his firm. The financial base of the region also remained strong although funds from previous economic successes were loaned to corporations largely located elsewhere. The region also had a cohesive leadership structure that focused its attention on the potential for science-based economic growth.

Turning now to Silicon Valley, as a developing region in the early 20th century, Santa Clara County lacked the accumulated resources of financial and social capital available to Boston. Nevertheless, university-industry cooperation was strong and provided a base to initiate the development process. Government became important after World War II through Federal grants and contracts. Stanford University, and the early generation of semi-conductor firms, positioned themselves to successfully bid for that Federal research money. Although the organizational infrastructure of Silicon Valley was relatively weak, its loose networking mode of operation was a virtue in the boom era. However, formal structures have been created, linking university, industry and government actors, to address downturns.

Until recently, other areas such as New York and Chicago had research-intensive universities but not the local leadership to bring together resources to translate research success into economic growth. San Diego is another growing success case in which creating a great science-based university has been the basis of a strategy to generate a local science-based industry in biotechnology. North Carolina's Research Triangle Park has largely relied on attracting branches of national laboratories and multi-national firms, and although such a strategy can jump start a region, without an entrepreneurial university it is difficult to make such an area self-sustaining[45].

The long-term criteria for a successful science city are not only creation of a cluster of high-tech firms, but the ability to regenerate itself as earlier successes are superseded, such as the process and trend illustrated in Graph 2. Relatively few regions have developed self-renewing capabilities. Strong conservative forces, typically emanating from large firms in existing industries and their academic and government supporters, subsume much of the resources needed to make the transition, which results in a regional economic trajectory that more closely approximates the dynamic depicted in Graph 1. Beyond research capacity in emerging and interdisciplinary fields with potential for commercialization is the capability to effectively utilize these knowledge resources. This innovation capacity is largely dependent upon the network of public/private entities that can provide firm-formation expertise, gap funding, seed capital, etc. The project to create a knowledge-based region typically relies on expanding the capacities of universities or even founding new academic institutions for this purpose as has been done in San Diego and Merced, California. The university, however, usually acts as part of a broader configuration and when it fails to play a regional role it is often because a broader institutional coalition is lacking[46].

Well-developed, explicit, transfer mechanisms and informal networks that link new entrepreneurs with previously successful mentors can enhance a culture of entrepreneurship within academia. Emerging technology regions emulate these characteristics through programmatic intervention even as organizational entrepreneurs, such as founders of angel networks in Silicon Valley, franchise their models to other regions. Imported models are

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[45] Etzkowitz (2005), p. 20.
[46] Ibid., p. 21

typically reinvented to fit the local context, such as Israel's "Yozma" public/private venture capital firm, after initial failures, jump-started that country's venture capital industry[47]. The broader potential of the incubator model, beyond high tech firms, was realized in Brazil as an educational format for co-operatives to create jobs for the unemployed[48]. Academic advance and regional growth are mutually supportive goals. A region with a cluster of firms, rooted in a particular technological paradigm, is in danger of decline once that paradigm runs out (again, see Graph 1). The need to periodically renew the technological capabilities of a region (as depicted in Graph 2) leads government, as well as companies and universities themselves, to explore ways for knowledge-producing institutions to make a greater contribution to the economy and society.

Some observers hold that Silicon Valley and Boston's Route 128 are unique and spontaneous developments (Dorfman, 1983). However, Etzkowitz argues that, to the contrary, the conditions for creating continuous high tech social and economic growth can be identified and traced to specific organizational initiatives that have much in common.

1. A Tale of Four "Science Cities": Four Case Studies

This section turns to a brief history of each one of the four most well known "science cities" in the U.S., starting, of course, with the two most famous science cities: Silicon Valley and Route 128. There has been a conventional wisdom that Silicon Valley and Route 128 were the products of completely unique factors, and therefore their experiences could not be replicated. As a result, they could not be relied upon as a template for other areas to follow as a guide to their economic development strategies. In fact, each region did have some important, unique aspects that contributed to their rise as science cities. Subpart 2 looks at those factors that were unique to each region in its development and, by definition, cannot be reproduced by another region. However, contrary to long-held belief, there are, in fact, lessons to be learned from each of the above case studies that can be generalized to other situations, because, in addition to a unique set of characteristics specific to a given region, there was a set of experiences shared by all four regions. It is these factors that all four science cities shared in common, that other regions can use as guideposts in their own strategies to survive or even prosper in the twenty-first century, world economy. Subpart 3 looks at those features shared by all four regions in their pursuit of building a dynamic, knowledge-based regional economy.

a. Silicon Valley[49]

Though not the first of the four studied science cities, it is certainly the most famous. The term "Silicon Valley" was coined in 1971 by journalist Don Hoefler, in a couple of articles about the semiconductor industry around Palo Alto in *Electronic News*, an industry weekly.[50] Originally the term was used only to describe Santa Clara County. Now, it refers to an area that stretches from the San Francisco Bay on the east, the Santa Cruz Mountains on the west, and to the Coast Range to the southeast. Until the middle of the 20th century, this agriculturally rich region of

[47] Ibid., p. 21.
[48] Ibid., p. 21.
[49] This section is based on The Next Silicon Valley Leadership Group, WHITE PAPER, December 2001; Etzkowtiz, Henry, MAKING SCIENCE CITIES: The "Triple Helix" of Regional Growth and Renewal (September 2005); THE HISTORY OF SILICON VALLEY, Downloaded from Web; author unknown, and Mackun, Paul, *Silicon Valley and Route 128: the Two Faces of the American Technopolis*.
[50] THE HISTORY OF SILICON VALLEY, p. 1.

northern California was better known for its apricots and walnuts than for its Apples (Rogers and Larsen, 1984). It was then known as the Valley of Heart's Delight[51].

How It All Started

What became the Silicon Valley science city had its impetus at Stanford University. Therefore, in order to understand the birth and development of the Valley, some knowledge of the history of Stanford is needed. Stanford University was founded in 1891 by Governor Leland Stanford at his estate nearby 'El Palo Alto' (the high tree) in the memory of his son Leland Stanford Junior. Later, it was especially Professor Frederick Terman, a Stanford graduate himself, whose role was crucial for the development of the local high-tech industry after and before World War II. In the 1920's, administrators at Stanford sought to improve the prestige of their institution by hiring highly respected faculty members from East Coast universities. One of the most important recruits those days turned out to be professor of electrical engineering Frederick Terman from the Massachusetts Institute of Technology (MIT), who is now called the "Father of Silicon Valley" by a lot of researchers[52].

Professor Terman was concerned that a lot of his graduates went to the East Coast because of the lack of jobs in the Valley. To solve that problem he started to encourage some of his students to start companies near the university. Among these students were William Hewlett and David Packard. Hewlett, a graduate student, had designed and built an audio-oscillator. Because Terman was convinced of the market potential he persuaded Packard, who had moved to the East Coast to work for General Electric, to return to Palo Alto and join Hewlett. Terman then encouraged them to commercially produce their audio-oscillator. In 1937, they started a small company in the now-famous garage in Palo Alto. Their audio-oscillator, designed with Terman's help, became the basis for a later deal with Walt Disney Studios in 1939, for the film "Fantasia". That was the start of an endless growth. Hewlett-Packard, or HP, is now a multinational corporation producing computers, electronic measuring devices, and equipment[53].

In the meantime, some other students founded small companies that would later become the center of a local electronics industry. William Hansen, professor of physics, teamed with Sigurd and Russell Varian in 1937 to develop the klystron tube, an electron tube in which bunching of electrons is produced by electric fields and which is used for the generation and amplification of ultra-high frequencies. During the Second World War, the brothers Sigurd and Russell Varian worked rent free in a Stanford lab on their klystron tube. Later on, radar and Varian Associates inventions, involving microwave radiation, evolved. Stanford gave them rent free lab use and $100 for supplies. In return, Stanford was to share in any profits. Stanford's investment was one of the best it ever made because it brought in several millions of dollars in royalties. During World War II, Professor Terman made good contacts within Washington. After his return to Stanford, he succeeded in getting a lot of governmental contracts for Stanford and local companies. During the fifties, Stanford introduced a lot of new ways of working as a university (which were revolutionary for that time). These included[54]:

- **The Honors Cooperative Program**: graduates could be updated in their specialty.

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[51] Ibid., p 1, Etzkowtiz (2005), p.1, and Mackun (undated), p. 1.
[52] THE HISTORY OF SILICON VALLEY, pp. 1-2.
[53] Ibid., p. 2.
[54] Ibid., pp. 2-3.

- **The Stanford Research Institute** (1946): practice focused, non-profit research, which didn't fit within the traditional tasks of a university.
- **The Stanford Industrial Park** (1951): offering facilities for starting companies.

Who Put the "Silicon" in Silicon Valley?

The answer to this question can be traced back to 1955 when Stanford graduate student William Shockley, together with some talented young scholars from the East Coast, founded Shockley Transistor. He had developed a transistor based on the principle of amplifying an electrical current using a solid semi-conducting material at the Bell Laboratory. The concept was based on the possibility of selectively controlling the flow of electricity through silicon by designating some areas as current conductors and adjacent areas as insulators. This principle gives meaning to the term *semiconductor*. The semiconductor was a suitable alternative to the commercially unreliable vacuum tube. Tubes carried out the essential task of voice amplification, electromechanical circuit switching, and other functions involving the regulated conduction of electrical current. The resultant discoveries combined to form the basic concept behind the *transistor*, the compact electrical *transfer resistor* that was to power the coming high tech revolution.

As fate would have it, an internal dispute arose over the choice between the two semi-conducting materials: silicon and germanium. Shockley had a strong preference for germanium, but engineers Gordon Moore[55], C. Sheldon Roberts, Eugene Kleiner, Victor Grinich, Julius Blank, Jean Hoerni and Jay Last chose silicon as the more appropriate semi-conducting material, which in turn led them to leave Shockley in 1957. Robert Noyce, who had worked for a short time for Shockley as well, joined the seven engineers and in 1958 they founded Fairchild Semiconductor in Mountain View with backing from Fairchild Camera and Instrument in Long Island, NY. Fairchild became the first company to successfully mass manufacture a micro-sized device capable of integrating large numbers of electrical "on-off" switching functions, stored in simple memory cells, all etched onto a silicon chip, nowadays better known as the *integrated circuit*. This company was the first one to manufacture exclusively in silicon and rapidly developed into one of the largest firms in the California electronics industry. Besides that, the company was the basis for a lot of spin-offs and start-ups such as Intel, Signetics (now Philips Semiconductors), National Semiconductors and AMD. These companies were the basis of the semiconductor industry in what later led to the name *Silicon Valley*.[56]

Postscript: Shockley Transistor Corporation never recovered from the blow of the Fairchild spin-off and was sold to Clevite in 1960, then to ITT in 1965, and finally it closed for good in 1968.

From Adversity Comes Innovation: Schumpeter and Silicon Valley

Four major waves of technology innovation have shaped Silicon Valley since World War II:

(1) Defense; (2) Integrated Circuit; (3) Personal Computer; (4) Internet

A brief timeline of each wave, and the boom-bust features of each, is presented in Table B in Appendix B. Each wave was initiated with a phenomenon in which there is a bunching of innovations during a boom period before a recession in Schumpeter's theory of the Business

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[55] As a note of interest, Gordon Moore is the father of *Moore's Law* (i.e., computing power doubles every 18 mos.).
[56] Ibid., p. 5.

Cycle, and captured by The GartnerGroup in their concept of the *Hype-Cycle*[57] (see Graph 1-C., Appendix C). The initial burst of economic activity leads to a saturation of the market with too many firms to be profitable, which leads to a scaling back of employment. Schumpeterian waves of innovation take the shape of "S" curves (see Section II, above) and have a natural product life cycle feature that follows the introduction of a life cycle product (e.g., semiconductors or PC's) as the basic technology diffuses from high-value to community products (e.g., DRAM chips, disc drives). Each wave was interrupted later by external shocks, including competitive threats, and each downturn resulted in significant job loss.

The process of continuous innovation and creative destruction that has characterized Silicon Valley's habitat has an upside and a downside. The Valley has experienced a boom-bust cycle throughout its history (again, see Table B). However, it is during the down cycles that Silicon Valley has proved itself to be a true center of innovation and entrepreneurship, which prepared it to catch the next wave. In each case, innovation was born out of adversity. This follows what Joseph Schumpeter observed in the early 1900's. His idea of *Gales of Creative Destruction* describes this boom-bust phenomenon. In line with the idea of creative destruction is the post-2000 Silicon Valley bust, which should have been expected, as entrepreneurs and investors swarmed to take advantage of a new opportunity, proliferated new companies and jobs, and eventually drove down potential profits[58].

b. Route 128[59]

The Boston area is the birthplace of the science city. It was here that the first development strategy, based on knowledge-based growth, was conceived and implemented. The motivation for the search, which led to this new approach to regional development, was the economic circumstances that Boston found itself in at the beginning of the 20th century. The Boston area had begun the industrialization of the U.S. However, gradually, shoes and then machine tool production gradually moved elsewhere to be near sources of raw materials or customers. It was apparent by the early 20th century that it had become necessary to replace the region's existing generation of firms that were either strapped with outmoded technology or had relocated out of the region. How the region approached the crisis would begin the knowledge-based strategy that proved to be the critical path to generating new wealth and devising policies to create what Gomory and Baumol (2001) refer to as *acquired comparative advantage.*

Response to Decline: The New England Council

In response to long-term decline from the turn of the century, the region's business and political leadership, including the governors of the six New England states and industry representatives, organized the *New England Council* in 1925 to renew the region. The Council soon drew university presidents, like MIT's Karl Compton, into its membership. The involvement of Compton and MIT would be critical to the future course of the New England Council and the re-development strategy of the Boston region. But, before proceeding, it will be helpful to introduce

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[57] The Next Silicon Valley Leadership Group (2001), p. 4 and The GartnerGroup **http://www.umich.edu/~cisdept/mba/CIS745/GartnerHypeCycle.html**

[58] Ibid., pp. 4-5.

[59] This section is based on Etzkowtiz, Henry, MAKING SCIENCE CITIES: The "Triple Helix" of Regional Growth and Renewal (September 2005), Dorfman, *Route 128: The Development of a Regional High Technology Economy*, RESEARCH POLICY (1983), and Mackun, Paul, *Silicon Valley and Route 128: the Two Faces of the American Technopolis*.

some background on the founding and unique features of MIT as a new kind of academic institution.[60]

MIT: A New Variant of the Land-Grant Idea

The Massachusetts Institute of Technology (MIT) was a special feature of the region. Founded in 1862, it was a unique industrial variant of the land grant universities established in each state to support the development of agriculture, the nation's major industry at the time. The land grant schools focused on practical subjects, rather than the classic liberal arts, although the latter were also included in the curriculum. MIT was designed as a technological university to train students and infuse new ideas into the region's industrial economy, and, in addition, to conduct basic research and pursue those liberal arts with technological relevance like the history of science and technology[61].

MIT had a broader academic model than the more specialized engineering schools such as West Point, with its military focus, and Rensselaer Polytechnic Institute (RPI), which was focused on civil engineering infrastructure projects like the Erie Canal. Looking to the European polytechnic tradition as a model, William Barton Rogers founded MIT as a source of new industrial technology arising from fundamental research. However, his vision was realized only gradually, as a lack of resources forced MIT to function as an engineering teaching college until the end of the 19th Century when it began to develop research and an entrepreneurial culture[62].

The "Tried and True" Paths Go Nowhere

Though it was founded to support existing industry, MIT eventually found its true regional role as a source of new industry through the New England Council, a regional development effort. The Council began its efforts based on conventional regional economic development strategies that are still in use today. The lynchpins of the conventional strategies, reducing taxes to improve the business climate and attract companies to relocate to the region were the critical pieces of their approach. In addition, initial efforts focused on a conventional marketing campaign, which emphasized the positive attributes of the region in comparison to other parts of the country. However, the effort to attract branch plants failed! New England was far too removed from the sources of raw materials and distribution networks to be an attractive location[63]. After running into this policy "brick wall," the Council's solution to this crisis was to invent a whole new approach to regional economic development strategy.

A New Approach: Knowledge-Based Economic Development

With the failure of the conventional approach, the Council began exploring some new avenues, including alternatives based on the knowledge resources of the region. The focus gradually shifted from incrementally improving existing firms, to a discontinuous approach: creating new industries. Early on, The Council recognized that New England's competitive advantage lied in its concentration of academic and industrial research laboratories. Initially, the idea was to encourage the formation of small firms. The Council's "New Products" committee, established to assist existing firms, turned to the more far-reaching idea that New England's intensive research

[60] Etzkowtiz (2005), p. 3.
[61] Ibid., pp. 3-4.
[62] Ibid., p. 4.
[63] Ibid., p. 4.

universities could substitute for the natural resources that the region lacked[64]. This was a critical epiphany. It was this approach that foreshadowed a completely new perspective on how to think about *comparative advantage*. In the early 21st Century, this approach would be formalized by Gomory and Baumol (2001) in their concept of *acquired comparative advantage*, and by modern, regional economic development theory with its emphasis on the *strategic management of places.* Acquired comparative advantage differs from the Ricardian idea of classical comparative advantage, which is based on a nation's or region's endowment of natural resources. According to the acquired comparative advantage idea, regions or nations that have little or no comparative advantage based on natural resources can develop comparative advantage based on such deliberate strategies as focusing on innovation and developing network economies (e.g., Japan, in the case of automobiles[65]), or science-based development founded on a regional advantage, which is predicated on the location of a high concentration of intellectual, or knowledge-based, resources that generate new processes and products, and even new industries (e.g., Silicon Valley and Route 128).

As a New Products Committee member, MIT President Compton saw instances of firm formation by MIT professors as a platform for a new wave of technical industry. Beyond Compton's stature as head of MIT, the respect for his personal qualities and scientific achievements, coupled with his pride in the region's educational and research institutions, assured him an audience for his ideas. At the National level, where too much technology and invention of labor-saving devices was blamed for causing the depression, his ideas would have not been well-received[66].

Another important contributor to the region's knowledge-based, and technology-transfer approach to economic development was Vannevar Bush. He was an electrical engineering professor and Dean and Vice-President of MIT, and the prototypical entrepreneurial academic, combining in a very effective manner both intellectual and commercial interests in the course of his career. Much of the model of university-based economic development was derived from the activities of Bush. As a young academic, he learned that a patent he obtained, though it secured legal rights, was no guarantee of a profit. Through his consulting, he learned that if existing firms did not take up an idea, then it was necessary to found a start-up firm to realize it[67].

The Invention of the Venture Capital Firm

Despite its capital and technology resources, New England lacked a systematic methodology for firm formation. Eventually, a strategy evolved that was based on a synthesis of: University-business-government elements (i.e., Etzkowtiz's Triple Helix) into a venture capital instrument[68]:

- *Government* changing investment rules;
- *The university* providing technology, human resources, and capital to form new firms; and
- *Business* providing capital and legitimacy to the new venture entity.

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[64] Ibid., p. 5.
[65] The Japanese automobile industry, through process innovation and quality control, has developed an *acquired comparative advant*age based on Product Differentiation and Increasing Returns to Scale (Krugman and Obstfeld 2002, p. 122-131) In addition, an automobile firm needs a network of distribution and dealerships to bring its vehicles from the assembly line to its customers [i.e., *Network Economies*, Gomory and Baumol (2001) pp. 16-18].
[66] Ibid., p. 5.
[67] Ibid., p. 5.
[68] Ibid., p. 4-5

After World War II, Compton organized a consortium of universities, investment banks, and insurance companies to found the first venture capital firm, ***American Research and Development*** (ARD) through the sale of equity in the firm. The organizational design and staffing of the project were derived from MIT and Harvard Business School. The elements included[69]:

1. A search mechanism: recent graduates of MIT who followed up leads and walked the corridors as Technology Scouts to identify promising technologies.
2. An evaluation procedure: an advisory board of senior MIT professors that assessed technologies and provided leads to promising projects.
3. Business development capability: recent graduates of Harvard Business School who provided business advice as consultants and monitored the development of companies.
4. Leadership and networking expertise: the head of the venture firm intervened in client-firm crises and linked the venture firm with academic, financial, and policy networks.

World War II R&D projects enhanced university-focused, technological opportunities. After the War, many R&D projects were expanded into civilian as well as military fields. After a decade of initial investments, ARD had its first success with the Digital Equipment Corporation (DEC), based on a Navy research project to develop a pilot training device. The project was not completed in time for war use; however, the Air Force continued to support the computer aspect of the project after the War, as a radar control device. Though the Air Force eventually dropped the project, it was far enough along to be used commercially, initially as a circuit board, and eventually as a full-fledged computer[70].

Due to the success of its DEC venture, it was decided that ARD would be transformed from a pro-bono regional development corporation into a partnership for the benefit of its managers and investors. The result of ARD's experience with DEC was the contemporary format for the venture capital model. The $400 million in DEC stock was distributed to ARD's shareholders. Interestingly, MIT did not gain financially from ARD's early-stage funding of DEC. It sold its ARD stock before this windfall, and, in fact, MIT played no direct role in regional development in the Post-Compton Era[71].

Broadening the Academic and Commercial Base

MIT's and Harvard's role in the second wave of firm formation in the 1980's was based on the two schools' early commitment to molecular biology. The academics involved in this new field were aware of its practical implications and were receptive to venture capitals' proposals to create biotechnology companies. The entrepreneurial infrastructure that had been created during the early post-World War II period supported firm formation projects. The expansion of the Boston biotechnology cluster built upon a broad academic base, which included not only MIT and Harvard, but also emerging research universities like Boston University and the University of Massachusetts-Boston. These schools built up research capabilities in response to the emergence of the biotech cluster. On the other hand, the mini-computer cluster grew apart from its academic source. In addition, as discussed in the next section, another contribution to the abrupt decline in

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[69] Ibid., p. 6.
[70] Ibid., p. 6.
[71] Ibid., p. 7.

the mini-computer industry, in addition to their relative isolation from the academic institutions in Boston and Cambridge, was their heir spatial isolation from each other, as well.

There were significant differences in the industries ‘development-dynamics over the mini-computer and biotechnology eras. In contrast to the mini-computer experience, the Boston biotech cluster exemplifies three positive characteristics of a science city[72]:

1. Firms located close to universities to encourage interaction of the cluster with its academic source;
2. A reciprocal process of regional and academic growth occurred in tandem; and
3. There is flow of polyvalent knowledge through collaborative projects, with multiple links through academic research groups and firms, mediated by university technology transfer offices and conflict-of-interest guidelines.

In addition, close ties typically exist between the firm and the research group that incubated the proto-firm. Often, conflicts emerge between researchers with interests that differ along economic and academic lines. Etzkowitz (2005) discusses Google’s incubation period within the Digital Library Project at Stanford as an example. At one point, researchers with divergent economic interests stopped talking to each other about “search,” while those with no economic interest were temporarily alienated from their colleagues. The founders took a leave of absence from the Ph.D. program, but their professor was a Google consultant and the algorithm was of dissertation quality. The engineering school has since worked out procedures to encourage firm founders to complete their degrees. A balance between integration and separation is found as people become more experienced in making the transition from “lab to market” and back again[73].

c. Metro Washington[74]

The newest of the U.S. science cities studied here is the U.S. Capital region, the Washington Metropolitan Area, which includes the states of Virginia, Maryland, and West Virginia, and the District of Columbia. There are actually two science cities within the region, representing the development of two high-tech industry clusters: Biotechnology is primarily concentrated in the Maryland suburbs in Gaithersburg and along the I-270 corridor, and the Internet companies are concentrated in the northern Virginia suburbs.

Planting the Seeds

Planted in the early 1970’s, the seeds of the Metro Washington science cities would not germinate until a decade later. These seeds represented the critical pieces to the development of a “Science City”. The critical pieces that took root in the Washington Metro area in the early 1970’s are:

A. Venture Capital
B. Social Capital
C. Entrepreneurial Support Services
D. Research Universities

[72] Ibid., p. 7.
[73] Ibid., p. 7.
[74] This section is based on Feldman, Maryann P., *The Entrepreneurial Event Revisited: Firm Formation in a Regional Context*, INDUSTRIAL AND CORPORATE CHANGE (2001) (10): 4

In 1971, there were three venture capital investments, as measured by the number of equity deals, in the U.S. Capital region for a total of $1.5 million. However, nationally there were only 68 equity deals for a total of $50 million in venture-capital investments that year. Bill Gust was recruited from Silicon Valley to the Washington region in 1976 to run a venture fund for the Bonaventure family; this appears to be the first actual venture capital firm in the region. Initially, investments were made in Silicon Valley and Route 128 due to a lack of local opportunities in the early 1970's. Thus, venture capital could not have been part of the original impetus that generated Metro Washington's science cities. Further, in the early 1970's the Washington Metro area did not have the necessary social capital needed to support entrepreneurship[75].

Not surprisingly, the Washington Metro economy owes much of its existence to the Federal Government. In the early 1970's, two-thirds of the regional economy was directly or indirectly dependent on Federal expenditures, and one-half of the workforce was employed by the Federal Government[76]. The region benefited from a strong presence of Federal laboratories and agencies such as[77]:

- National Institutes of Health (NIH)
- U.S. Food and Drug Administration (USFDA)
- U.S. Agricultural Research Service
- National Institutes of Standards and Technology (NIST)
- National Science Foundation (NSF)
- U.S. Defense Department, including the Defense Advanced Research Projects Agency (DARPA)

Since Federal employment is typically stable and offers job security and benefits, the perceived work ethic of the region's labor force was not viewed as one that would promote a social culture supportive of entrepreneurship. Further, star scientists in the region were primarily interested in doing basic research that would bring them academic, rather than commercial rewards, and they viewed starting a business as "selling out" and betraying scientific integrity. There was little interest in commercially applying the region's resources and the business community had no appreciation of the power of technology-transfer to generate new start-ups with little capital[78].

However, there were many individuals with high levels of intellectual capital in the region and who were most likely to belong to social networks. The critical feature of an environment that promotes entrepreneurship is the presence of local linkages among individuals for the purpose of advancing industrial activity and promoting commercial interests. A frequently cited example of the type of social capital that promotes entrepreneurship is the Home Brew Computer Club in the San Francisco Bay area, which began as an informal forum for individuals from different educational, social, and professional backgrounds to get together and discuss their common interest in PC technology in the early 1970's. It is considered to be a critical social network that played a pivotal role in the development of PC technology in the early 1970's[79].

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[75] Feldman (2001), p. 865.
[76] Ibid., p. 866.
[77] Ibid., p. 866.
[78] Ibid., p. 866.
[79] Ibid., p. 866-867 and THE HISTORY OF SILICON VALLEY, p. 7.

Such social networks or interest groups did not appear to exist in the early days of the development of the industry in Metro Washington. Feldman (2001) suggests that a proxy for social capital may be government activity or other types of collective action to promote or encourage entrepreneurship such as interest or advocacy groups, or technology councils[80]. However, there is a significant structural limitation to this route in the U.S. Capital region. This limitation is a jurisdictional problem. The region includes three states (Maryland, Virginia, and West Virginia), and the District of Columbia. Thus, many jurisdictions within the metro area are responsible for economic development, making it difficult to coordinate government actions across jurisdictions even though they compose one economic region with a unified labor market with strong interrelationships. In fact, Virginia and Maryland are well-known competitors rather than collaborators and have been known to engage in bidding companies away from one another rather than promoting a regional agenda. Following a national trend, both states began promoting entrepreneurship in the mid-1980's, but before then support for entrepreneurship was minimal and reinforcing social capital largely did not exist[81].

A Period of Hibernation

Entrepreneurial expertise or support services provide resources to support a new start-up by providing guidance in such critical areas as intellectual property, business formation, and legal requirements, as well as routine accounting and business compliance issues. Typically, small businesses will not have in-house resources to address these issues. In the 1970's and 1980's, though Washington certainly had a large concentration of lawyers, however, their expertise was not focused in areas that would facilitate new, high-tech businesses. Also, due to the limited presence of corporations in the Metro Washington area, support services, in general, were lacking. In 1970, the only three Fortune 500 Corporations headquartered in the area were the defense aircraft company, Fairchild Hiller, household toolmaker Black and Decker and, aluminum producer EASCO[82].

Though research universities figure prominently in the development of the Boston-Route 128 and Silicon Valley science cities, not every research university has spawned technology-intensive economic development. Like the two most well known science cities, the Capital region is home to several prominent research universities (e.g., Johns Hopkins, University of Maryland, Georgetown, George Washington), however, none of them embarked on a program of *technology transfer* in the 1970's. In fact, Johns Hopkins was the single largest recipient of Federal R&D expenditures, even larger than MIT, which is credited with spawning Route 128, or Stanford University credited with the development of Silicon Valley. But, unlike MIT and Sanford, Johns Hopkins had no policies to encourage the commercialization of technology developed in its labs, and the culture was relatively hostile to academic entrepreneurship. In addition, research at Federal labs was not available for commercial use[83].

The Seeds Begin to Sprout: Entrepreneurship Comes to Washington

It was the mid-1980's when things began to change. Since then, the regional economy has been transformed from an economy characterized by little or no entrepreneurial activity to a fully functioning entrepreneurial economy. The U.S. Capital region has established leadership in two

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[80] Ibid., p. 867
[81] Ibid., p. 867
[82] Ibid., p. 868.
[83] Ibid., p. 868.

new industries that have seeded and established themselves in the last 20 years. This leadership is based on entrepreneurial activity in biotechnology and the Internet. The two high-tech industries have clustered around two separate geographic areas within the Washington MSA.[84] Biotechnology is primarily concentrated in the Maryland suburbs in Gaithersburg and along the I-270 corridor. The Internet companies are concentrated in the northern Virginia suburbs. The next two sections recount the rise of these two high-tech industrial clusters[85].

The Making of a Biotechnology Cluster

The U.S. Capital region is recognized as having the third largest concentration of biotech companies in the U.S. Leading biotech companies include Human Genome Sciences (HGS) and Celera Genomics Corporation. As of 2001, there were 300 small- and medium-sized biotech firms in the region. The fathers of the biotech industry are Stanley Cohen and Herbert Boyer. And, its origin can be traced back to 1973 when they developed genetic engineering techniques at the University of California-San Francisco[86]. And, it was during this time of high opportunity that the earliest entrepreneurs in the Capital region began start-up firms in biotechnology. However, since there were no significant pharmaceutical firms in the region, the earliest biotech firms were formed by individuals previously employed by prominent suppliers to the National Institutes of Health (NIH). The presence of the NIH in the Washington region is a defining characteristic. It employs a large number of researchers at its home campus in Bethesda, MD. The NIH has been a spawning ground for new start-ups over the last 10-15 years. Other government agencies such as the Walter Reed Army Institute for Research (WRAIR) and the U.S. FDA have also been a significant source of biotech entrepreneurs[87].

The region's universities have only recently spawned new start-ups, and university-based, firm-formation activity did not occur at the earliest stages. Initially, entrepreneurs came from government institutions and large corporations, but it was the subsequent generation of new start-up firms that became particularly fruitful in generating second-, third-, and fourth-generation start-ups[88].

The Making of an Information and Communications Technology (ICT) Cluster

Another high-technology industry with a significant presence in the Metro Washington region is Information and Communications Technology (ICT). It is concentrated in northern Virginia. And, since ARPANet, the forerunner of the Internet, was developed at the Pentagon in Arlington, it may be regarded as the birthplace of the Internet. Prominent companies in the region include MCI, AOL, NexTel, Teligent, and WinTel. Over 400 small- and medium-sized enterprises in the region are ICT firms. Companies in the region supply one-half of the worldwide Internet backbone[89].

The modern computer networking technologies that are the backbone of the Internet and ICT emerged in the early 1970's from ARPANet, which was developed at the U.S. DOD Advanced

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[84] For a definition of the Washington-Arlington-Alexandria DC-MD-VA-WV MSA see the U.S. Census Webpage at **http://www.census.gov/population/www/estimates/metro_general/2006/List4.txt**
[85] Ibid., p. 869-870.
[86] BIOTECH-The National Health Museum **http://www.accessexcellence.org/RC/AB/WYW/wkbooks/SFTS/part2.html**
[87] Ibid., p. 870.
[88] Ibid., p. 870.
[89] Ibid., p. 871.

Research Projects Agency (DARPA, known then as ARPA). It was individuals leaving the Defense Department and the military services who formed the first start-ups. In addition, individuals from private industry, both within the region and from without, figure prominently. Notably absent from the list of sources of ICT, start-up firms are the local universities.

While biotech and ICT are very different industries, the objective here is to discern the patterns in the origins of companies and to explore the paths along which entrepreneurial activity developed. Feldman (2001) notes several patterns that emerge[90]:

1. Entrepreneurs hail from a variety of different organizations. Government agencies served an important incubator function in both industries. However, they were not the sole source of entrepreneurial talent. There is evidence of a great diversity in the backgrounds of the entrepreneurs.
2. The earliest start-ups were service firms that were not originally involved in the types of R&D activities that generate new industries. Firms such as Bethesda Research Labs and AMS were not launched as product development firms, although they have evolved in that direction over time. Thus, the industry had rather humble beginnings – not the type of start-up that would attract much attention from investors, the media, or local economic development officials.
3. Entrepreneurship picks up momentum. Over time new generations of firms spin-off from the earliest start-ups and entrepreneurs who cashed in from one new venture created other new companies.

Mr. Schumpeter Goes to Washington: Federal Downsizing and Outsourcing

Between 1970 and 1990, the U.S. Capital region was affected by a series of exogenous shocks to its employment base. Several rounds of shocks were initiated by dramatic shifts in government policy. These policy-shifts resulted in initiatives, such as the downsizing of government employment, the initiation of Federal outsourcing, especially in services that could be adapted to the commercial sector, and changes that allowed access to intellectual property in high-opportunity sectors. In addition, the favorable treatment of small firms with regard to securing government contracts or financing provided a further impetus for firm formation. Consequently, from 1970 to 2000, the U.S. Capital region's employment base went through a dramatic structural change. This transformation was set in motion by the significant downsizing of the Federal workforce, which began under the Carter Administration, and continued under Reagan. These workforce-reductions were the consequence of policies that were based on a perceived general dissatisfaction with the size of the Federal Government and the efficiency of the private sector relative to the public[91].

As a consequence of these policies, Federal employment became less secure, and employment conditions and future prospects deteriorated. Further, compensation levels for the members of the senior service declined. During the 1980's, public sector pay scales badly lagged behind those of the private sector. Many of those affected were inhibited from leaving the area due to *location inertia*—they had strong ties to the local region. In addition, other regions that offered alternative technology-intensive private sector employment had higher housing costs, which also inhibited

[90] Ibid., p. 861.
[91] Ibid., p. 873.

mobility. Individuals in the prime of their careers found entrepreneurship a viable employment option. The threshold for such risk-taking was lowered by the exogenous shocks mentioned above. Thus, with the *Federal cushion* not so comfortable anymore, the incentive to leave government employment was higher. Opportunities for entrepreneurship were provided simultaneously as Federal jobs were downsized.

The *Civil Service Reform Act of 1978* put limits on the size of the Federal workforce, and contained an initiative to outsource the production of goods and services to the private sector. This provided an incentive for highly skilled individuals to leave Federal employment and start firms to provide goods and services to their former employer The nature of these contractual arrangements required proximity to the Federal Government, which favored local firms. Federal procurement spending in Metro Washington grew by 114%, compared to 3.1% nationally, between 1983 and 1997, which created enormous opportunities for private sector firms. Over this same period, nationally Federal procurement spending increased by 3.1% (Haynes et al., 1997, p. 149). Most importantly, the Reagan Administration was responsible for a pronounced defense build-up that was coupled with the policy of outsourcing to the private sector.[92]

"Star Wars", or the Strategic Defense Initiative (SDI), was different than other defense build-ups, in that it focused on the technical and software aspects of weapons systems, such as electronics, design, and systems management. Thus, SDI funded broad-based technical expertise rather than armaments production. While this initiative stimulated economic growth throughout the U.S., the Capital region, in particular, was a major beneficiary. For example, the earliest ICT entrepreneurs were systems integrators who provided a customized set of arrangements of procured items such as computer components and software to create a functioning deliverable product. These firms began working as contractors on complex government computing services and telephone systems, and moved to the forefront of Internet development, electronic commerce, and satellite communications and wireless telephony. The ARPANET was built and developed by U.S. DOD contractors who invented the technology as they built the system. After the Federal Government removed the commercial restriction on using the Internet in 1989, two for-profit companies were spun off from then non-profit Internet Service Providers (ISP's), UUNET and PSYNET, which was spun off from NYSERNET[93].

The U.S. Capital region was affected by other exogenous changes that affected entrepreneurship. The changes in the structure of the employment base and incentives were coupled with new opportunities for the commercial exploitation of intellectual property rights that accrued from publicly funded research. These legislative changes created new commercial opportunities that have lured many scientists into starting their own companies. Most companies appear to have been started with personal funds rather than venture capital[94].

Federal Legislation Favored Small Business Formation

In response to declining American competitiveness, the *Stevenson-Wydler Innovation Act* and the *Bayh-Dole University and Small Business Patent Act* were passed and signed into law by President Carter in 1980. These acts ushered in a new policy that fostered the transfer of publicly funded intellectual property to industrial firms. The new policies were based on a belief that

[92] Ibid., p. 875.
[93] Ibid., p. 876.
[94] Ibid., p. 877.

private access to, and ownership of, public research would ensure that research results would be widely disseminated and have the largest effect on commercial development and subsequent economic growth. The two acts are summarized as follows[95]:

- *The Stevenson-Wydler*:
    - Facilitated the transfer of technologies that originated in Federal labs.
        - Thus, many Federal labs in the Capital region were allowed to license their innovations to private firms.
        - This allowed employees of those labs, faced with potential downsizing, to license technology that could form the basis for a new firm.
- *The Bayh-Dole Act*:
    - Allowed universities to retain ownership rights to intellectual property arising from Federally funded research and license the right to use this property to private firms.
- This provided an incentive to promote commercial development of university research discoveries.

Two subsequent acts and amendments were passed in 1982 and 1986[96]:

- *The Small Business Innovation Development Act of 1982*:
    - Established the **Small Business Innovation Research** Program (SBIR).
    - All Federal agencies with an annual R&D budget greater than $100 million are required to set aside a percentage of R&D funds for small business.
    - Defined a *small business* as a firm with less than 500 employees and less than $2.5 million in sales.
    - Act greatly increased the funding available to technologically oriented small businesses.
- *The 1986 Technology Transfer Act* amended the *Stevenson-Wydler Act*:
    - Authorized **Cooperative Research and Development Agreements** (CRADA's) between Federal agencies and private firms
- It specifically gave a major boost to the Capital region's technology community.
    - Allowed companies to form partnerships with government agencies for the first time. This new ability to form CRADA's resulted in the creation of an array of new firms, especially in the biotechnology sector.

Scientists who licensed technology out of their own university or government research labs chose to locate new start-up firms close to their homes. In other cases, venture capitalists and executives in large companies recognized the potential in commercial research and either licensed the technology directly or formed a partnership with the scientist to jointly develop new products or services based on the technology. Although each Federal agency maintains its own records, it appears that the first CRADA's went to companies in the Capital region. Further, in

[95] Ibid., p. 877.
[96] Ibid., p. 877-878.

the initial stages, spatial proximity to their Federal lab or other agency partner would seem to be critical in establishing and maintaining such a partnership[97].

Entrepreneurship as a Response to Crisis

Entrepreneurship in the region was a response to exogenous factors. The region was suddenly confronted with large numbers of underemployed skilled workers that were the product of changes in Federal employment policy that, coupled with new opportunities for the private sector to contract with the Federal Government and commercialize new technologies, motivated many former government employees and contractors to respond to the crisis by starting up new firms. The two cases here responded to two different pressures. The advent of entrepreneurship was reactive and adaptive. While both sectors benefited from great opportunities for commercial products, biotechnology was more influenced by CRADA's, and opportunities for licensing and joint product development; ITC benefited more from outsourcing opportunities. In both cases, locational inertia kept the entrepreneurs in the area. Over time, the region developed the supporting infrastructure that the literature associates with entrepreneurial environments[98].

d. Research Triangle Park[99]

The last of the studied science cities is different from the other three in the sense that the approach was more along the lines of attracting the R&D facilities of existing firms and government agencies, rather than being the birthplace of new firms, industries and products, and innovations. Another unique feature of Research Triangle Park is that North Carolina is in the South. (Although Virginia is a Southern state, Maryland and West Virginia are considered to be border states, and they were not in the Confederacy.)

The All-Too-Familiar Industrial Decline

After World War II, the North Carolina economy was very unstable. Historically, the state's economy had relied almost exclusively on three traditional industries: furniture, textiles, and tobacco. The furniture industry was leaving the state and expanding into the northeastern U.S.; the textile industry was facing growing competition from Asian producers; and tobacco-manufacturing employment was on the decline.

North Carolina's per capita income had long been one of the lowest in the nation, and the decline in its traditional industries made it even more difficult for the state to employ its own college graduates[100].

An Idea to Stop the Brain Drain

During the early 1950's, North Carolina's academic community was becoming increasingly concerned about the out-migration of its better college students and they began conferring with the state's economic development leaders about how to attract new industries. The idea of using the three triangle universities, the University of North Carolina, North Carolina State University, and Duke University, to attract research companies into a park area, in a location central to the

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[97] Ibid., p. 878-879.
[98] Ibid., p. 879.
[99] This section is based on Link, Albert N and John T. Scott, *The Growth of Research Triangle Park* (2000) DRAFT [Final article appeared in SMALL BUSINESS ECONOMICS Springer, vol. 20 (2), pages 167-75, (March 2003)].
[100] Link and Scott (2003) p. 2.

universities, quickly emerged from the dialog. In early 1954, Brandon Hodges, the State Treasurer of North Carolina; Robert Hanes, the President of Wachovia Bank and Trust Company; and Romeo Guest, a Greensboro building contractor (credited by some as giving birth to the idea of a research park in the triangle area), met to discuss North Carolina's need for industrial growth.[101]

Hanes was not immediately sold on the idea. However, in the fall of 1954, Hodges and Guest were able to enlist the support of key deans and faculty at North Carolina State, and in December 1954 they convinced Chancellor Carey Bostian to take the idea to Governor Luther Hodges. Like Hanes, the Governor was not immediately sold on the potential benefits for North Carolina. Nevertheless, he was willing to commission a concept report. William Newell, Director of the Textile Research Center at North Carolina State, wrote a 10-page report that he delivered to the Governor on January 6, 1955. The triangle idea quickly became known as the "Governor's Research Triangle"[102].

By April 1955, Governor Hodges had organized the Research Triangle Development Council, with Robert Hanes as its Chairman, and solicited the support of Gordon Grey, President of the University of North Carolina, and Hollis Edens, President of Duke University. Over the next year, the Council and its various subcommittees agreed that the Research Triangle Project should be maintained as a private effort and that the universities would act as a magnet to attract industry. Soon after, Professor of Sociology at Chapel Hill, George Simpson, agreed to take a one-year leave of absence to be director of the organization. On September 25, 1956, it would be named the *Research Triangle Committee, Inc*. His task was to attract research companies to the Triangle[103].

While the leaders of the state believed that the Research Triangle was a good idea, a number of obstacles immediately stood in the way[104]:

1. Although North Carolina was in the South, it had a progressive reputation, and it had reacted relatively well to the Supreme Court's 1954 *Brown vs. Board of Education* decision.
2. There was a tendency for large companies to maintain their research facilities near their manufacturing sites.
3. There was a folk wisdom that Route 128 near Boston and Stanford Research Park were not planned, but rather just happened, so there was no clear path to follow.

Simpson realized that the universities' cooperation was critical for the park idea to succeed. To insure their participation, he assembled a team of faculty to develop brochures documenting the research expertise in selected fields of the three universities, and to travel and visit companies to market the park idea. However, save a concept, the faculty really had nothing tangible to "sell". After visiting over 200 companies by the end of 1957, it was clear that land would be needed[105].

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[101] Ibid., p. 2.
[102] Ibid., p. 2.
[103] Ibid., p. 3
[104] Ibid., p. 3.
[105] Ibid., p. 3.

The Next Steps

As early as January 1957, Governor Hodges anticipated the need for land and had tried, unsuccessfully, to identify investors in North Carolina to finance the purchase of land for the Research Triangle. However, William Saunders, Director of the State's Department of Conservation and Development, had the idea to approach Karl Robbins, who had retired to New York in the 1950's. However, he was familiar with the area because he had previously owned textile mills in North Carolina, and he was a friend of Guest's. Robbins showed interest and, committed up to $1 million for the project, but his initial investment was only $30,000[106].

Guest took the lead in creating a private land venture that was separate from the planning and marketing of the Research Triangle Committee. By 1957, he and his group acquired options to purchase nearly 800 acres at an average price of $161 per acre in what would eventually become Research Triangle Park. In their land purchases, Guest and his associates operated secretly under the name Pinelands, Inc. They acquired options for 3,430 acres of an identified 4,000 acres by September, when the press began to publicize the park idea. Most of the options were due at the end of November. But up to that point, no North Carolinians had invested, so Robbins was reluctant to put in any more than the $109,000 he already had invested[107].

A Shift in Strategy

By early 1958, Pinelands, Inc., the Research Triangle Committee, the State, and the university planning and marketing group realized that they were running into problems. Further, they could no longer rely on Robbins to provide sufficient capital to assemble the land. In the meantime, the Committee was trying to identify and attract research companies to the area[108].

In August 1958, Governor Hodges and Hanes approached Archibald (Archie) Davis, also of Wachovia Bank and Trust, to help attract North Carolina investors for Pinelands, Inc. Davis recognized that the Research Triangle had significant potential for the state's future economic direction, and that if it would be much easier to raise money from corporations and institutions if their contributions were seen as serving the interests of the State of North Carolina—i.e., the public interest, as opposed to the private interest.. Thus, he agreed to raise contributions, as opposed to soliciting financial investments. Further, the contributions were to be used to pay the Pinelands Company's borrowed debt ($415,000), finance the establishment of a research institute (estimated to be $500,000), and construct a building (estimated to be $250,000)[109].

Davis presented his proposal to the Committee in October, and they accepted it. On December 1st, he began his fund raising efforts. On January 9, 1959, Governor Hodges announced that Davis had raised $1.425 million. The funds would be used to acquire the land assembled by Pinelands, pass control of this enterprise to the recently constituted non-profit Research Triangle Foundation of North Carolina, establish the Research Triangle Institute, which would serve as a centerpiece for the park, and, finally, to be used for doing contract research for business,

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[106] Ibid., pp. 3-4.
[107] Ibid., p. 4.
[108] Ibid., p. 4.
[109] Ibid., p. 4.

industry, and government, and for constructing a building to house the Foundation and Institute in the middle of the Research Triangle Park[110].

Research Triangle Park: Open for Business (But Business Was Slow)

The Park got off to a slow start. Although Chemstrand Corporation announced its decision to relocate from Decatur, Alabama to the Park in May 1959 (making Chemstrand and the Research Triangle Institute the first two anchors), for the next five years the Foundation had little success in attracting companies. In fact, the Foundation borrowed $1.3 million to redeem outstanding shares in Pinelands, to purchase additional tracts of land, and to sustain Park operations[111].

The Turning Point

The turning point for the Park was in 1965. The announcements of two new significant tenants marked the beginning of the Park's sustained growth. The first, announced on January 6th by Governor Terry Sanford, was that the U.S. Department of Health, Education, and Welfare (HEW) had selected the Research Triangle Park for its $70 million National Environmental Health Sciences Center. The second, announced by Governor Dan Moore on April 14th, was that IBM would locate a 600,000 square-foot research facility on 400 acres in the Park[112].

In early 1974, there was a key event that distinguished Research Triangle Park from all other science parks in the World. Archie Davis, in his role as President of the Foundation, charged the leadership of Duke University (President Terry Sanford) and the University of North Carolina (President William Friday) to formulate a plan to ensure the continued presence of the three sister institutions in the Park. Since the Park began with those three institutions at its core, their continued presence would be needed for its ultimate prosperity. As a result of their discussions, the committee decided that the Foundation would donate approximately 120 acres of the campus for housing organizations that could bring together faculty from the three universities and Park scientists to work collaboratively. The "park within a park" was to be called the **Triangle Universities Center for Advanced Studies, Inc.** (TUCASI)[113].

Thanks to Davis's vision and leadership, and that of Sanford and Friday (and others over the years), there are today six organizations on the TUCASI campus[114]:

- National Humanities Center
- Microelectronics Center of North Carolina
- North Carolina Biotechnology Center
- Sigma Xi
- National Institute of Statistical Sciences
- Burroughs Wellcome Fund

[110] Ibid., p.4.
[111] Ibid., p.5.
[112] Ibid., p.5.
[113] Ibid., p.5.
[114] Ibid., p.5.

These organizations are an outward reflection of the universities' core values and, as such, TUCASI is an intangible asset that makes Research Triangle Park unique and helps attract new organizations into the area.

2. Factors Unique to Each Case

There are, of course, factors that are unique to each science city that cannot be replicated in another region. Its very location cannot be replicated. The features, including the geography, of Santa Clara County are unique to that place and cannot be transplanted to Boston, Washington, or North Carolina. In addition to a unique geographic location, each has its own history and culture, and each had a critical individual or group that was instrumental in rallying the necessary resources to realize a vision they had for the future of their region. In each case, the individual or group that sought to ensure the economic vitality of their region was motivated by an emotional, physiological, social and economic commitment to future of the area.

Individuals critical to their region's development were the unique personalities of Professor Frederick Terman, sometimes called "The Father of Silicon Valley;" President Karl Compton of MIT; Brandon Hodges, the State Treasurer of North Carolina; Robert Hanes, the President of Wachovia Bank and Trust Company; and Romeo Guest, a Greensboro building contractor who some say gave birth to the idea of a research park in the Triangle area. However, in the case of Washington D.C., true to its unique characteristics, the "critical individual" was the Federal Government, particularly two agencies: DARPA and the National Institutes of Health. Each one of the "individuals" or groups that changed the fortunes of their regions was a product of their region and the set of circumstances that came together at that point in time to thrust them into their pivotal roles.

The presence of unique institutions also played critical roles in the success of these science cities. Again, as mentioned above, it was the Federal Government that played the critical role in Washington's case. However, it was a unique academic institution that was critical for success in the cases of Boston and Silicon Valley: MIT in Boston's case, and Stanford University in the case of Silicon Valley. At the time they played their critical roles in their regions' economic development, nothing like these two universities existed anywhere else in the U.S. and they were different from each other in many respects. In addition, the Boston area's approach was initiated by the six New England states forming a council to approach development from a region-wide perspective. This was a product of the New England region's unique characteristics. As for Research Triangle, it was the collaboration among several institutions, including three universities (two public, one private) and a bank that characterized that area's unique approach to local-regional development. Another unique feature of Research Triangle Park is its focus on attracting the R&D facilities of existing firms, whereas the other three pursued a path of spawning new firms and products and industries, rather than attracting existing firms' operations.

Finally, there were those events that were unique to a given region, that just could not be foreseen, because they arose out of the distinctive sets of dynamics that resulted from the interaction of individual personalities under a given set of circumstances. In that sense, they are the product of serendipity. They arose out of the social connections and interactions specific to a given time and place. A case in point is the dispute between William Shockley, inventor of the transistor and founder (along with several fellow graduate students) of Shockley Semiconductor. Shockley had a strong preference for germanium, but engineers Gordon Moore, C. Sheldon Roberts, Eugene Kleiner, Victor Grinich, Julius Blank, Jean Hoerni and Jay Last chose silicon as the more appropriate semiconducting material, which in turn led them to leave Shockley in 1957. Robert Noyce, who had worked for a short time for Shockley as well, joined the seven engineers and in 1958 they founded *Fairchild Semiconductor* in Mountain View. It subsequently became the first company to successfully mass manufacture a micro-sized device capable of integrating large numbers of electrical "on-off" switching functions, stored in simple memory cells, all etched onto a silicon chip (i.e., the *integrated circuit*). They were the first to manufacture exclusively in silicon and it was Fairchild that was the basis for a lot of spin-offs and start-ups such as Intel, Signetics (now Philips Semiconductors), National Semiconductor and AMD. It was these companies that put the "silicon" in Silicon Valley.

3. Common Factors Shared by All Four Cases

As noted in the historical sketch of the birth and development of Research Triangle Park, when the first meetings got under way to discuss the idea of a research park, the group did not look to Silicon Valley or Route 128 for guidance, as there was a folk wisdom that Route 128 and Stanford Research Park were not planned, but rather just happened, so there was no clear path to follow. This, of course, was a myth. Though there are certainly unique aspects of the rise of each one of the four science cities that cannot be transplanted to another region, there are many important features that each one shared, and can, in fact, be used to guide economic developers and policymakers in their own efforts to build science cities as a path to creating a dynamic regional economy. Table C, in Appendix C, will serve as a framework for discussing those characteristics common to all four science cities. Six common characteristics are featured in Table C. Although they are not intended to be exhaustive, they do seem to have played a significant role in the birth and evolution of the science-based clusters that currently define these four regions. These six common characteristics are:

- The region faced a problem or crisis.
- An individual, or group of individuals, took the lead in trying to solve the problem or crisis.
- A local institution, or institutions, played a critical role in generating regional economic renewal.
- The region pursued an economic development strategy based on technology transfer and science-based growth.
- The region developed an ecology that fostered entrepreneurial activity.
- In the initial stages, regional inter-firm networks developed along the Social Network type of industry cluster (Based on the typology suggested by McCann, Arita, and Gordon; 2002).

The region faced a problem or crisis.

In each case, the future science city faced a problem or crisis, and the response to that problem or crisis ultimately led to the birth, or re-birth, of the regional economy.[115] Professor Terman, at Stanford, did not face a crisis, as much as he perceived that there was a problem. Talented

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[115] As a note of interest, the logograph for "danger" plus the logograph for "opportunity" does *not* equal "Crisis" in Chinese (whether Mandarin or other Sinitic languages). Victor H. Mair, *Danger + Opportunity ≠ Crisis* < **http://www.pinyin.info/chinese/crisis.html** > accessed on January 16, 2007.

Stanford graduates were going off to the East Coast because there were no opportunities for them in the region, an agricultural center, at the time. He then set out to solve the problem, which ultimately led to the Silicon Valley science city. The remaining three sciences cities all faced crises. Economic decline was the crisis faced by Boston and North Carolina, and a tectonic shift in federal policy, in the case of Washington. As a consequence of these policies, federal employment became less secure, and employment conditions and future prospects deteriorated, and compensation levels for the members of the senior service declined. Many of the affected individuals were the victims of *location inertia*—they had strong ties to the local region.

In each case, the region was forced to re-think its economic identity. Past successes, or mainstays, were no longer working. It was clear that a new direction was needed. It was the response to the perceived problem, or crisis, that led to the birth, or re-birth, of the region's economic vitality.

An individual, or group of individuals, took the lead in trying to solve the problem or crisis.

As noted above, it was Professor Fredrick Terman at Stanford that took the lead to solve what he perceived as a problem. He encouraged some of his students to develop and commercialize their inventions, and to start companies near the university. Among these students were William Hewlett and David Packard. He helped them design their audio-oscillator and encouraged them to commercially produce it. In 1937, they started their company in the famous garage in Palo Alto. Their audio-oscillator became the basis for a later deal with Walt Disney Studios in 1939, for the film "Fantasia". In addition, William Hansen, Professor of Physics, teamed with Sigurd and Russell Varian to develop the klystron tube, an electron tube in which bunching of electrons is produced by electric fields and which is used for the generation and amplification of ultra-high frequencies. It was instrumental in the development of radar.

Critical to the birth and development of Boston-Route 128, was the six New England governors who formed the New England Council to study the feasibility of revitalizing the Boston Area's declining economic base. The Council recruited Karl Compton, President of MIT, as a member of the New England Council. This was a critical and important move. President Compton extrapolated instances of firm formation by MIT professors into a vision for a new wave of technical industry. Because of respect for his personal qualities and scientific achievements, his prestige as head of MIT, and pride in the region's educational and research institutions, Compton gained an audience for his ideas. In essence, he conceived the idea of knowledge-based growth and development.

As for Research Triangle Park, the original impetus for what would become the Park was in early 1954, when Brandon Hodges, the State Treasurer of North Carolina, Robert Hanes, the President of Wachovia Bank and Trust Company, and Romeo Guest, a Greensboro building contractor, who some say, gave birth to the idea of a research park in the Triangle Area, met to discuss North Carolina's need for industrial growth.

Washington was different from the other three science cities, in this regard. In the case of the Capital region, it was federal policy and legislation, in conjunction with the presence some key Federal agencies, such as the NIH and DARPA, that "got the ball rolling" in the region. There was no specific individual, or group of individuals, as there were in the other three instances. In Washington's case, the "individual, or individuals" were institutions and legislation. The process began during the Carter Administration, with the significant downsizing in Federal employment that continued during the Reagan Administration.

A local institution, or institutions, played a critical role in generating regional economic renewal.

Though other academic institutions, such as the California Institute of Technology (CalTech), have played a role at one time or another in the development of Silicon Valley, it is Stanford University that has played the critical role. Founded in 1891 by Governor Leland Stanford at his estate near 'El Palo Alto' (the high tree), he dedicated it to the memory of his son Leland Stanford Junior. Later, it was especially in the 1920's that administrators at Stanford sought to improve the prestige of their institution by hiring highly respected faculty members from East Coast universities. During the 1950's, Stanford introduced a lot of new ways of working as a University (which were revolutionary for that time), which included:

- **The Honors Cooperative Program**: graduates could be updated in their specialty
- **The Stanford Research Institute** (1946): practice focused, non-profit research, which didn't fit within the traditional tasks of a university
- **The Stanford Industrial Park** (1951): offering facilities for starting companies

Critical to the early stages of the development of the Boston-Route 128 science city was the Massachusetts Institute of Technology (MIT), which was founded in 1862. William Barton Rogers, MIT's founder, envisioned the Institute as a source of new industrial technology from fundamental research. However, his vision was realized only gradually as a lack of resources forced MIT to function as an engineering teaching college until the end of the 19th Century when it began to develop research and an entrepreneurial culture as a unique industrial variant of the land grant universities established in each state to support the development of agriculture, the nation's major industry at the time. The land grant schools focused on practical subjects rather than the classic liberal arts, although the latter were also included in the curriculum. MIT was designed as a technological university to train students and infuse new ideas into the region's industrial economy. However, it was also envisioned that would conduct basic research and pursue those liberal arts with technological relevance, like the history of science and technology. Further, MIT's academic model was broader than specialized engineering schools of the era, such as West Point with its military focus, or Rensselaer Polytechnic Institute (RPI), with its civil-engineering focus, particularly on infrastructure projects like the Erie Canal. In founding MIT, Rogers drew upon the European polytechnic tradition. This expanded the idea of an academic institution from an agriculture focus to an emphasis on technology-transfer to the industrial sector, with a mission to transfer technology from "the lab to the market." This would prove critical for the development of a knowledge-based economy.

Although the University of North Carolina, North Carolina State University, and Duke University were not revolutionary academic institutions in the sense of MIT or Stanford, they were nevertheless critical to the idea, and the actual birth and development, of Research Triangle Park. In fact the three closely located universities inspired the very name of the research park. In addition to the three universities, executives from Wachovia Bank and Trust also played major roles in the establishment of Research Triangle Park.

Academic institutions would play an important role only at later stages of the development of the Capital region's high tech clusters. In the embryonic and take-off stages, it was the federal R&D-oriented agencies that played the critical role in the development of Metro Washington's biotech and ICT clusters. The presence of NIH in the Washington region is a defining characteristic for the region's biotech cluster. It employs a large number of researchers at its home campus in Bethesda, MD. NIH has been a spawning ground for new start-ups over the last 10-15 years. Other government agencies such as the Walter Reed Army Institute for Research (WRAIR) and the U.S. FDA have also been a significant source of biotech entrepreneurs. Critical for the development of the ICT cluster has been the presence of the Defense Department, and its R&D agencies. The modern computer networking technologies that are the backbone of the Internet and ICT emerged in the early 1970's from ARPANet, which was developed at the U.S. DOD Advanced Research Projects Agency (DARPA, known then as ARPA). Individuals leaving the Defense Department and the military services formed the first start-ups. In addition, individuals from private industry, both within the region and from without, figure prominently in the development of this cluster.

The region pursued an economic development strategy based on technology transfer and science-based growth.

In addition to Professor Terman's assistance in the design of Hewlett and Packard's audio-oscillator in 1937, William Hansen, Professor of Physics, teamed with Sigurd and Russell Varian to develop the klystron tube, an electron tube in which bunching of electrons is produced by electric fields and which is used for the generation and amplification of ultra-high frequencies. During World War II, the Varian brothers worked rent free in a Stanford lab on their klystron tube. Later on, radar and Varian Associates' (1948) inventions involving microwave radiation evolved. Stanford gave them, besides rent free lab use, $100 for supplies. In return, Stanford was to share in any profits. The investment of Stanford was one of the best ever because it brought in several millions of dollars in royalties. Also, during World War II Professor Terman made good contacts within Washington. After his return to Stanford, he succeeded in getting a lot of governmental contracts for Stanford and local companies.

The knowledge-based approach to regional economic development got its start in Boston after the region faced industrial decline in the beginning of the 20th century. When the conventional approaches failed, the New England Council explored a series of alternatives based on the knowledge resources of the region. The focus gradually shifted from incrementally improving existing firms to a discontinuous approach; that is, creating new industries. The Council recognized early on that a concentration of academic and industrial research laboratories was New England's competitive advantage. The initial idea was to encourage the formation of small firms. The Council's "New Products" committee, established to assist existing firms, turned to the more far-reaching idea that New England's intensive research universities could substitute for the natural resources that the region lacked. This approach foreshadowed a completely new perspective on how to think about comparative advantage. Rather than being predicated on Ricardo's idea of comparative advantage based on natural resource endowments and unskilled labor, the committee's approach was based on the deliberate and directed development of comparative advantage based on the regional concentration of a *produced* resource: *human capital*. This knowledge-based strategy of regional advantage and economic development foreshadowed, by 80 years, Gomory and Baumol's (2001) concepts of *acquired comparative advantage* and *retainability*, as well as modern regional economic development theory with its emphasis on the *strategic management of places*. Much of the model of university-based economic development was derived from the activities of Vannevar Bush, an electrical engineering professor and then Dean and Vice-President of MIT. Bush was a prototypical entrepreneurial academic, combining in a very effective manner both intellectual and commercial interests in the course of his career.

Unlike Boston-Route 128 and Silicon Valley, the U.S. Capital region's move to science-based growth, predicated on technology transfer was exogenously imposed, as opposed to policies developed by individuals and institutions indigenous to the region. The changes in employment structures and incentives were coupled with new opportunities for the commercial exploitation of intellectual property rights that accrued from publicly funded research. These new structures and incentives were, in turn, the result of changes in federal policy and legislation that created a pool of educated, unemployed workers in the Metro Washington region. This, in conjunction with new opportunities for the private sector to contract with the Federal Government and commercialize new technologies, motivated many former government employees and contractors to respond to the crisis by starting up new firms. These legislative changes created new commercial opportunities that have lured many scientists into starting their own companies and thereby facilitate the process of technology transfer.

Unlike the other three science cities, Research Triangle Park would approach knowledge-based economic development from a different perspective. Instead of creating new firms and products, the founders' vision of the Park was a place to attract the R&D operations of existing firms. They believed that, due to the close proximity of the three universities, they would provide "…a wellspring of knowledge and talents for the stimulation and guidance of research by industrial firms." Further, their approach was new in the sense that they were attempting to get existing firms to geographically separate their R&D facilities from the other stages of production. Up until then, most firms in most industries located their R&D facilities near their production sites. The idea that one location would specialize as the site of R&D was a new idea (see discussion below on the fifth common characteristic in Table C).

The region developed an ecology that fostered entrepreneurial activity.

Stanford Professor Fredrick Terman was concerned that a lot of his graduates went to the East Coast because of the lack of jobs in the Valley. To solve that problem he started to encourage some of his students to start companies near the university. Among these students were William Hewlett and David Packard. In the mean time, some other students founded small companies that were going to be the center of a local electronics industry. So, not only did Professor Terman help in design problems of a technical nature, but he also encouraged entrepreneurship in the Silicon Valley region right from the beginning. Another builder of the region's entrepreneurial culture was William Hansen, the Stanford Physics Professor who teamed with Sigurd and Russell Varian to develop the klystron tube. As noted earlier, Stanford encouraged their entrepreneurial activity by giving the Varian brothers rent free lab use and $100 for supplies in return for a share in any profits they realized.

An entrepreneurial focus was evident in the development of Boston's knowledge-based economy. MIT President Karl Compton, a New England Council member, extrapolated instances of firm formation by MIT professors into a vision for a new wave of technical industry. In addition, much of the model of university-based economic development also came from MIT. In particular, Vannevar Bush, an electrical engineering professor and later dean and vice-president of MIT, was instrumental in connecting the university with entrepreneurial activity. Bush was a prototypical entrepreneurial academic, combining in a very effective manner both intellectual and commercial interests in the course of his career. Nevertheless, though New England had capital and technology and creative leaders like Compton and Bush, it still lacked the financial infrastructure for funding higher-risk start-up ventures to bring new technology from the lab to the market. In response, immediately after World War II, Compton organized a consortium of universities, investment banks, and insurance companies to found the first venture capital firm, *American Research and Development* (ARD), through the sale of equity in the firm. The organizational design and staffing of the project were derived from MIT and Harvard Business School. Technological opportunities were enhanced by World War II R&D projects focused at universities and expanded after the War into civilian as well as military fields. ARD's initial success, after a decade of investments, was the Digital Equipment Corporation (DEC), based on a Navy research project to develop a pilot training device.

Entrepreneurial activity in the Metro Washington region came about from the most unlikely of circumstances, and it contradicted the conventional wisdom about who entrepreneurs are and what conditions foster entrepreneurial activity. The earliest start-up, biotech firms, in the Metro Washington region, were those started by individuals who had previously been employed by prominent suppliers to, or former Federal employees of, the National Institutes of Health (NIH). The presence of NIH in the Washington region is a defining characteristic. It employs a large number of researchers at its home campus in Bethesda, MD. NIH has been a spawning ground for new start-ups over the last 10-15 years. The modern computer networking technologies that are the backbone of the Internet and ICT emerged in the early 1970's from ARPANet, which was developed at the U.S. DOD Advanced Research Projects Agency (DARPA, known then as ARPA) Individuals leaving the Defense Department and the military services formed the first start-ups. In addition, individuals from private industry, both within the region and from without, figured prominently. Entrepreneurs hailed from a variety of different organizations. Government agencies served an important incubator function in both industries, though they were not the sole source of entrepreneurial talent. There is evidence of a great diversity in the backgrounds of the entrepreneurs. Over time, new generations of new firms spun-off from the earliest start-ups and entrepreneurs who cashed in from one new venture created other new companies.

As previously mentioned, the Research Triangle Park followed a different path than the other three science cities studied here. The idea of using the three triangle universities to attract research companies into a park area central to the universities quickly emerged from the early discussions. Thus, there was not the emphasis on entrepreneurship and new firm formation. Rather, the emphasis was on attracting the R&D facilities of existing firms. Nevertheless, this approach was still new at the time. Manufacturing firms tended to have their R&D facilities near their production facilities. The idea of spatially separating these activities, and concentrating the R&D facilities of different firms from different industries in one location to tap into externalities and economies of scale and scope, was a new idea. Further, the founders of Research Triangle Park recognized the now frequently followed policy of basing the future economic fortunes of the region on being the location for the high-end, high-skilled, earlier, pre-standardization, stage of the production and product cycle.

In the initial stages, regional inter-firm networks developed along the social network type of industry cluster (based on the typology suggested by McCann, Arita, and Gordon; 2002).[116]

McCann, Arita, and Gordon (2002) identify three distinct types of industry clusters, based on the *transactions costs* approach. Their typology and characteristics are reproduced in Table 2, below. The three distinct ideal types of spatial industrial clusters, ***pure agglomeration,*** the ***industrial complex,*** and the ***social network***, are classified according to the nature of the relations between, or among, the firms within the cluster. In the model of *pure agglomeration*, inter-firm relations are inherently transient. Firms are essentially atomistic, that is, they have no market power, and they continuously change their relations with other firms and customers in response to market arbitrage opportunities. The pure agglomeration environment leads to intense local competition. Consequently, there is neither loyalty between firms, nor are there any particular long-term relations. The external benefits of clustering accrue to all local firms simply by reason of their local presence. The cost of membership to this cluster is the local real estate market rent. There are no free riders, access to the cluster is open, and consequently it is the growth in the local real estate rents that is the indicator of the cluster's performance. The notion of space in these models is essentially urban space in that this type of clustering only exists within individual cities.

[116] McCann, Arita, and Gordon, *Industrial clusters, transactions costs and the institutional determinants of MNE location behaviou*r, INTERNATIONAL BUSINESS REVIEW 11 (2002), 647–663.

TABLE 2: Three Types of Industry Clustering

(Based on McCann et al.'s Transactions Cost Approach)

CHARACTERISTIC	TYPE OF CLUSTER		
	PURE AGGLOMERATION	**INDUSTRIAL COMPLEX**	**SOCIAL NETWORK**
FIRM SIZE	Atomistic	Some firms are large.	Variable
RELATIONSHIPS	Non-Identifiable; Fragmented and Unstable	Identifiable; Stable; Trading	Trust; Loyalty; Joint Lobbying; Joint Ventures; Non-Opportunistic
MEMBERSHIP	Open	Closed	Partially Open
CLUSTER ACCESS	Rental Payments; Location Necessary	Internal Investment; Location Necessary	History, Experience; Location Necessary, but not Sufficient
SPATIAL OUTCOMES	Rent Appreciation	No Effect on Rents	Partial Rent Capitalization
NOTION OF SPACE	Urban	Local, but not Urban	Local, but not Urban
EXAMPLES	Competitive Urban Economy	Steel or Chemicals Production Complex	New Industrial Areas
ANALYTICAL APPROACHES	Models of Pure Agglomeration	Location-Production Theory; Input/Output Analysis	Social Network Theory (Granovetter)

SOURCE: McCann et al., 2002, Table 1, p. 650.

The *industrial complex* is characterized, primarily, by long-term stable and predictable relationships among the firms in the cluster. This type of cluster is most commonly observed in industries such as steel and chemicals. The industrial complex is the type of spatial cluster typically discussed by classical and neo-classical location-production models, which represents a fusion of locational analysis with input/output analysis. Component firms within the spatial grouping each undertake significant long-term investments, particularly in terms of physical capital and local real estate, in order to become part of the grouping. Access to the group is therefore severely restricted both by high entry and exit costs. The rationale for spatial clustering in these types of industries is that proximity is required primarily in order to minimize inter-firm transport, transactions costs. Rental appreciation is not a feature of the cluster because the land, which has already been purchased by the firms, is not for sale. The notion of space in the industrial complex is local, but not necessarily urban, in that these types of complexes can exist either within or outside of an individual city. The industrial complex model is actually the single explicitly spatial element in the transactions costs approach of Williamson, where the focus is on the types of flow-process scale economies that firms can realize by being part of vertically integrated production complexes. It is this framework that has served as the basis for policies that are aimed at fostering industrial enclaves, particularly in developing economies[117].

The third type of spatial industrial cluster is the *social network* model. This is associated primarily with the work of Granovetter (1973) and is a response to the hierarchies model of Williamson (1975). The social network model of clustering is based on a foundation of mutual trust relations between key decision-making agents in different organizations. Particularly, these trust relations may be at least as important as decision-making hierarchies within individual organizations. They will be manifested by a variety of features, such as joint lobbying, joint ventures, informal alliances and reciprocal arrangements regarding trading relationships. However, the key feature of such trust relations is an absence of opportunism in that individual firms will not fear reprisals after any reorganization of inter-firm relations. Inter-firm cooperative relations may therefore differ significantly from the organizational boundaries associated with individual firms and these relations may be continually reconstituted. All of these behavioral features rely on a common culture of mutual trust, the development of which depends largely on a shared history and experience of the decision-making agents. This social network model is essentially aspatial, but from the point of view of geography, it can be argued that spatial proximity will tend to foster such trust relations, thereby leading to a local business environment of confidence, risk taking and cooperation. Spatial proximity is necessary but not sufficient to acquire access to the network. As such, membership of the network is only partially open in that local rental payments will not guarantee access, although they will improve the chances of access. The geographical manifestation of the social network is the so-called “new industrial areas" model. In this model, space is, once again, local but not necessarily urban[118].

As McCann et al point out, in reality, all spatial clusters will contain characteristics of one or more of these ideal types, although one type will tend to be dominant in each cluster. They then turn to applying their framework to the spatial and organizational issues of the much-discussed semiconductor industry. McCann et al then recount the industry-related issues surveyed in the literature including the advantages of industrial clustering for internationally competition, which focus on the geographical aspects of the U.S., and in particular the Silicon Valley, semiconductor

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[117] McCann, et al, pp. 650-651.
[118] McCann, et al, pp. 651-652.

industry, the important role that informal local information spillovers have played in the development of the semiconductor industry, and the advantages associated with a high quality and highly flexible local labor market for the industry's competitive advantage. In these clusters, the means by which both firms and the local industry evolve are largely non-price mechanisms in the sense that information and labor market externalities play a key role, as do certain 'trust' relationships between local firms, if and where they exist. In terms of their cluster classifications, McCann et al, place Silicon Valley in the primarily a *pure agglomeration* category, with some aspects of a *social network* (see Table 2, above). They then point to the literature that has questioned the empirical validity of some of these arguments. Despite this, this type of industrial clusters is perceived to be the ideal spatial and organizational arrangement for 21st century innovative industries. However, McCann et al, find it difficult to translate Silicon Valley clustering arguments to the case of multi-plant and multinational firms because the simple clustering arguments are predicated on completely different principles to Multinational Enterprises (MNE). The basic principles underlying the clustering arguments is that the presence of local information spillovers and a highly flexible labor pool allows firms to efficiently and rapidly restructure their internal organizations and inter-firm relations in order to optimally respond to the continuously changing technological and competitive economic environment. These continuous structural innovations are assumed to allow for the maximum level of product and process innovations. Any previous advantages accruing to large multi-plant, and multinational organizations by way of hierarchical decision-making structures, is assumed to have been largely superseded by spatial clusters. That is, decentralized, flexible and autonomous firms, which are able to share information and rapidly restructure their relations accordingly[119].

Given the above arguments, McCann et al. take issue with the characterization of the semiconductor industry, the very identity of Silicon Valley, as fitting the pure agglomeration type with social network aspects.

> The currently popular arguments outlined here, regarding the presumed incompatibility between hierarchical multi-plant and multinational firms and industrial clusters, are very limited in their general applicability to most sectors or locations. The reason for this is that the clusters literature is based on a very narrow and stylized description of the optimal relationship between spatial and industrial organization. As we have seen, referring to Table 1, these cluster models are characterized by a combination of the model of 'pure agglomeration' along with, possibly, aspects of the 'social network'. Yet, this cluster literature generally ignores the possibility that other institutional arrangements, such as the 'industrial complex' arrangement described in Table 1, may not only be optimal in many innovative industries, but may also be widespread in reality. Even more surprising, this clusters literature ignores the possibility that institutional arrangements such as the 'industrial complex' may actually be optimal in the case of the semiconductor industry. The importance of this oversight is that the 'industrial complex' model provides an obvious rationale for industrial clustering on the part of multi-plant and multinational firms in cases where the firm wishes to use location as a means of maintaining control and internalizing information within a defined group rather than sharing it with the local industry in general. In other words, industrial clustering can be a means of internalizing externalities and avoiding non-market signals within the well-defined organizational boundaries typical of multi-plant and

[119] McCann, et al, pp. 651-653.

multinational firms, and yet can still be entirely compatible with the existence of a dynamic and innovative industry.[120]

The point is well taken and, in fact, the chemical and pharmaceutical industries, historically characterized by significant investments in R&D and innovation,[121] are oligopololistic, with large firms and clustering that follows along the industrial complex type, as described by McCann et al. in the above passage. In fact the industrial complex has characterized the chemical industry almost right from its beginnings. However, much of the misidentification of the true inter-firm relations in many situations where spatial clustering is found may have more to do with a misunderstanding of the nature of clusters themselves. Clusters are not static; in most instances, they are dynamic and pass through phases as they evolve. Like, and probably due to, products, industries, and technologies, they have life cycles.[122] In some cases, clusters can abruptly die-off from technological discontinuities, or from gradual decline, ultimately resulting in their demise. The Silicon Valley emerging cluster in the 1930's did not resemble the Silicon Valley cluster of the 1980's, which, in turn, does not resemble the Silicon Valley of 2006. Though the large firm (relative to the size of the product market) organization of the chemical industry has pretty much characterized its structure throughout its history, the semiconductor industry, which has been a rapidly evolving industry, with some discontinuous jumps, has gone through a much more dramatic metamorphosis in its structure, and in a more compressed period of time. The relation among firms in the semiconductor industry changed as the technology changed and as the nature of the firms in the industry changed from entrepreneurial start-ups to vertically integrated multi-plant, multi-national firms. Social networks and fluid relations gave way to hierarchical structures characterized by formalized and standardized transactions. The clustering relationships took on the trappings of the industrial complex as the industry matured.

To illustrate this, Table 3 combines Tables 1 and 2 by matching up the idealized clustering type from Table 2 with the industry life cycle stages presented in Table 1 to suggest an evolutionary path that may describe the development of the semiconductor industry from its beginnings to its current state.

Clearly, when Shockley, one of the inventors of the transfer resistor, or *transistor*, and his colleagues started Shockley Semiconductor, it was an entrepreneurial venture. The semiconductor industry was at the first stage of its life cycle, as depicted in Table 3, the "Early Exploratory Stage." In fact, the split between Shockley and the "traitorous eight" over the best conductor, germanium, favored by Shockley, or silicon, favored by his eight colleagues, emphasized the trial-and-error phase of the industry's still embryonic stage of development at the time.

In addition, in regard to the motivation of the individuals involved to strike out on their own, this follows Arrow (1962). As discussed earlier, a divergence in the valuation of an idea between an individual knowledge worker, or team of knowledge workers, and the decision-making hierarchy of an incumbent firm forces the individual knowledge worker, or team of knowledge workers, to make a fundamental choice: either ignore the idea and redirect activities and work in a direction

[120] McCann, et al., p. 653
[121] Freeman and Soate, ECONOMICS OF INDUSTRIAL INNOVATION
[122] Karlsson, Charlie, Borje Johansson, and Roger R. Stough, *Industrial Clusters and Inter-Firm Networks: An Introduction*, in INDUSTRIAL CLUSTERS AND INTER-FIRM NETWORKS, Eds. Charlie Karlsson, Borje Johansson, and Roger R. Stough (2005) Edward Elgar: Northhampton, MA.

more compatible with the organization's goals, or appropriate the value of the new idea within an organizational context outside the framework of the incumbent firm by leaving that organization and starting a new firm. In this case, the "traitorous eight" left Shockley Semiconductor over their differences in their valuation of silicon over germanium.

TABLE 3: Suggested Changing Industry Life Cycle and Clustering Patterns for the Semiconductor Industry

STAGE	CHARATERISTICS	CLUSTER TYPE
Early Exploratory Stage	• Supply of a new product of a relatively primitive design • Manufactured on comparatively specialized machinery • Marketed through a variety of exploratory techniques.	Social Network
Intermediate Development Stage	• More refined manufacturing techniques • Market definition is sharpened • Output grows rapidly in response to: o Newly recognized applications o Unsatisfied market demands	A weakening Social Network developing some Industrial Complex Characteristics.
Mature Stage	• Management, Manufacturing, and Marketing reach advanced degree of refinement. • Markets grow at a more regular and predictable rate. • Established supplier/customer connections buffer changes and protect market shares. • Innovations are fewer and incremental.	Industrial Complex

SOURCE: Tables 1 and 2 in Section III.

After their split with Shockley, Moore, Noyce, and the other six engineers founded Fairchild Semiconductor. Since Shockley Semiconductor ultimately went out of business and Fairchild went on to spin off numerous new companies, among them Intel, National Semiconductor and AMD, it is clear that the industry had refined its manufacturing techniques and the semiconductor market was rapidly expanding, putting the industry into the "intermediate development" stage of the industry life cycle. As such, the type of clustering found would have moved from the purely social network type of relations to also taking on the trappings of an industrial complex as the industry evolved from being composed of start-up firms in the early stages of the technology/product cycle to a later stage of development characterized by larger, increasingly vertically integrated firms engaged in a more standardized mode of production.

Finally, the state of the semiconductor industry that McCann et al. observed in their 2002 research had clearly reached the "mature stage" of development where inter-firm relations were dominated by the industrial complex type of clustering. In fact, reaching the mature stage of the industry cycle and taking on some exaggerated characteristics of the industrial complex may have played a role in the demise of the minicomputer industry in the Boston area,[123] particularly those aspects of the industrial complex where "the firm wishes to use location as a means of maintaining control and internalizing information within a defined group rather than sharing it with the local industry in general."[124] DEC, Wang, DataGeneral, and other minicomputer firms migrated out to I-495 [125] where they lost communication with the academic community, centered in Boston and Cambridge, and became isolated from each other, both spatially and socially. Many located off of the highway in isolated spots and, in some instances, as far as 60 miles apart. Thus, they never saw their own mass extinction coming. Consequently, the cluster disappeared almost literally overnight. The minicomputer industry is a stark example of the complete life cycle of a cluster, from birth and development, to growth and maturity, then rapid decline due to obsolescence, and finally a swift death.

B. IS CLONING SILICON VALLEY AND ROUTE 128 THE ANSWER?

Given that the development of the four science cities studied in Part A involved unique aspects that were specific to each region, and given that some of the shared characteristics were stamped with the culture and history of each region's own particular set of circumstances, cloning Silicon Valley or Route 128 would be an impossibility. It is the unique aspects of a region that forms an important resource for that region to draw on for its strengths. Nevertheless, there were several features, recounted in Part A, that either a couple or, in some cases, all four science cities had in common, and it is these common characteristics that can be adapted, or modified, to reflect a given region's culture and history. It should be emphasized that these are not "hard and fast" rules, but flexible guideposts along a region's own unique path to transforming the local economy into a dynamic, knowledge-based competitor in the global market.

So what can other regions, facing their own industrial decline or other economic crisis, learn from the development of the science cities in Silicon Valley, Boston-Route 128, Metro Washington, and Research Triangle Park to guide them in their own strategies for economic

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[123] Buendia, Fernando, *Towards a System Dynamics-Based Theory of Industrial Clusters* in INDUSTRIAL CLUSTERS AND INTER-FIRM NETWORKS, Eds. Charlie Karlsson, Borje Johansson, and Roger R. Stough (2005) Edward Elgar: Northhampton, MA.
[124] McCann, et al, p. 653.
[125] I-495 is Boston's "outer" outerbelt, as opposed to the famous Route 128 (which is now also I-95), which is Boston's original Outerbelt.

revitalization? As discussed in Part A, in the cases of Silicon Valley, Boston-Route 128, and Research Triangle Park, there was an individual, or a group of individuals, that took the lead in reversing the economic slide of the region. In fact, one of the most striking similarities in the birth of Boston-Route 128 and Silicon Valley was the development of a social network, driven by a mentor, or mentors, who guided and encouraged students or other protégés to bring their basic research not only to the applied stage, but also to then go on and engage in entrepreneurial activity; that is, to cross the "innovation bridge" and transfer the technology to the market. This was due to the decision, consciously or otherwise, to use science-based knowledge to spawn new products, firms, and industries as the path to developing a dynamic regional economy. These two examples clearly support Audretsch's (1995) notion of inverting the model of the knowledge production function. As noted earlier, the conventional approach assumes that the firm exists exogenously and then, if large, undertakes the necessary investments, or if small, engages in strategic alliances, to endogenously create the knowledge required to innovate. Instead, Audretsch inverts the model and assumes that the *knowledge is exogenous*. Thus, new and potentially valuable knowledge does not exist abstractly "in the firm." Rather, it is embodied in people, either in individuals or in groups or teams of individuals. In the above two examples, this valuable knowledge was embodied in Stanford's Fredrick Terman and MIT's Karl Compton, as well as others. Hence, the adherence to McCann et al.'s social network clustering type at the early stages of the development of the two clusters.

Later, Metro Washington would develop two important clusters and science cities along similar lines—though it was Federal research institutions that played the facilitating role in the capital region. As previously discussed, Research Triangle Park embarked on a different path than the other three science cities.

In addition, two of the science cities considered here, Boston-Route 128 and Silicon Valley, were pioneers in developing and nurturing the technology transfer/entrepreneurial ecology found by Innovation Associates (IA) in the 10 model university-industry collaborations they studied in their report to Connecticut's Technology Transfer and Commercialization Advisory Board (see Section II of this report). The models selected by IA were particularly innovative or had exemplary qualities tied to commercialization, such as strong university-industry collaboration, entrepreneurial programs, incubators or research parks, seed/pre-seed initiatives, and innovation centers. Thus, subsequent successful science cities adopted, at least in part, some of the characteristics of Boston-Route 128 and Silicon Valley.

A final, and critical, characteristic common to all the successful science cities, not only in the U.S. and North America, but also in European and other developed countries, is the development of Etzkowitz's "Triple Helix" model[126] of *university-industry-government* relations that facilitates science-based regional economic growth. It is what generates the conditions for sustainable, high value-added growth, which concentrates on the early stage of the product/technology cycle where the volume of output is relatively low, there is a high degree of uncertainty, and the standardized, higher-volume stage of the product's production has yet to be worked out. It is at these R&D and prototype stages where high skilled, high wage workers are needed, as opposed to the lower-skilled, lower-paid workers characteristic of regions that have the comparative advantage in the later, standardized-production stages of the product cycle.

[126] Etzkowitz, Henry, *Making Science Cities: The "Triple Helix" of Regional Growth and Renewal* (September 23, 2005) Keynote Address to Science Cities National Workshop: York, U.K.

But how can a region's revitalization be sustained? The answer goes back to the introductory comments to this section, Section III, Sustainable Dynamism: Innovation as a region's "Leading Product."

C. WHAT HAS ALL THIS GOT TO DO WITH CONNECTICUT?

In the PowerPoint presentation of *Benchmarking Growth in Demand-Driven Labor Markets*, Point B, in Slide 7 ("Macro Effect on Local Economy"), states:

> Excess supply of unemployed or underemployed labor in a region implies a demand for **entrepreneurs**!

This is what it all has to do with Connecticut. Connecticut has a shortage of science-based entrepreneurial activity! Recall from Subpart B that one thing three of the four science cities had in common is their response to crisis in their regional economies.[127] Once the one or two industries that served as their economic base matured and declined, adopted a new generation of technology, or moved its routine/standardized stages of production to lower-cost locations,[128] the regions were faced with abandoned plant and equipment (i.e., *derelict capital*), declines in per capita income and GDP, and ultimately population loss. In each case, their labor markets were suddenly confronted with an excess supply of labor and out-migration. However, as the above citation indicates, this implied that there was also an excess demand for entrepreneurs. A strong common thread running through the successful responses to crises by the above studied science cities is the building of their economic regeneration on an entrepreneurial-based foundation, fueled by science-based growth. The framework for science-based growth is Etzkowitz's Triple Helix Model: the university-industry-government nexus.

Connecticut's crisis was sparked by the end of the Cold War, when the State's economies[129] were faced with the collapse of the market for their principal export: defense goods. On the heels of this shock to the export base, another export mainstay, insurance services, was shifting its back-office functions out of Hartford to lower-cost regions, such as Omaha and Des Moines, as the industry began a massive restructuring. The State's export base was shattered. As of 2006, no new economic driver has replaced the loss of defense-related manufacturing employment and the jobs at the more routine/standardized stages of insurance services production.[130] Consequently, except for the securities, commodities, contracts industry (NAICS 523),[131] centered in Fairfield County, which is a satellite of, and benefits from, the New York City economy, Connecticut's economic fortunes are tied to coattail effects of the movements in the U.S. economy. Such an economy cannot "take its own economic fate in its hands," but instead must passively rely on externally generated economic fortunes.

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[127] Of course, the fourth, Silicon Valley rose up out of a "Greenfield," that is, the Silicon Valley "science-city" economy supplanted the agriculturally-based economy that existed before it in Santa Clara County.

[128] In the case of Metro Washington, it was a sudden, tectonic shift in federal policy that resulted in an abrupt excess supply of highly skilled labor.

[129] The use of the plural is intentional here. There are, at least, three economies that are partially or wholly in the State.

[130] This is not to dismiss, or ignore, the casino jobs created by the tribal nations in New London county, but the leisure/tourism industry, for the most part, is not based on highly skilled, highly paid labor-inputs to produce its "product". Most of the jobs created are semi- to low-skilled.

[131] Dyer, Lincoln, *Connecticut's Investment Employment Rising*, Connecticut Economic Digest (March 2007).

Just as physicists must attain some critical threshold fission process to achieve a sustainable chain reaction, a regional economy must attain some critical mass of applied R&D and innovation, coupled with entrepreneurial activity, which leads to the development of new products, the pipeline to bring them to the market and create new wealth, and which achieves a sustainable "chain-reaction" of successive generations of spin-offs and further new innovations and products. Such economic chain reactions have been achieved, at one time or another, by the four "science cities" discussed earlier. This brings up the question: How can Connecticut create the conditions that will achieve such a self-sustained, economic chain-reaction? The answer to this question, with an emphasis on the role of workforce investment and labor market information, is addressed in Section VI. First, before discussing the role of workforce investment, the next section identifies one emerging and two potential science cities in Connecticut.

V. EMERGING AND POTENTIAL SCIENCE CITIES IN CONNECTICUT

A. AN EMERGING SCIENCE CITY: New Haven-Yale

The first possible Connecticut science city has already started to take shape. However, the emerging New Haven-Yale University science city is at a critical juncture. In recent years, Yale University has made a strong effort to work more closely with the New Haven community and has invested in revitalizing neighborhoods. This was critical in making the new cancer center a reality. Those strategies have made a demonstrable difference. The IA report recommends that the State, University, and community continue to work together to improve New Haven and make the area around the university a more attractive environment for entrepreneurs. IA's report to the technology transfer group also suggested that the State, in conjunction with the University, should examine building and infrastructure improvements to support incubation efforts at 300 George Street and in and around Yale Science Park. Another issue that was brought to the attention of IA investigators was the need for more air traffic into New Haven's airport in order to promote New Haven as a commercial center. The State should closely examine the potential benefits of infrastructure improvements around Tweed-New Haven Airport to facilitate airline access to New Haven.

Yale Science Park has had some negative history to overcome before being accepted by the University and the community. The resolution of the issues surrounding the construction of the cancer center went a long way toward repairing University-community relations. IA's report pointed out that the President's participation in recent events had been valuable; however, even more valuable would be to locate some labs or office space, or both, in the Science Park. This would make a statement of support for the Park and promote movement between the Park and the campus. Science departments located near the Park are the most likely candidates.

On the other hand, a recent development that further strengthens the emerging science city centered around Yale is the University's purchase of 137 acres of property and 1.5 million square feet of buildings in West Haven and Orange from pharmaceutical company Bayer HealthCare, which Bayer announced it would vacate by 2008 due to a corporate restructuring. The deal would increase the University's laboratory space by 550,000 square feet and, at least initially, will most likely house School of Medicine researchers. The complex of 17 buildings includes three large science research buildings constructed within the last decade. Yale University

President Richard Levin said that the deal would not affect the University's plans to add 2 million square feet of buildings in New Haven.[132]

B. TWO POTENTIAL SCIENCE CITIES

1. Storrs-UConn

The first of the two potential science cities in Connecticut, Storrs-UConn, has been discussed and considered for several years now, but it has never gone beyond those stages. To be sure, there have been several studies that have identified the significant potential, including the Innovation Associates report to the Technology Transfer and Commercialization Advisory Board of the Governor's Competitiveness Council. As the technology transfer report points out, most major state universities now have a research park located at the university (Purdue, University of Wisconsin-Madison, Georgia Tech, and now Yale University with its recent purchase of the Bayer campus). The report suggests that a research park at UConn would add a "technology presence" to the university and provide a site for expanding incubator tenants. Though previous studies addressed this issue, IA noted that those studies were, by then, outdated and did not take into account then current circumstances. In addition, since IA's report to the technology transfer group, a significant development has taken place in Storrs. This will be discussed later.

IA recommended that a new feasibility study be conducted that includes identification of potential anchors, requirements of the potential anchors, and possible incubation space incorporated as part of the park. Federal funds (such as EDA) could be explored to support a feasibility study and later to help fund infrastructure. However, two other obstacles also stand in the way of the development of a science city centered around UConn and Storrs. The first is access; the second is the absence of a town center in Storrs. Due to recent developments, the issue of the lack of a town center will be addressed first.

As of fall 2006, pending zoning approval, construction of a building to house temporarily relocated businesses was to begin. It was to be the first phase in the development of Storrs Center.[133] A village center has long been an issue in the Storrs area. In the 1970s, the Town's Plan of Development recognized the need for a "downtown" in the area. In several surveys, the students of UConn indicated that the lack of a downtown detracted from their overall university experience. University leaders have long bemoaned that the university is not near a vibrant downtown, unlike its major competitor, the University of Massachusetts (with its proximity to Amherst). Meanwhile, the relationship between the Town and the University deteriorated during the previous two decades, largely over conflicts of land use. These issues came to a head in the 1990s as the University began its expansive UConn 2000 project, funded by $1 billion in state funds.[134] However, due to a process that was transparent and inclusive of the community, a plan to construct a town center was developed and it gained the approval of the Town, the landowner (the University of Connecticut), and the citizenry. It now appears that the critical problem of a lack of a downtown, or town center, is now being addressed. Once completed, it should greatly enhance the attractiveness of the Storrs-UConn area, which is critical to recruiting outstanding

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[132] Hill, Tyler, *Yale buys Bayer labs in West Haven*, YALE DAILY NEWS, Wednesday, June 13, 2007
[133] Toledano, Macum C., *Sharing a Vision for a New Storrs Center*, STORRS CENTER, Vol. 1: 2006 and Jones, Maggie, *Mansfield CT: Planning a New Village Center*, in the New England Environmental Finance Center's NEXT COMMUNITIES INITIATIVE, Richard Barringer, ed., Edmund S. Muskie School of Public Service, University of Southern Maine, Portland ME, August 2006.
[134] Jones (2006), Footnote 37.

faculty and students, and to providing an environment attractive for entrepreneurs to locate future University-based spin-offs and start-ups.[135]

The problem of access still remains. Wrangling over extending what is now I-384, or the "Route 6 highway," has stalled for decades the construction of a major highway that could be easily accessed by the Storrs-UConn area. In addition, I-84 is several miles to the north and can only be accessed by a two-lane road (Route 195), which cannot handle the traffic during peak load periods. Without access, attempts to develop a science city in the Storrs-UConn area would be limited at best (i.e., Location! Location! Location![136]).

2. Hartford-RPI-UConn-CCC

The second potential Connecticut science city, Hartford-RPI-UConn-Capital Community College (and the third emerging, or potential, science city), is not even on the "radar screen." It is the most overlooked, and it would be at least five years to a decade into the future before all the pieces came together, but the process of bringing it about should begin as soon as possible. There is already an example of cooperation between a university and the community in Hartford: the Learning Corridor[137] centered around Vernon Street. Plans for the Learning Corridor were unveiled in 1996, following a decision by Trinity's Board of Trustees to commit $5.9 million from the College's endowment to launch a $175-million neighborhood revitalization plan.[138] However, the scale of the current proposal is even larger. The biggest, immediate step that needs to be taken is to "connect the dots," and the "dots" are there. They are: the City of Hartford, RPI-Hartford, the UConn-Downtown Campus, and Capital Community College (CCC). "Connecting" them will take some time, effort and resources, but the payoff could be substantial.

There is a potential for Hartford to look at the cooperation between Carnegie-Mellon and the University of Pittsburgh, across the street from each other in Pittsburgh, to develop the link between technology transfer and entrepreneurship by drawing on each university's strengths to complement their unique contributions to knowledge-based economic activity in the region's economy.[139] Though not across the street from each other, RPI-Hartford and the UConn-Downtown Campus are, nevertheless, both located fairly close to each other in downtown Hartford. However, it should be noted that I-84 currently acts as a barrier cutting off the RPI campus from the rest of downtown (including the UConn-Downtown Campus). Nevertheless, the potential for RPI-UConn collaboration is still significant. In addition, Capital Community College (CCC) also has a role to play by coordinating the first two years of business and technical and engineering degrees with the two four-year institutions (RPI and UConn-Downtown) allowing students to transfer directly from CCC to RPI or UConn. In addition, CCC also provides two-year business and technical degrees.

Corresponding to the science and engineering specialties of Carnegie-Mellon could be RPI-Hartford. This would require working with the RPI administration on the main campus in Troy to

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[135] It should be noted that the planned construction of the temporary building to house affected businesses while the project is underway, which was to begin in the fall of 2006, was delayed and as of June 2007 construction had not yet begun.

[136] Or, should it be "Access! Access! Access!"

[137] For information on the Learning Corridor, go to their website at: **http://www.learningcorridor.org/**

[138] *The Learning Corridor Opens for Learning*, THE TRINITY REPORTER **http://www.trincoll.edu/pub/reporter/W01/Corridor.htm**, accessed on June 15, 2007.

[139] The Carnegie-Mellon model of the 10 case studies in the IA technology-transfer report.

create full-fledged undergraduate programs for majoring in science and engineering at the Hartford campus. In addition, it would require a significant expansion of graduate and research programs at the Hartford campus, with an emphasis on both basic and applied R&D, including technology transfer. Further, eventually building dormitories to house full-time, resident students should be an integral part of the plan.[140] Even now, the RPI "About Us" webpage on their website reads:

> From its campuses in Troy, N.Y., and Hartford, Conn., to locations all over the globe, the impact of Rensselaer, its students, faculty, and alumni, is felt in the way people live, work, and play.[141]

The expansion of the RPI campus could provide the same function to Hartford that Carnegie-Mellon does to Pittsburgh: technology transfer activity in the Hartford regional economy. Further, RPI-Harford could work with UTC and other greater Hartford companies in joint R&D projects. This would take the RPI-UTC relationship to another level, resulting in a more innovative and dynamic Hartford regional economy. The counterpart to Carnegie-Mellon's complementary institution, the University of Pittsburgh, in Hartford, could be the UConn-Downtown Campus business school. UConn, in this capacity, would offer entrepreneurship and venture capital programs in conjunction with the science and engineering programs at RPI-Hartford to train and produce entrepreneurs and venture capitalists to transfer technology developed in RPI labs to the Hartford and surrounding area's economy through start-ups as vehicles for bringing new inventions to the market. Students could register jointly at both RPI and UConn and matriculate with degrees from both institutions—a technical degree from RPI and a degree in entrepreneurship with seed/venture financing from UConn. In addition, CCC could be the entrance-point for many students into this pipeline.

Many of the institutions and programs cited by the technology transfer report could be put in place and centered around the principal involvement of the major participants: the City of Hartford, RPI-Hartford, UConn-Downtown Campus, and CCC, as well as UTC and other corporations. At a later stage, a research/science park could be developed in, or near, downtown within proximity of CCC, RPI, and UConn.

VI. IMPLEMENTING A STRATEGY FOR SUSTAINED REGIONAL DYNAMISM: The Role of Workforce Investment and Labor Market Information

What follows is a strategy for implementing the workforce investment and labor market information based solutions to the problems and challenges facing Connecticut's economic future, as pointed out in *Benchmarking Growth in Demand-Driven Labor Markets*, and to follow up on critical areas of the recommendations of the technology transfer report. The strategies focus on the role that workforce investment and labor market information can play in meeting the challenges of Connecticut's economic future. Part A discusses the role of Worker Profiling and the Workforce Investment Act in an entrepreneurship-based and workforce development

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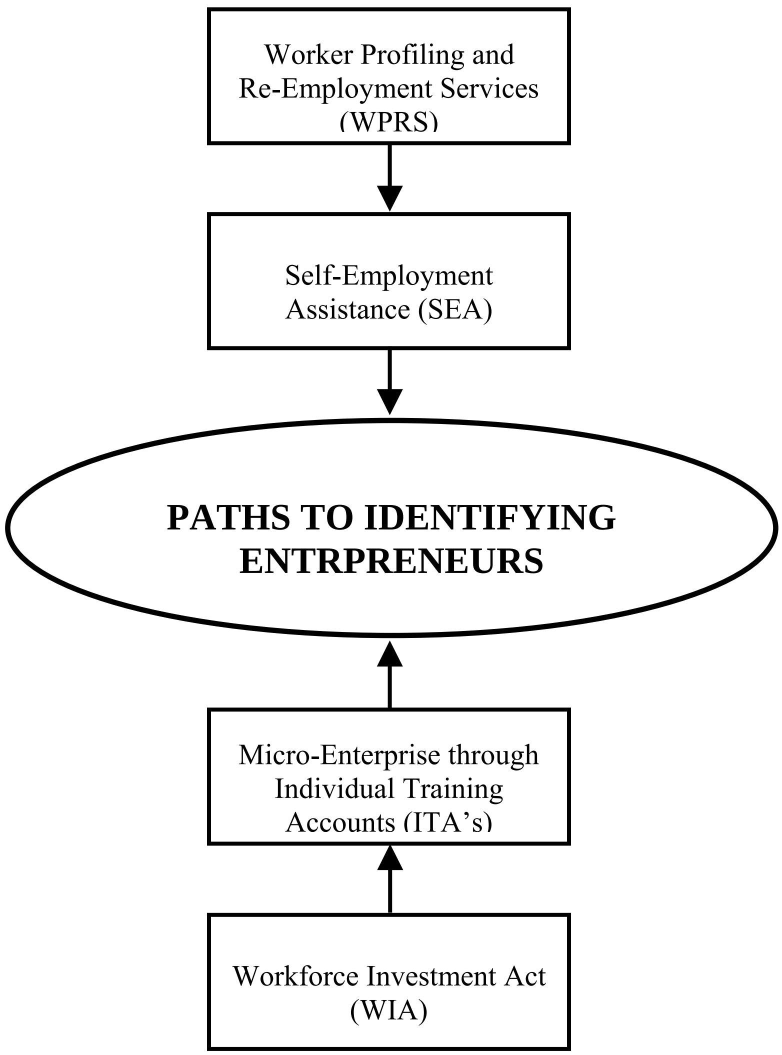
[140] In the very long run, such an expanded full-fledged RPI-Harford Campus could serve as the basis for a new independent institution (e.g., a "Hartford Polytechnic Institute" or "Hartford Institute of Technology").
[141] **http://www.rpi.edu/about/index.html**, accessed on February 8, 2007.

strategy. Part B focuses on how a skilled and creative workforce is the critical component of the nexus that also includes R&D, technology transfer, and early-stage funding. Finally, Part C concludes with the importance of LMI databases in the quantitative assessment and tracking of entrepreneurial and science-based economic development strategies.

FIGURE 1: Two Workforce-Investment Paths to Entrepreneurship and Economic Development



A. WORKFORCE INVESTMENT, ENTREPRENEURSHIP, AND KNOWLEDGE-BASED ECONOMIC DEVELOPMENT

Two existing programs already provide potential vehicles for fostering a workforce investment-based entrepreneurship strategy within a larger economic development framework: Self-Employment Assistance (SEA) under the Worker Profiling and Re-Employment Program, and micro-enterprise through Individual Training Accounts (ITA) under the Workforce Investment Act. These paths to producing the needed supply of entrepreneurs in the State's economy are illustrated in Figure 1. The two paths illustrated are not the only routes to identifying and fostering new entrepreneurs. However, since the focus here is on workforce and labor market approaches to entrepreneurship and economic development, the many other sources of public funding will not be discussed here. For a more complete enumeration of the sources of public funding for micro-enterprise development, the reader is referred to the Microenterprise Fact Sheet Series[142] published by the Association for Enterprise Opportunity (AEO).

The ***Self-Employment Assistance*** (SEA) program was authorized in Section 507 of the North American Free Trade Agreement Implementation Act on December 8, 1993.[143] It sought to give states the ability to add self-employment training and support to the options available to facilitate transition of dislocated workers back into the workforce. Section 507 exempted SEA participants from the regular UI requirements of having to be available and actively searching for work, and from accepting any reasonable employment offer that might be extended to them. In addition, SEA participants are exempted from a portion of the regular UI provision relating to disqualifying income and are permitted to earn self-employment income without a subsequent reduction in unemployment compensation. However, income not from self-employment (i.e., income from wages or salary) continues to disqualify recipients from all or part of their SEA payment. Additional provisions specify that to be eligible for participation in the SEA programs, a claimant must qualify for regular unemployment compensation, and their total SEA allowance may not exceed the maximum unemployment benefit amount. Also, SEA participants must be profiled as likely to exhaust benefits by the state worker profiling system. Furthermore, participants must be engaged in activities approved by the state agency offering entrepreneurial training, business counseling, and technical assistance either privately or through public entities. A final requirement is that participants must be engaged full time in activities related to starting a business, although disqualification criteria are not specified. The legislation limits the number of participants in the program to 5% of a state's regular unemployment compensation recipients. In addition, costs to the UI Trust Fund may not exceed what would have been paid in the absence of a self-employment program, making it a budget-neutral program from the perspective of the UI Trust Fund.

Originally, the program was to last five years. However, the year it was to take effect, the sunset provision was repealed. In October 1998, the SEA program received permanent authorization in Section 3 of the Non-citizen Benefit Clarification and Other Technical Amendments Act of 1998. The requirements of the original legislation remain unchanged except that states are no longer required to submit a plan for approval by the U.S. Department of Labor prior to implementing an SEA program. As of 2001, seven states were operating Self-Employment Assistance programs, including Delaware, Maine, Maryland, New Jersey, New York, Oregon, and Pennsylvania. California operated a program for a brief period, but terminated it due to lack of participants. SEA programs remain fairly small in each state, with most serving much less than 1% of the unemployed population. New York operates the largest program both in number served and percent of the unemployed population, with 2.5% of its UI population participating in SEA.

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[142] Association for Enterprise Development, *Sources of Public Funding for Microenterprise Development in the United States,* MICROENTERPRISE: Fact Sheet (Summer 2005)
[143] Kosanovich, William T. and Heather Fleck, *FINAL REPORT: Comprehensive Assessment of Self-Employment Assistance Programs*, DTI Assoc. Inc: Arlington, VA. (June 2001)

The ***Micro-Enterprise Program*** through Individual Training Assistance (ITA) vouchers is part of the Work Force Investment Act. On August 7, 1998 Congress enacted the Workforce Investment Act (WIA). Prior to WIA, the major Federal employment and training program was the Job Training Partnership Act (JTPA). WIA replaced the old JTPA system and attempts to coordinate 11 Federal employment assistance programs. While much of the discussion about implementing WIA has focused on comparisons with the JTPA system and its service to disadvantaged workers, WIA was not designed solely to restructure JTPA – its aim was to fundamentally redesign the entire public workforce development system for job seekers, workers and employers. To achieve this goal, WIA specifies several components and tools that states and localities should use in the design of their workforce development systems. The Act has five primary goals:

1. Streamline services through a One-Stop service delivery system involving mandated public sector partners.
2. Provide universal access for all jobseekers, workers and employers.
3. Promote customer choice through use of vouchers and consumer report cards on the performance of training providers.
4. Strengthen accountability by implementing stricter and longer-term performance measures.
5. Promote leadership by the business sector on state and local Workforce Investment Boards (WIBs), which are discussed below.

The major elements of WIA include:

- One-Stop Delivery System and Mandated Partners
  - WIA requires the establishment of a One-Stop delivery system to provide core employment-related services and access to other employment and training services. Each local WIB selects, through a competitive process, the One-Stop operator.
- WIA requires One-Stop partners to provide:
  - Training and employment for youth and adults as well as dislocated workers;
  - Adult education;
  - Employment service (Wagner-Peyser);
  - Vocational rehabilitation;
  - Welfare-to-Work programs;
  - Senior community service employment, as specified under Title V, Older Americans Act;
  - Post-secondary vocational education (Perkins);
  - NAFTA, Trade Adjustment Assistance (TAA);
  - Veterans employment and training;
  - Employment and training activities administered by the U.S. Department of Housing and Urban Development; and
  - Unemployment insurance.

- Creation of State and Local Workforce Investment Boards
    - Each state must designate a Workforce Investment Board (WIB) to develop a five-year strategic plan that describes the workforce development activities of the state and the state's implementation strategy for WIA. The state WIB also designates local Workforce Investment Areas (WIA), previously called Service Delivery Areas under JTPA. Local WIBs are responsible for planning and overseeing local programs but are prohibited from providing training services directly. Both state and local boards are required to have a majority of business representatives.

In addition, WIA encourages partnerships with Temporary Assistance to Needy Families (TANF), Food Stamp Employment and Training, National and Community Service Act programs, and other appropriate Federal, state and local programs and agencies. Each agency must establish a memorandum of understanding with the local WIB outlining the services to be provided, plans for cost-sharing and referral methods. WIA requires training programs to meet state and local requirements and limits certification to individual programs, not organizations. During the first phase of the eligibility process, post-secondary educational institutions and apprenticeship programs are automatically eligible to receive funds; all other programs must apply for eligibility through processes developed by the state and local WIBs. During the last phase, which must begin within 18 months of the first, all providers must apply and meet performance criteria to receive funds.

WIA divides workforce development services for adults and dislocated workers into three tiers. Participants use the services in one tier before moving to the next.

1. Core Services. The One-Stop operator provides job search and placement assistance, information about the local labor market, job banks, support services, information on filing for unemployment compensation, and performance and cost information on eligible training providers.
2. Intensive Services. More in-depth services are available to those who are unable to obtain employment through core services and to those employed but needing additional services to reach self-sufficiency. Intensive services include comprehensive and specialized assessment of skill levels, individual employment plans, case management and short-term prevocational services—all of which may be delivered by the One-Stop operator or through contracts with service providers.
3. Training Services. Training is available to those who have not found employment through intensive services. The programs include occupational training, on-the-job training, skills upgrading and job readiness—all delivered by providers meeting the eligibility requirements.

Particularly important for entrepreneurship and micro-enterprise is the third tier. Training funds for adult participants are placed in ***Individual Training Accounts*** (ITAs). To promote competition among providers, WIA then allows participants to select the programs that best fit their needs. Four exceptions to the use of ITAs exist: contracts may be used for on-the-job training, customized training, special populations (to be defined by each local WIB), and when too few providers exist to meet the competitive purposes of ITAs. State and local WIBs are responsible for establishing the amount of the ITA and the policies for its implementation.

It is through the training services and ITAs that WIA permits micro-enterprise training and considers self-employment to be an allowable employment outcome. However, most state and local WIA systems do not include micro-enterprise training and self-employment in their service delivery due to a lack of information and clear understanding of micro-enterprise as a viable job creation and poverty alleviation strategy.

The Corporation for Enterprise Development suggests several ways in which to incorporate micro-enterprise training into the local WIA service delivery system.[144]

- Determine the process for certification of micro-enterprise programs as WIA training providers. Find out from the local WIB whether any micro-enterprise training programs have been certified. Ask the programs how difficult or easy it has been for them to enter and remain in the system and what kinds of resources they need to meet performance requirements.
- Identify and organize micro-enterprise programs willing to become certified and serve WIA participants.
- Work with the local One-Stops to develop and implement a plan for referring WIA participants with ITAs to micro-enterprise programs.
- Identify WIA-eligible individuals interested in micro-enterprise. Develop a micro-enterprise orientation for WIA-eligible individuals, and tools for assessing their interest in and aptitude for micro-enterprise development.

In accordance with the WIA, Connecticut produces two-year workforce plans. The State's 2005-2007 Workforce Investment Plan states that:

> At the higher end of the "dual economy," initiatives must be pursued to generate and retain the high-skill talent that can support the State's ongoing competitiveness in the knowledge economy.[145]

The Workforce Investment Plan does include entrepreneurship as a cornerstone in its economic development strategy. Four aspects of producing and retaining talent are presented:

1. Generating talent (building and fortifying the educational pipeline)
2. Sustaining talent (back-filling key skilled-occupational shortage areas and retraining older workers for emerging jobs
3. Advancing talent (addressing both sides of Connecticut's dual economy)
4. Using talent **(increasing academic R&D and "entrepreneurism" in Connecticut)**

Aspect 4, "Using Talent" is at the heart of the two-sided coin idea articulated in *Benchmarking Demand-Driven Growth*; that is, an excess supply of skilled labor implies an excess demand for entrepreneurs. Connecticut can address its excess demand for entrepreneurs through the SEA and ITA options. They, potentially, could be important policy tools for retaining unemployed, or

[144] Corporation for Enterprise Development, *Using the Workforce Investment Act to Support Microenterprise Development*, EFFECTIVE STATE POLICY AND PRACTICE, Vol. 3: No. 3 (2003)
[145] State of Connecticut, STRATEGIC TWO-YEAR STATE WORKFORCE INVESTMENT PLAN FOR TITLE I OF THE WORKFORCE INVESTMENT ACT OF 1998 (WORKFORCE INVESTMENT SYSTEMS) AND THE WAGNER-PEYSER ACT for the Period of July 1, 2005 to June 30, 2007, p. 3.

underemployed, high-skilled workers and for creating new jobs. An important step toward achieving that goal is to provide the opportunity for highly skilled talent in Connecticut's labor force to pursue the entrepreneurship avenue as a means to not only re-employment, and thus "using talent", but to eventually get to the point where this utilized talent becomes a source of further job creation as their business start-ups expand. Further, the entrepreneurship outlet offers a way to keep an excess supply of highly skilled labor from out-migrating from the State, draining it of a critical economic resource. In the Metro Washington economy, in the face of massive federal layoffs, entrepreneurial opportunities were critical to tapping into the excess supply of high-skilled workers for first generation start-ups in the development of the biotech and the information and communications technology (ICT) clusters.

In *A Talent-Based Strategy to Keep Connecticut Competitive in the 21st Century*, Connecticut's Office of Workforce Competitiveness (OWC)[146] identifies three priorities in advancing a 21st century talent pipeline: (1.) Growing Talent, (2.) Using Talent, and (3.) Enriching Talent. To that end, state organizations are directed toward three corresponding areas of focus: (1.) Focus on 21st Century Careers, (2.) Focus on Business Innovation Services, and (3.) Focus on Workforce Investment. As in the State's two-year Workforce Investment Plan, "using talent" is one of the major action steps identified in the OWC report that the Governor and General Assembly have worked on together in the 2005 and 2006 legislative sessions.[147] The report notes that:

> Connecticut is also slipping in the utilization of its research and development base to support innovation.[148]

Connecticut's Workforce Investment Plan does recognize the importance of technology transfer as the platform for knowledge-based economic development:

> Advancing R&D, innovation and commercialization through higher education-industry partnerships with the implementation of an *Innovation Challenge Grant program*.[149]

And:

> Developing a focused technical assistance resource for Connecticut tech-business start-ups to improve the State's performance in receiving SBIR and other development grants.[150]

Most policy discussions view entrepreneurial development, and especially the area of technology transfer, as falling more under purview of "Focus on Business Innovation" rather than "Focus on Workforce Investment", but the approach advocated here is that existing resources can be harnessed to forge new links to connect business innovation and workforce investment. Thus, workforce programs discussed above, such as the Micro-Enterprise program through Worker Profiling and the Self-Employment Assistance through WIA, could work in conjunction with business development and innovation programs to foster entrepreneurial-based economic

[146] Office of Workforce Competitiveness, "A Talent-Based Strategy to Keep Connecticut Competitive in the 21st Century", State of Connecticut (February 2007), p. 3.
[147] Ibid., p.10.
[148] Ibid., p.10.
[149] State of Connecticut, STRATEGIC TWO-YEAR STATE WORKFORCE INVESTMENT PLAN FOR TITLE I OF THE WORKFORCE INVESTMENT ACT OF 1998 (WORKFORCE INVESTMENT SYSTEMS) AND THE WAGNER-PEYSER ACT for the Period of July 1, 2005 to June 30, 2007, p. 5.
[150] Ibid., p. 5.

development strategy. For example, there were two business innovation programs cited above from the Workforce Investment Plan report: the Innovation Challenge Grant Program and the Small Business Innovation Research Program.

The Innovation Challenge Grant Program was authorized by Public Acts 05-198 and 06-187. The OWC report identifies the Innovation Challenge Grant Program as an important opportunity for Connecticut to build capacity and foster an environment for greater collaboration among and between higher education institutions with business and industry in the areas of talent generation, technology commercialization, and applied and basic research. Further, it offers a comprehensive program that can be tailored to specific strategic technology areas for reinvigorating Connecticut's economic competitiveness, including nanotechnology, marine and ocean research, translational biomedical research, and alternative energy.[151]

The Small Business Innovative Research (SBIR) program, created by Congress in 1982, helps small businesses more actively participate in federal research and development (R&D). All federal agencies with an annual extramural R&D budget exceeding $100 million are required to participate in the SBIR program. Participating agencies are required to conduct an SBIR program by reserving a percentage of their R&D budget to be awarded to small businesses through a three-phase process: (1.) Feasibility Study, (2.) Development, and (3.) Commercialization.[152]

Eligible companies must have 500 employees or less and must be the primary place of employment of the principal investigator. The Small Business Administration (SBA) is responsible for setting general policy guidelines, as well as coordinating and monitoring the progress of the SBIR program. The SBA posts a pre-solicitation announcement that contains information that allows extra planning time for SBIR proposal submissions.

Connecticut has a competitive award that is modeled after the national SBIR program to identify problems or "topics" that can be solved by small businesses and entrepreneurs through advanced research for the development of innovative, next-generation products. The Connecticut Small Business Innovation Research (SBIR) Office is an initiative of the Connecticut Center for Advanced Technology, Inc. (CCAT). CCAT awards SBIR grants, which are funded by the Connecticut Development Authority (CDA) and the Governor's Office of Workforce Competitiveness (OWC). OWC designated that the Connecticut SBIR Office be housed at CCAT to develop and administer this program. CCAT provides resources and assists in the process to connect small nanotechnology companies with other industry and university resources to help in the development of innovative technologies.[153] In addition, the 2007 OWC report calls for expanding the SBIR office into a full-service center:

> Expand Connecticut's Small Business Innovation Research (SBIR) Office into a full service business innovation and commercialization services resource center to include technical assistance to broaden the base of Federal R&D funding to industry, enhance

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[151] Office of Workforce Competitiveness, "A Talent-Based Strategy to Keep Connecticut Competitive in the 21st Century", State of Connecticut (February 2007), p. 11.
[152] The Defense Advanced Research Projects Agency (DARPA) Website at **http://www.darpa.mil/sbir/sbir.html** for an overview of the SBIR Program.
[153] Nanotechwire.com, "Connecticut Small Business Innovation Research Office Awards $195,000 To Three Connecticut Nanotechnology Companies" (March 16, 2007).

business commercialization services and foster industry partnerships in product development across Connecticut's technology core competency areas.[154]

These two small business and technology transfer programs are not the only policy tools available, but they offer good examples of instances where the business innovation/development focus can be pursued in conjunction with workforce development. Two conduits to these business development and innovation programs, in addition to academia and other avenues, could be the two workforce development programs discussed above: Worker Profiling and WIA. Currently, the focus on business development and workforce development are viewed as separate approaches to advancing the flow of talent through the pipeline. However, these two approaches could be viewed as having an important area of intersection; that is, a more effective path to the dual goals of on-going technology transfer and entrepreneurial-based economic development is an integrated approach that would coordinate the efforts directed toward the second and third points of focus stated in the OWC report: business innovation services and workforce investment. This would be an important next step in "breaking down silos."[155] In particular, it would require not only the existing collaboration between the Connecticut Labor Department and Department of Higher Education, but also collaboration between the Labor Department and other entities not previously considered, such as Connecticut Innovations (CI), the Connecticut Center for Advanced Technology (CCAT), the Connecticut Development Authority (CDA), and the Connecticut SBIR Office. Selected candidates from the Self-Employment Assistance (SEA) program (through the Worker Profiling process) or the Micro-Enterprise Program (through Individual Training Accounts) could be referred to CI, CCAT, CDA, or the SBIR Office and their available programs to obtain the funding and training needed to achieve self-employment through a business start-up.

B. START-UP AND EARLY STAGE FUNDING FOR WORKFORCE INVESTMENT IDENTIFIED ENTREPRENEURS

If Connecticut were to institute an entrepreneur identification option through SEA as part of Worker Profiling and through ITA's under WIA, how would these entrepreneurs follow up on their entrepreneurship training and obtain funding to actually begin or sustain the early stage phase of their business start-up? There are private venture capital groups in Connecticut such as the Connecticut Venture Group,[156] which is a voluntary professional organization whose purpose is to connect leading venture investment professionals with high growth emerging companies. It was founded in 1974 for the purpose of creating a forum for business venturing opportunities as well as generally promoting venturing activity in the State. Its formal stated mission is to assist in the development of high growth enterprises through the promotion of capital formation in Connecticut. Connecticut biotechnology and high-tech companies appear to be attracting venture capital, at least in the New Haven area.[157] Further, the State provides start-up and early stage funding through Connecticut Innovations and the Connecticut Development Authority.

[154] Office of Workforce Competitiveness, "A Talent-Based Strategy to Keep Connecticut Competitive in the 21st Century", State of Connecticut (February 2007), p. 11.
[155] Ibid., p.3.
[156] Their website can be accessed at: **http://www.cvg.org/entrepreneurzone.asp**
[157] Higgins, Steve, *Biotech firms luring venture capital to state*, NEW HAVEN REGISTER (April 25, 2006).

Connecticut Innovations (CI) was created by the State legislature in 1989.[158] It provides strategic capital and operational insight to push the frontiers of high-tech industries such as energy, biotechnology, information technology, and photonics. Of particular interest for entrepreneurs would be CI's Seed Investment Fund and Pre-Seed Support Services. The Connecticut Innovations Seed Investment Fund will provide funding to qualified non-bioscience companies in Connecticut. Seed investments of up to $500,000 are structured as equity (preferred stock), convertible debt, or debt with warrants depending on the individual circumstances of the deals. In addition**,** the Pre-Seed Support Services Program helps innovative, high technology entrepreneurs develop companies in Connecticut. CI provides mentoring, coordination of services and limited funding for business assistance to prepare the tech company for future investments. Funding for small and start-up high-tech ventures may also be obtained through the Eli Whitney Fund, the Connecticut Bioseed Fund, the Bioscience Facilities Fund, and the CT Clean Energy Fund.[159]

The **Connecticut Development Authority** (CDA)[160] provides debt financing and investment capital to help businesses grow in Connecticut. The CDA states that they finance companies and projects that contribute to Connecticut's economy, technology base, intellectual capital, urban infrastructure, employment or tax revenues, and that private sector financial institutions are unable to accommodate. There are a couple of CDA programs that are targeted toward small and early stage businesses. URBANK provides banks with loss protection on loans up to $350,000. URBANK loans can be coupled with loans or investments from other public or private sector sources. Any Connecticut business in which the bank is unable to approve the borrower's loan request without URBANK assistance is eligible. Another CDA small business funding program is Early Stage Financing. This program consists of direct loans or mezzanine financing that is normally made in tandem with loans or investments from other private or public sector lenders or investors. Eligible businesses are those that have the potential to contribute significantly to the State's technology base, intellectual capital, economic-base employment, urban infrastructure, or tax revenues.

In another development for small business in Connecticut, the U.S. Small Business Administration (SBA) announced in November 2006 that it selected Central Connecticut State University (CCSU) to host the Connecticut Small Business Development Center (CSBDC), which is located in CCSU's Institute of Technology & Business Development. Sub-centers will be located at Eastern, Southern and Western Connecticut State Universities, as well as at the Department of Economic and Community Development's (DECD) Office of Small Business. The cooperative agreement took effect on January 1, 2007. The SBA will provide a first-year grant for nine months of $703,270, which will be matched by State of Connecticut and other non-federal grants of $930,255, for a total project cost of $1,633,525. After the first year, the SBA grant for a full year will be $938,000.[161]

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[158] For more information go to the CII website: **http://www.ctinnovations.com/about/about.php**
[159] For details on these funds, go to the "CII Funding" web page at: **http://www.ctinnovations.com/funding/introduction/ci_funding.php**
[160] For more information on the CDA, go to their website at: **http://www.ctcda.com/**
[161] Kilduff, Peter, "U.S. Small Business Administration Selects CCSU As Host For Small Business Development Center in Connecticut; $1.6 Million Project Will Add State Business" Statement Released by Central Connecticut State University (November 3, 2006).

Despite these and other programs, Connecticut needs to do more. According to an article appearing in *The Hartford Courant* in July 2006, it is noted that:

> … – start-up and early stage technology ventures with admittedly high risk – that Connecticut's economy must nurture to maintain the sort of inventive spirit and commercial success that has made the state a wealthy cradle of industry for 200 years.[162]

And:

> But despite endless lip service, it's not happening, at least not often enough.[163]

"It" is venture financing. Ironically, there is a lot of money in Connecticut, but it is not flowing into high-risk, new start-ups. Instead:

> For other types of investment, Connecticut very much is where the money is – hedge funds, real estate deals, bond trading, blue-chip stock ownership and the like. There is also no shortage of research and invention here, measured by academic activity and patents.[164]

And:

> Still, many people familiar with the technology scene in Connecticut say it's worse here than it ought to be. Few venture capital funds are looking at early stage deals in this State.
>
> Connecticut is losing ground to places such as Oklahoma and Iowa, which have public funding programs in place. The state's risk-averse culture and its mix of industries, changes in the venture capital business and a scattered set of agencies working on technology development all contribute to the problem.[165]

Another interesting observation is that, except for New Haven, there are no major universities in Connecticut's larger cities. Further, Connecticut's "larger" cities are really medium-sized cities (e.g., the cities of Hartford, New Haven, and Bridgeport all have populations significantly less than 250,000[166]), and thus there is no large center of mass, such as Boston or Denver, to provide the gravitational pull needed to generate the spatial concentration required to spawn the social networks and economies of urbanization, critical to the development of knowledge-based clusters (see Part A. "Economic Development and the Role of 'Science Cities'" of Section III, above). An exception might be Fairfield County, part of the New York City CMA. This reinforces the argument made above about the need to aggressively develop and expand the presence of RPI-Hartford and to coordinate the development of complementary curricula and R&D/technology transfer/entrepreneurial activities with the UConn-Downtown Campus. This would provide the spatially proximate, large concentration of academic-research activity needed

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[162] Haar, Dan,, *The Venture Gap*, THE HARTFORD COURANT (July 23, 2006).
[163] Ibid.
[164] Ibid.
[165] Ibid.
[166] In addition, the three cities are too far apart to be "tri-cities", but close enough to dissipate each other's gravitational attraction. However, the Hartford and Springfield economies, linked by Bradley International Airport and commuting patterns, are becoming more integrated and forming a single regional economy. Nothing like Bradley exists between Hartford and New Haven. Further, commuting patterns based on the 2000 Census indicate that New Haven's link is to the southwest through Fairfield County, not north to Hartford.

to generate knowledge-based growth centered around downtown Hartford, which because of the presence of Yale, is beginning to take shape in New Haven (see Part B. "Two Potential Science Cities" of Section V).

C. ASSESSING THE PERFORMANCE OF ENTREPRENEURIAL AND SCIENCE-BASED ECONOMIC DEVELOPMENT STRATEGIES: QUANTIFYING RESULTS AND TRACKING PROGRESS

Having discussed the link between workforce investment, business development and innovation, and entrepreneur-based economic development, this section now turns to the importance of labor market information and the assessment of the performance of economic development policies centered around entrepreneurship and technology transfer.

The Advanced Technology Program of the U.S. Department of Commerce has developed a set of evaluation criteria that uses data from the Quarterly Census of Employment and Wages (QCEW) database. The Advanced Technology Program (ATP), administered by the National Institute of Standards and Technology (under the U.S. Department of Commerce's Technology Administration), provides cost-shared funding to private company research and development (R&D) projects that promise significant commercial payoffs and widespread benefits for the nation. ATP project selection focuses on generic technologies developed by upstream producers that enable downstream producers to improve the quality of their products or reduce their costs. To facilitate tracing the flow of ATP-enabled technologies and their spillover benefits, a methodology was developed to identify each project participant's North American Industry Classification System (NAICS) code.

NAICS codes were assigned to the downstream use-industries for each separate proposed commercial application for all ATP projects that started between January 1999 and July 2003. The motivation for this project was twofold:

> First: NAICS coding enabled matching of ATP projects with external data that use NAICS codes (e.g., the Economic Census data, National Science Foundation R&D expenditure data, and Compustat data). This matching in turn facilitated research on project impacts and economic outcomes.
>
> Second: NAICS coding provided evidence that ATP project selection focused on projects with high spillover potential. ATP invests in risky, challenging technologies with the potential to deliver significant national economic benefits.[167]

The ATP Economic Assessment Office (EAO) uses multiple survey instruments, collectively referred to as the BRS, to capture project participants' business data and commercialization progress; these data help in evaluating the success of ATP projects. Between 1993 and 1998, EAO used a disk-based survey instrument that asked companies to provide the SIC codes applied to their potential commercial applications. Beginning in 1999, EAO switched to a web-based survey instrument and to the collection of NAICS codes. In 1999 and 2000, companies were asked to identify the three-digit NAICS codes for both their own industry and the industry of their potential business applications. Starting in 2001, EAO reevaluated this request when it determined that it placed a large reporting burden on the companies but did not yield particularly

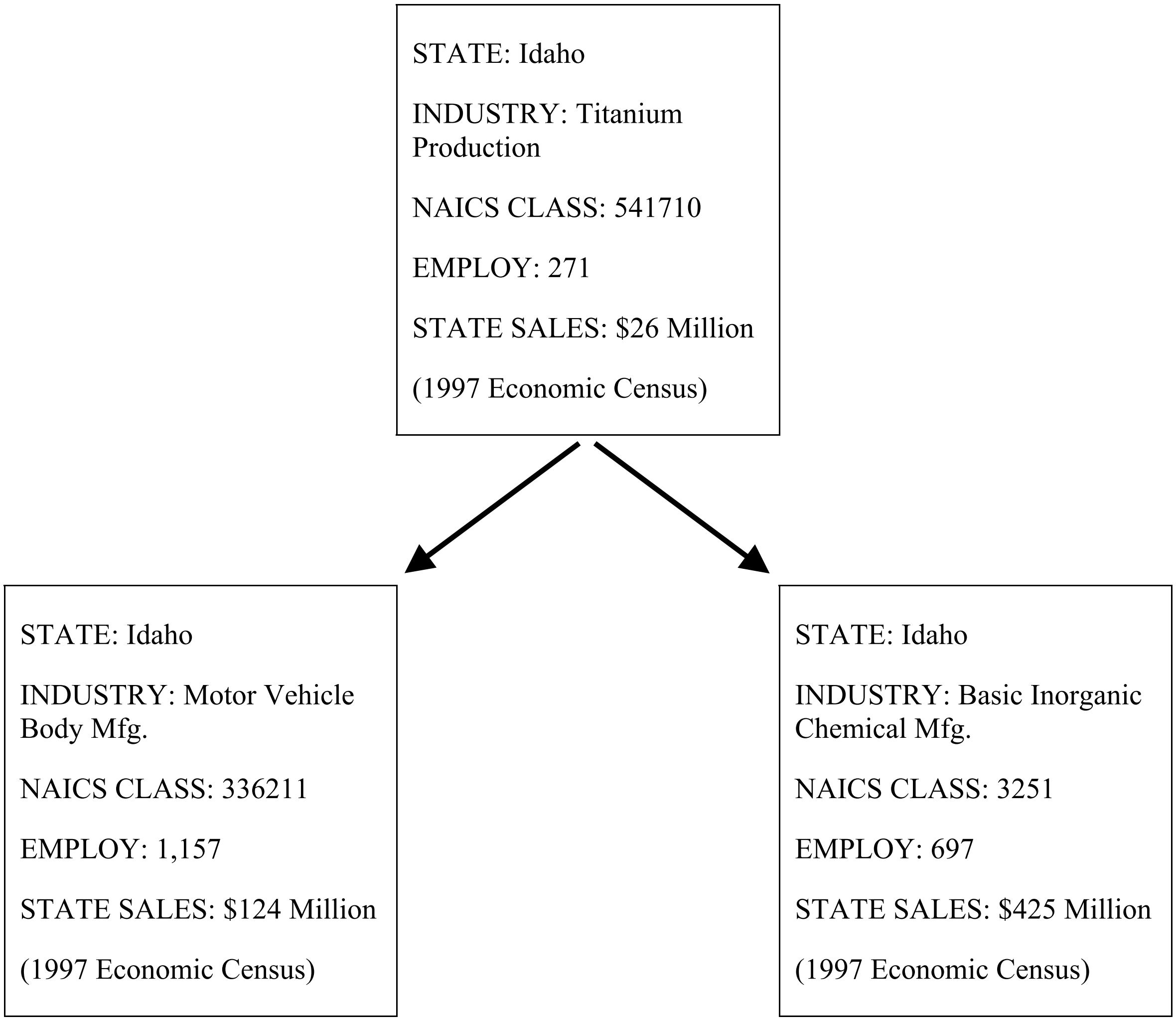
[167] Nail, John and Hayden Brown, "Identifying Technology Flows and Spillovers through NAICS Coding of ATP Project Participants", (April 2006) NISTER 7280, U.S. Department of Commerce: Washington.

helpful or consistent data. Using this focal information as guidance, EAO assigned six-digit NAICS codes to project participants' own- and use-industries. Potential spillovers and other associated economic impacts from an ATP project can be more precisely measured using six-digit NAICS codes than can be done at the three-digit level. For example, NAICS code 325, which represents all chemical manufacturing, contains 34 separate six-digit industries. By assigning six-digit NAICS codes to industries, these data will better enable ATP to trace the technology flows that potentially result from ATP projects.

Table 4, below, is adapted from Figures 4-3 and 4-4 of the ATP technology spillovers report. It illustrates the use of NAICS codes to follow the flow of an ATP project and how it diffuses technology from midstream to downstream industries. Since NAICS data are available at the national, state, and county levels, different levels of industry aggregation can be selected to make this point. The example presented in Table 4 is that of a titanium project based in Idaho. This project encompasses two applications, motor vehicle bodies and titanium powders, both of which industries are important to the Idaho economy. The project originates from a small research company specializing in titanium powders. If the project is successful, the benefits will flow into the Idaho economy through use by the motor vehicle body manufacturing sector, which generated $126 million in sales in 1997 for Idaho, and the inorganic chemical manufacturing sector, which generated sales of $450 million and whose jobs pay an average of $52,000.

However, though the sales data are restricted to the economic census years, the employment and wages data could be available on an annual, and even quarterly, basis from the Quarterly Census of Employment and Wages (QCEW) program, housed in labor market information (LMI) divisions of state workforce agencies. In the same vein, workforce investment-based entrepreneurship and economic development programs can be tracked for quality control and for evaluating outcomes by tapping into the QCEW and other data derived from the Unemployment Insurance (UI) program. Thus, the success of entrepreneurs identified through either the SEA program under Worker Profiling, or the Micro-Enterprise Program under WIA, could be gauged by following up with quantifiable indicators of the programs' outcomes (without overburdening the business start-up with onerous reporting requirements). Critical information about their expanding and hiring of employees (and thus, creating jobs), and the wages paid, are reflected in the information they provide to the state UI program. Random samples of new start-ups generated by the workforce-based programs could be used to obtain information on in-state purchases and sales of intermediate inputs and in-state sales of final demand; that is, surveys of start-up firms could identify the in-state firms and industries that they purchase intermediate inputs from, and the in-state firms and industries that they sell their products and services to as intermediate inputs, and any in-state purchasers of their goods and services as final demand. If the new start-up fails, is sold, or must expand, or move out-of-state, then follow-up surveys could identify those critical factors that played a role in these outcomes. Such feedback would provide valuable information for constantly improving the workforce-based entrepreneurial programs, and in insuring that they meet the needs of the clients served.

TABLE 4: Flow of Potential Economic Benefits to the State of Idaho: Spillovers from an ATP Project



SOURCE: Figure 4-3, Nail and Brown (April 2006), p. 27.

VII. CONCLUDING REMARKS

This report has presented a framework for implementing strategies to address the challenges to Connecticut's economic future that were identified in *Benchmarking Growth in Demand-Driven Labor Markets.* The goal of this report was to provide a blueprint for implementing the necessary steps to translate the required, remedial measures, as suggested by *Benchmarking Growth in Demand-Driven Labor Markets*, into specific policy actions. The focus of this strategy is based on the recent resurgence of interest in the regional economy, the role of entrepreneurial activity, and new firm formation in generating local and regional economic growth and development as an on-going process. Specifically: What are the policies and programs needed to foster the conditions that put a local-regional economy on the path to sustained innovation and re-invention? Critical to achieving such success is for the local-regional economy to tap into a locally available knowledge base, and to create the environment, including access to early stage capital financing, that encourages a high start-up rate of entrepreneurial-type, higher-risk firms that exploit science- and technology-based knowledge to introduce new products and services into the market, and to develop new process innovations for producing and distributing goods and services.

The focal point of the approach has been on identifying policies and programs that foster the development of a dynamic that produces a sustained process in which R&D is focused on applied technology, developed in the lab, and transferred to the market in the form of new goods and services, through entrepreneurial start-ups. These entrepreneurial start-ups serve as the innovation bridge that transfers new inventions and process innovations from academic, government, and corporate labs to the marketplace. Critical to developing such a knowledge-based ecology is the *government-academic-industry* helix identified by Etzkowitz (2005) in his study of the development of "science cities." One emerging Connecticut science city, Yale-New Haven, was identified, along with two potential science cities: RPI-Hartford-UConn-Downtown Campus-Hartford and UConn-Storrs.

From the workforce development standpoint, tapping into the potential of existing programs that Connecticut has not taken advantage of, could be the key to connecting workforce development to entrepreneurial activity and knowledge-based economic development. The Self-Employment Assistance (SEA) opportunities under the Worker Profiling and Re-Employment program, and the Individual Training Accounts (ITA) under the Workforce Investment Act (WIA) have not been exploited by Connecticut. Further, utilizing the potential for fostering the creation of micro-enterprise through SEA and ITA's could complement, and have potential synergies with, existing funding/early stage financing and training programs currently offered by Connecticut Innovations (CI) and the Connecticut Development Authority (CDA). In addition, there are private venture capital groups in Connecticut such as the Connecticut Venture Group,[168] which is a voluntary professional organization whose purpose is to connect leading Venture Investment Professionals with high-growth emerging companies.

This study also extended the work of the Connecticut technology transfer report, completed by Innovations Associates (IA) in October 2004 for the Technology Transfer and

[168] Their website can be accessed at: **http://www.cvg.org/entrepreneurzone.asp**

Commercialization Advisory Board of the Governor's Competitiveness Council.[169] While the technology transfer report and the current report both concentrated on the lessons that could be learned from successful science cities, the approaches by the two reports are complementary. The technology transfer report focused on the current, and recent past, entities, policies and programs that have characterized the successes of the example university-based centers (i.e., a cross-sectional, *point-in-time* view), studied by IA, whereas the current report focuses on the birth, motivation, development and evolution, and current life cycle stage of the four case study science cities (i.e., a history and development, *over time* view). In addition, the current report focuses on the importance of spatial proximity in the transfer of technology at its early stages of development. Though information has become "footloose" as a result of advances in information technology, the diffusion of knowledge across space is still characterized by a steep decay function. Thus, for transmitting knowledge, spatial proximity is still critical, and, in turn, knowledge is a critical factor in creating an ecology that fosters invention and innovation, which plays a pivotal role in the birth and development of knowledge-based clusters.

Finally, the important role of labor market information in assessing and tracking the progress of workforce-based entrepreneurial/knowledge-based policies and programs has been highlighted. Particularly, LMI databases are critical resources in the development of quantitative assessments and the tracking of entrepreneurial and science-based economic development strategies. A good model to follow in the development of quantitative evaluation methods is that of the Advanced Technology Program of the U.S. Department of Commerce, which provides cost-shared funding to private company R&D projects that promise significant commercial payoffs and widespread benefits for the nation. The Advanced Technology Program has developed a set of evaluation criteria that traces the flow of ATP-enabled technologies and their spillover benefits, and enables research on project impacts and economic outcomes.

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[169] Innovations Associates, Inc., *Report to the Connecticut Technology Transfer and Commercialization Advisory Board of the Governor's Competitiveness Council* (October 2004).

VIII. APPENDICES

A. Introduction to the Production Function

1. A Functional Relationship

Neoclassical growth theory is based on the *production function*, a specific instance of the mathematical relationship called a “function.” A *function* is a special kind of relation of ordered pairs of numbers, or groups of numbers, such that there is only one value for a corresponding value, or group of values. In the simple case of a functional relationship between two values, there is an *independent* or *input* value, or *variable,* usually denoted as “x,” and a d*ependent* or *output variable* denoted as “y.” In a functional relationship, any x value *uniquely* determines a value of y. It is also sometimes said that the set of x-values are mapped into the set of y-values. Thus, a function is sometimes called a *mapping* or *transformation*. Symbolically, y is a function of x is expressed as:

$y = f(x)$, which is read: “y equals f of x” (i.e., y is a *function* of x). (A-1.)

The set of all values x can take is called the *domain* of the function, and the set of all values y can take is known as the *range* of the function.[170]

Of particular interest for explaining the production function is the extension of the idea of the function to include two or more variables. The extension to two independent variables can be expressed as:

$$z = f(x,y) \qquad \text{(A-2.)}$$

Now, to determine the value of z, the values of both x and y must be specified. There will be only one value z for every pair of values for x and y.[171] This function is particularly relevant for understanding the *production function*.

2. The Production Function

The production function relates the quantities of capital (K) and labor (L) inputs used to produce a given level of output (Q). Within this context, Equation (A-2.) would be re-stated as:

$$Q = Q(K,L) \qquad \text{(A-3.)}$$[172]

Further, Equation (A-3.) implies that the minimum combination of inputs of K and L were used to produce some given level of output, Q.

For instance, for an auto plant to produce so many lot-runs of 1,000 cars each (Q), it would require a given amount of plant and equipment (K) and workers (L). Thus, within the context of this example, Equation (A-3.) could be re-stated as:

1,000 Cars = Q(Plant and Equipment, Workers) (A-4.)

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[170] Chiang, Alpha, FUNDAMENTAL METHODS OF MATHEMATICAL ECONOMICS, 3rd Edition (1984) McGraw-Hill: New York, pp. 20-23.

[171] Ibid., p. 29.

[172] For some references on an introduction to the production function see Reynolds, R. Larry, *Production and Cost*, BASIC MICROECONOMICS (2000), Call, Steven T. and William L. Holahan, MICROECONOMICS, 2nd Ed. (1983) Wadsworth Publishing: Belmont, CA. Ch. 5, and Mansfield, Edwin, MICROECONOMICS: Theory and Applications, 2nd Ed. (1975) W.W. Norton: New York, Ch. 5.

Thus, the *factor inputs* are plant and equipment (K) and workers (L), and the *output* (Q) is the lot-run of 1,000 cars, which expresses the functional relationship between the two independent, or input, variables, K and L, and the dependent, or output, variable, Q.

Time is an important determinant of the form of a given production function. In the *immediate run*, nothing can be changed. All factors are fixed. In the *short run*, some factor inputs, like labor, can be varied. In the *intermediate-to-long run* all factor inputs are variable. How each of the three perspectives might be defined in terms of the length of time for each depends on many factors, including the industry and the capital-intensity of its production process. For the auto plant example above, a period of probably a week would be an immediate-run perspective. A couple of weeks to even months would be a short-run perspective. Clearly, hours could be increased or reduced, and shifts expanded or contracted, as the number of lot-runs is increased or decreased to meet changing market conditions. But, save idling or closing the plant, changing the plant will be a longer time frame perspective. That is, significantly expanding or building a new plant could take up to a couple of years. Thus, the time frame defining each one of the three perspectives would be different for other industries. In the *long run*, not only are all factor inputs variable, but so is technology.

In the immediate-to-short- run, the production function would take the following form:

$$Q_1 = Q(K_o,L_o) \qquad \text{(A-5.)}$$

The above expression conveys the idea that both inputs are fixed in the immediate-run for a single lot-run (Q_1) of 1,000 cars.

In the short-run, the plant, and probably much of the equipment too (K), will be fixed, with other factor inputs, particularly labor (L), variable. This is expressed as follows:

$$Q_n = Q(K_o; L) \qquad \text{(A-6.)}$$

Now, Q_n conveys the idea that more than one lot-run (i.e., n lot-runs) is being produced, while K_o implies that capital is fixed (i.e., the plant cannot be varied), and that the labor input can be varied (L); that is, it is not fixed in the short run.

In the intermediate-to-long run, *all* inputs are variable. The intermediate-to-long run is distinguished from the long run in the way *technology* is specified in the neoclassical production function. Technology is now introduced into the production function in Equation (A-7.). An expression for an intermediate-run production recipe would include a term for technology being held constant, or fixed:

$$Q = Q(\overline{T}; K,L) \qquad \text{(A-7.)}$$

Equation (A-7.) indicates that though capital and labor are both variable, technology is held constant, or fixed ($\overline{T}$). In the long run even technology varies. This is expressed in Equation (A-8.):

$$Q = Q(T,K,L)^{173} \qquad \text{(A-8.)}$$

[173] For now, technology is entered as a third argument to the production function. Alternative ways to enter technology into the Neoclassical production function are discussed in Section II, Volume II.

Returning to the auto plant example above, Equation (A-8.) would describe long-run conditions as the old “Fordest” assembly-line methods were replaced with the introduction of robotics, computerized numerical controlled (CNC) machinery, and the team approach into the auto production process. In this case, technology varied, as the industry adopted information technology-based production techniques, in combination with organizational and process innovations. The new technology could be introduced by building new, “state-of-the-art” plants, and closing older, obsolete facilities or, if possible, retrofitting existing plants, or some combination of both.

3. Some Features of the Production Function

Several features of the production process arise from the specification of the neoclassical production function. The first set of points arises from the short-run perspective of production. Recall from above that in the short run, plant size and much of the equipment (i.e., capital, K) and technology (T) are held constant. It is assumed that the variable input over the short run is the labor input. Thus, in the short run, the production function may be expressed in the following form:

$$Q = Q(L) \tag{A-9.}$$

Total product (TP) is the total output (Q). That is: TP = Q = Q(L).

Average product (AP) is the output per unit of input, or AP= TP/L = Q/L. In this case, since all other factors and technology are held fixed, and labor is the only variable input, AP = AP_L, which is the *average product of labor*.

Marginal product (MP) is the change in output due to a change in the factor inputs. In this case, since there is only one variable factor input, the marginal product is defined as the *marginal product of labor* (MP_L), which is $MP_L = \Delta TP/\Delta L$ = change in TP/change in the labor input (where Δ= change).

Technical efficiency is defined as the ratio of output to input, or output/input. This is distinguished from the AP in that AP is the ratio of output to a *variable input* and a set of *fixed inputs*. For instance, the *average product of labor* is AP_L =

TP (=Q) / inputs ($\overline{T} + \overline{K} + L$), where *technology* and *capital* are fixed at $\overline{T}$ and $\overline{K}$, and *labor*, L, is the variable input. The maximum value of the AP_L is the point where $MP_L = AP_L$, and it represents the *technically efficient* use of the labor input.

4. The Law of Diminishing Returns

The following result is one of the most well known from microeconomics. It will have important implications for the focus of this paper on the evolution of, and the competing theories of, economic growth and development. It applies to the short-run perspective of production.

As a variable input, such as labor, is added to a set of fixed inputs, such as a given size plant, and holding technology constant, output increases rapidly. That is, TP, or Q, increases at an increasing rate. Returning to the auto plant example, eventually, as more and more workers are added to the line of a given auto plant, with a given set of technologies, in a given short-run time period, to produce lot-runs of cars, the number of cars produced would begin to level off and grow at a constant rate, and then grow at a decreasing rate. This is because, at some point, additional workers would become redundant. Then, TP, or Q, would be increasing at a decreasing rate. There would be too many workers on the line trying to produce cars in a fixed-sized plant. In general, when more and more of a variable input is added to a fixed input (with technology held constant), in a given time period, output, at first, increases at an increasing rate, then it increases at a constant rate, and eventually at a decreasing rate. If the process is carried far enough, and the variable input reaches the saturation point, relative to the fixed input, then there would actually be negative returns to scale. That is, output (i.e., TP, or Q) would actually start declining. This is known as the ***Law of Diminishing Returns.*** It can be traced back to Ricardo and Mathus.[174] Mansfield notes several points that summarize the assumptions behind the law of diminishing returns.[175]

1. The law of diminishing returns is an empirical generalization, not a deduction from physical or biological laws. In fact, it seems to hold for most production functions in the real world.
2. It is assumed that technology remains fixed. The law of diminishing returns cannot predict the effect of an additional unit of input when technology is allowed to change.
3. It is assumed that there is at least one input whose quantity is being held constant. The law of diminishing returns does not apply to cases where there is a proportional increase in all inputs.
4. It must be possible, of course, to vary the proportions in which the various inputs are used.

[174] Cannan, Edwin, *The Origin of the Law of Diminishing Returns, 1813-15*, ECONOMIC JOURNAL (1892): 2
[175] Mansfield (1975), p. 128.

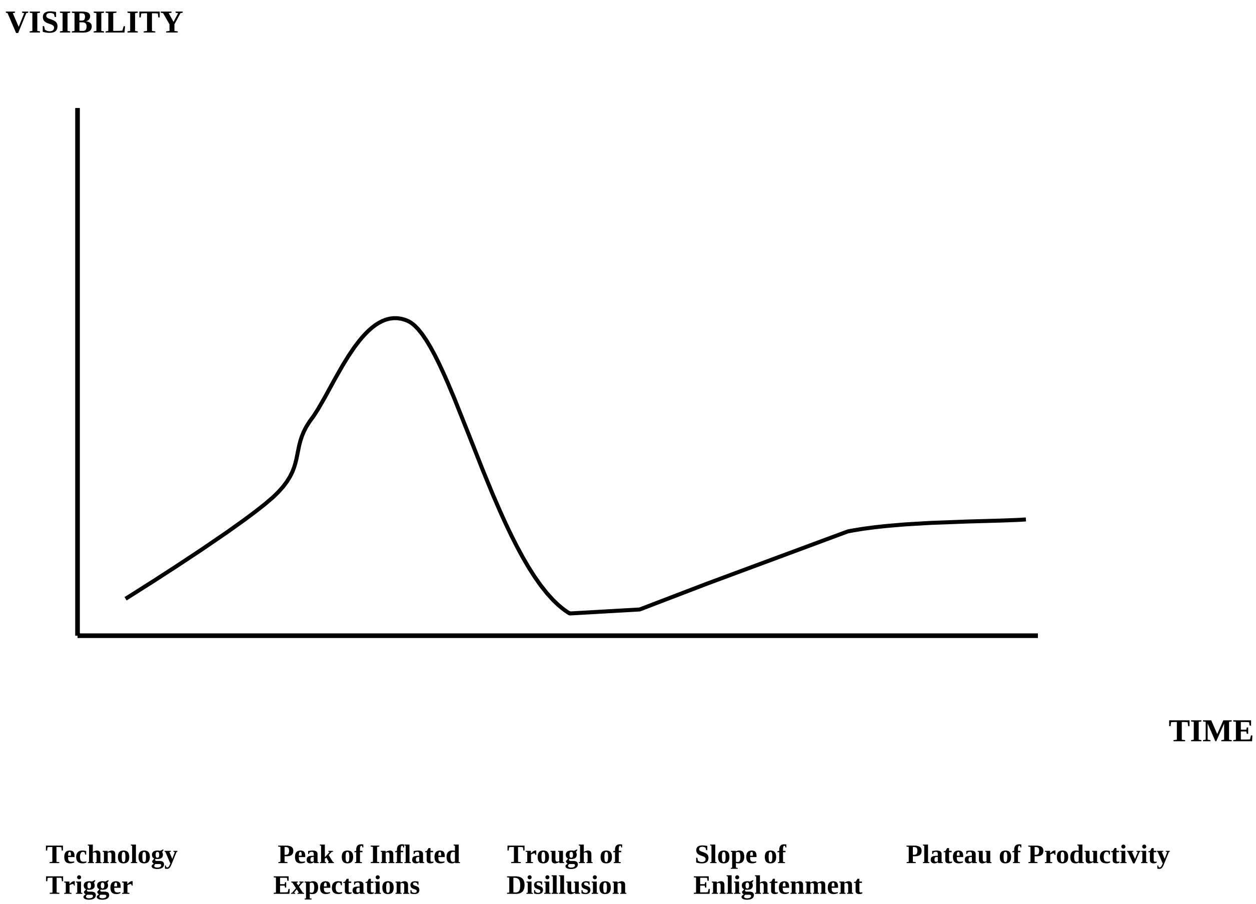
B. TABLE B--Silicon Valley's Waves of Innovation

<table>
<tr><th>WAVE</th><th>DRIVER</th><th>PERIOD</th><th>FEATURES</th></tr>
<tr><td>First</td><td>Defense</td><td>WW II-1970</td><td>• WW II and Korean War increased demand for the Valley's electronics products from firms such as HP and Varian Assoc.
• Defense spending helped build technology infrastructure of firms and support institutions in the 1950's.
• During the Cold War and Space Race, how the DOD procured technology is what drove innovation:
o DOD would specify their requirements and let the firms innovate to find solutions.
o DOD also required second-source arrangements to insure alternate suppliers, thereby spreading technology capabilities throughout the region.</td></tr>
<tr><td colspan="4">1970 NATIONAL/REGIONAL RECESSION: Ended the First Wave. Cutbacks in Vietnam Defense spending, which had stimulated the commercial application of defense technology.</td></tr>
<tr><td>Second</td><td>Integrated Circuits</td><td>1959-1976</td><td>• Explosive growth in the semiconductor industry in the 1960's and 1970's after the invention of the integrated circuit in 1959.
o This spawned the development of 30 semiconductor firms in the Valley during the 1960's, including Shockley with its spin-off Fairchild and its offspring Intel, AMD, and National Semiconductor.
o Only 5 of the 45 independent semiconductor firms started in the U.S. between 1959 and 1976 were outside Silicon Valley. "Silicon Valley" got its name during this period.
• This technology wave had an additional push with the invention of the microprocessor at Intel in 1971, which established the foundation for the next wave led by the Personal Computer (PC).</td></tr>
<tr><td colspan="4">FOREIGN COMPETITION: in the commodity chip business challenged this wave and forced the semiconductor industry to shift into specialized chips, including microprocessors.</td></tr>
<tr><td>Third</td><td>Personal Computers (PC)</td><td>1973-1990</td><td>• The technology foundation established by the Defense and Integrated Circuit waves established the environment for launching this wave.
• Silicon Valley had attracted a critical mass of technology firms, support industries, venture capital, and talent that helped ignite the PC Revolution.
o Young talent meeting at the Home Brew Computer Club eventually gave birth to more than 20 computer companies, including Apple.
• Explosive growth during this technology wave resulted in the number of Valley firms increasing from 830 in 1975 to 3,000 in 1990, while employment increased from 100,000 to 267,000.
• The initial focus on PC's that became commodities quickly led to the development of more sophisticated workstations (led by Sun Microsystems).
• This wave planted the seeds for the next innovation wave built around networks.
continued on next page</td></tr>
</table>

1985 REGIONAL RECESSION: The end of this wave was brought about by overcapacity and foreign competition in the semiconductor industry.			
1990 NATIONAL/REGIONAL RECESSION: End of the Cold War and subsequent cutbacks in defense spending.			
WAVE	**DRIVER**	**PERIOD**	**FEATURES**
Fourth	Internet	1990-2000	• The end of the Cold War, cutbacks in defense spending, and growing global competition in the semiconductor and computer hardware industries ushered in a period of slow growth in the early 1990's. Could the Valley re-invent itself again? • The answer came with the commercial development of the Internet in 1993, and the creation of the World Wide Web (WWW). • Building on its prior technology strengths, the Valley became a leader in the Internet Revolution. The result was the explosive growth of internet-related firms. o At the forefront were Netscape, Cisco, and 3Com. o Between 1992 and 1998, software jobs grew by more than 150%, and jobs in computer networking doubled. o Computer firms such as Sun and HP, and semiconductor firms such as Intel and AMD grew along with their Internet markets.
2000 NATIONAL/REGIONAL RECESSION: The Fourth Wave ended with the bursting of the Internet bubble and the overcapacity in the Telecommunications Sector as a result of the Internet bubble and the *1996 Telecommunications Act.*			

SOURCE: The Next Silicon Valley Leadership Group, NEXT SILICON VALLEY: Riding the Waves of Innovation, White Paper (December 2001) pp. 8-10.

C. GRAPH 1-C—The Hype Cycle



Graph 1-C is an adaptation of the "Hype Cycle of Emerging Technology" graph on page 5 of The Next Silicon Valley Leadership Group *NEXT SILICON VALLEY: Riding the Waves of Innovation* (December 2001), which was developed by The GartnerGroup <**http://www.umich.edu/~cisdept/mba/CIS745/GartnerHypeCycle.html**>.

D. TABLE D: Characteristics Common in the Development of the Four Studied Science Cities

COMMON CHARACTERISTIC	PRESENCE IN THE FOUR SCIENCE CITIES
The region faced a problem or crisis.	• SILICON VALLEY: Professor Fredrick Terman was concerned that his Stanford graduates were having to go to the East Coast after graduation, due to the lack of jobs in the area. • BOSTON: The Boston region found itself facing industrial decline in the beginning of the 20th Century. • METRO WASHINGTON: The U.S. Capital region faced an economic crisis triggered by the massive downsizing of the Federal workforce by Presidents Carter and Reagan. • RESEARCH TRIANGLE PARK: North Carolina faced industrial decline, and a brain-drain of its college graduates, in the period following World War II.
An individual, or group of individuals, took the lead in trying to solve the problem or crisis.	• SILICON VALLEY: Prof. Terman started to encourage some of his students to start companies near Stanford University. Among these students were William Hewlett and David Packard. He helped and encouraged them to commercially produce their audio-oscillator, and, in 1937, they started their company in the famous garage in Palo Alto. • BOSTON: MIT President Karl Compton, a member of the New England Council, extrapolated instances of firm formation by MIT professors into a vision for a new wave of technical industry. Beyond respect for his personal qualities and scientific achievements, his prestige as head of MIT, as well as pride in the region's educational and research institutions, gained Compton an audience for his ideas. In essence, he conceived the idea of *knowledge-based growth and development.* • METRO WASHINGTON: In the case of the Capital region, it was Federal policy and legislation, in conjunction with the presence of some key Federal agencies, such as the NIH and DARPA, that "got the ball rolling" in the region. There were no specific individuals, or group of individuals, as there were in the other three instances. In this case the "individuals" were institutions: the NIH and DARPA. • RESEARCH TRIANGLE PARK: The original impetus for what would become the Park was in early 1954, when Brandon Hodges, the State Treasurer of North Carolina, Robert Hanes, the President of Wachovia Bank and Trust Company, and Romeo Guest, a Greensboro building contractor, who, some say, gave birth to the idea of a research park in the Triangle Area, met to discuss North Carolina's need for industrial growth. *continued on next page*

There was the presence of an institution, or institutions, that played a critical role in generating regional economic renewal.	• SILICON VALLEY: Stanford University was founded in 1891 by Governor Leland Stanford at his domain nearby 'El Palo Alto' (the high tree) in memory of his son Leland Stanford Junior. Later, it was especially Prof. Frederick Terman, who was a Stanford graduate himself, whose role was crucial for the development of the local high-tech industry before and after World War II. In the twenties, administrators at Stanford sought to improve the prestige of their institution by hiring highly respected faculty members from East Coast universities. During the fifties, Stanford introduced a lot of new ways of working as a university (which were revolutionary at that time): **The Honors Cooperative Program**: graduates could be updated in their specialty. **The Stanford Research Institute** (1946): practice focused, non-profit research, which didn't fit within the traditional tasks of a university. **The Stanford Industrial Park** (1951): offering facilities for starting companies. • BOSTON: The Massachusetts Institute of Technology (MIT) was founded in 1862, as a unique industrial variant of the land-grant universities, established in each state to support the development of agriculture, the nation's major industry at the time (Rossitor, 1973). The land-grant schools focused on practical subjects, rather than the classic liberal arts, although the later were also included in the curriculum. MIT was designed as a technological university, to train students and infuse new ideas into the region's industrial economy, but also to conduct basic research and pursue those liberal arts with technological relevance like the history of science and technology. • METRO WASHINGTON: Though academic institutions would play an important role at later stages of the development of the Capital region's high-tech clusters, in the embryonic and take-off stages, it was the Federal R&D-oriented agencies, that played the critical role. The presence of the NIH in the Washington region is a defining characteristic for the region's Biotech cluster. It employs a large number of researchers at its home campus in Bethesda, MD. The NIH has been a spawning ground for new start-ups over the last 10-15 years. Other government agencies such as the Walter Reed Army Institute for Research (WRAIR) and the U.S. FDA have also been a significant source of biotech entrepreneurs. Critical for the development of the ICT cluster has been the presence of the Defense Department, and its R&D agencies. The modern computer networking technologies that are the backbone of the Internet and ICT emerged in the early 1970's from ARPANet, which was developed at the U.S. DOD Advanced Research Projects Agency (DARPA, known then as ARPA) (see Kahn and Cerf, 1999). Individuals leaving the Defense Department and the military services formed the first start-ups. In addition, individuals from private industry, both within the region and from without, figure prominently in the development of this cluster. • RESEARCH TRIANGLE PARK: Critical to the idea, and actual birth and development, of Research Triangle Park were the three closely-located academic institutions that inspired the very name of the research park: the University of North Carolina, North Carolina State University, and Duke University. In addition to the three universities, executives from Wachovia Bank and Trust also played major roles in the establishment of Research Triangle Park. *continued on next page*

The region pursued an economic development strategy based on technology transfer and science-based growth.	• SILICON VALLEY: In 1937, William Hansen, Professor of Physics, teamed with Sigurd and Russell Varian to develop the klystron tube, an electron tube in which bunching of electrons is produced by electric fields and which is used for the generation and amplification of ultra-high frequencies. During World War II, the brothers Sigurd and Russel Varian worked rent free in a Stanford lab on their klystron tube. Later on, radar and Varian Associates' (1948) inventions, involving microwave radiation, evolved. Stanford gave them, besides rent free lab use, $100 for supplies. In return, Stanford was to share in any profits. The investment of Stanford was one of the best ever because it brought in several millions of dollars in royalties. Also during World War II, Professor Terman made good contacts within Washington. After his return to Stanford, he succeeded in getting a lot of governmental contracts for Stanford and local companies. • BOSTON: When the conventional approaches failed, the New England Council explored a series of alternatives based on the knowledge resources of the region. The focus gradually shifted from incrementally improving existing firms, to a discontinuous approach, that is, creating new industries. The Council early recognized that a concentration of academic and industrial research laboratories was New England's competitive advantage. The initial idea was to encourage the formation of small firms. The Council's "New Products" committee, established to assist existing firms, turned to the more far-reaching idea that New England's intensive research universities could substitute for the natural resources that the region lacked. This approach foreshadowed a completely new perspective on how to think about comparative advantage. This foreshadowed, by 80 years, Baumol and Gomory's (2003) concept of *acquired comparative advantage*, and modern, regional economic development theory, with its emphasis on the *strategic management of places*. Much of the model of university-based economic development was derived from the activities of Vannevar Bush, an electrical engineering professor, and then Dean and Vice-President of MIT. Bush was a prototypical entrepreneurial academic, combining in a very effective manner both intellectual and commercial interests in the course of his career. • METRO WASHINGTON: The U.S. Capital region's move to science-based growth, predicated on technology transfer was exogenously imposed, as opposed to policies developed by individuals and institutions indigenous to the region. The changes in employment structures and incentives were coupled with new opportunities for the commercial exploitation of intellectual property rights that accrued from publicly funded research. These new structures and incentives were, in turn, the result of changes in Federal policy and legislation that created a pool of educated, unemployed workers, in conjunction with new opportunities for the private sector to contract with the Federal Government and commercialize new technologies, motivated many former government employees and contractors to respond to the crisis by starting up new firms. These legislative changes created new commercial opportunities that have lured many scientists into starting their own companies, and thereby, facilitate the process of technology transfer. • RESEARCH TRIANGLE PARK: Unlike the other three science cities, Research Triangle Park would approach knowledge-based economic development from a different perspective. Instead of creating new firms and products, the founders' vision of the Park was a place to attract the R&D operations of existing firms. They believed that, due to the close proximity of the three universities, they would "by the very research atmosphere that their very existence creates," will act as a magnet to attract industry "by providing a wellspring of knowledge and talents for the stimulation and guidance of research by industrial firms."
The region developed an ecology that fostered entrepreneurial activity.	• SILICON VALLEY: Stanford Professor Fredrick Terman was concerned that a lot of his graduates went to the East Coast because of the lack of *continued on next page*

jobs in the Valley. To solve that problem, he started to encourage some of his students to start companies near the university. Among these students were William Hewlett and David Packard. In the meantime, some other students founded small companies that were going to be the center of a local electronics-industry. During 1937, William Hansen, Professor of Physics, teamed with Sigurd and Russell Varian to develop the klystron tube, an electron tube in which bunching of electrons is produced by electric fields and which is used for the generation and amplification of ultra-high frequencies. During the Second World War the brothers Sigurd and Russell Varian worked rent free in a Stanford lab on their klystron tube. Later on, radar and Varian Associates (1948) inventions, involving microwave radiation, evolved. Stanford gave them, besides rent free lab use, $100 for supplies. In return, Stanford was to share in any profits. The investment of Stanford was one of the best ever because it brought in several millions of dollars in royalties.

- BOSTON: MIT President Karl Compton, a New England Council member, extrapolated instances of firm formation by MIT professors into a vision for a new wave of technical industry. In addition, much of the model of university-based economic development also came from MIT, specifically from the activities of Vannevar Bush, an electrical engineering professor, and then Dean and Vice-President of MIT. Bush was a prototypical entrepreneurial academic, combining in a very effective manner both intellectual and commercial interests in the course of his career. Nevertheless, though New England had capital and technology, and creative leaders like Compton and Bush, it still lacked a systematic methodology for firm formation. Immediately after World War II, Compton organized a consortium of universities, investment banks, and insurance companies, to found the first venture capital firm, *American Research and Development* (ARD), through the sale of equity in the firm. The organizational design and staffing of the project were derived from MIT and Harvard Business School. Technological opportunities were enhanced by World War II R&D projects, focused at universities, and expanded after the War into civilian as well as military fields. ARD's initial success, after a decade of initial investments, was the *Digital Equipment Corporation* (DEC), based on a Navy research project to develop a pilot training device.

- METRO WASHINGTON: The beginning of the biotech industry can be traced to 1973 when Stanley Cohen and Herbert Boyer invented their genetic engineering techniques. The earliest entrepreneurs in the Capital region started firms during this time of high opportunity. The earliest biotech firms were started up by individuals who had previously been employed by prominent suppliers to the National Institutes of Health (NIH). The presence of the NIH in the Washington region is a defining characteristic. It employs a large number of researchers at its home campus in Bethesda, MD. The NIH has been a spawning ground for new start-ups over the last 10-15 years. The modern computer networking technologies that are the backbone of the Internet and ICT emerged in the early 1970's from ARPANet, which was developed at the U.S. DOD Advanced Research Projects Agency (DARPA, known then as ARPA) Individuals leaving the Defense Department and the military services formed the first start-ups. In addition, individuals from private industry, both within the region and from without, figure prominently. Entrepreneurs hail from a variety of different organizations. Government agencies served an important incubator function in both industries. However, they were not the sole source of entrepreneurial talent. There is evidence of a great diversity in the backgrounds of the entrepreneurs. Over time, new generations of new firms spun-off from the earliest start-ups, and entrepreneurs who cashed in from one new venture created other new companies.

- RESEARCH TRIANGLE PARK: As previously mentioned, the Research Triangle Park followed a different path than the other three science cities studied here. The idea of using the three triangle universities to *attract research companies into a park area* central to the universities quickly emerged from the early discussions. Thus, there was not the emphasis on entrepreneurship and new firm formation. Rather, the emphasis

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	was on attracting the R&D facilities of existing firms. Nevertheless, this approach was still new, at the time. Manufacturing firms tended to have their R&D facilities near their production facilities. The idea of spatially separating these activities, and concentrating the R&D facilities of different firms, from different industries, in one location, to tap into externalities, and economies of scale and scope was a new idea. Further, the founders of Research Triangle Park recognized the now frequently followed policy of basing the future economic fortunes of the region on being the location for the high-end, high-skilled, earlier, pre-standardization, stage of the production and product cycle.
In the initial stages, regional inter-firm networks developed along the Social Network type of industry cluster. (Based on the typology suggested by McCann, Arita, and Gordon; 2002.)	• SILICON VALLEY: Silicon Valley actually developed such that it has the characteristics of both the Pure Agglomeration and Social Network types of clustering. Particularly, the benefits of industrial clustering for the semiconductor industry have been analyzed in terms of the role played by informal local information spillovers, and also in terms of the advantages associated with a high quality and highly flexible local labor market. Both firms and the local industry have evolved largely by non-price mechanisms, in the sense that information and labor market externalities play a key role, as do certain 'trust' relationships between local firms, if and where they exist. In terms of McCann et al.'s cluster characterizations, Silicon Valley is primarily a 'pure agglomeration,' with possibly also some aspects of a 'social network.' In fact, the historical record indicates that its social network features were the original spark that ignited the Silicon Valley cluster-from Professor Terman's and other Stanford professors' social networks to the Home Brew Computer Club in the 1970's. • BOSTON: The science city aspects of Boston's resurgence had the characteristics that were similar to, though not exactly, those that later characterized the development of the Silicon Valley science city, and discussed above. And, like Silicon Valley later, it appears to be social networking that launched Boston's revolutionary approach to regional economic resurgence. As Silicon Valley would do later, it took on the characteristics of both the Pure Agglomeration and the Social Network type of cluster. However, as its first success, the mini-computer industry, matured, it took on the more extreme features of a purely Industrial Complex, particularly losing its social network aspects. This may have played a critical role in its subsequent extinction. This is a trap the region's Biotech cluster seems to have avoided. • METRO WASHINGTON: As in the case of Boston-Route 128, a city and surrounding suburbs already existed long before the Biotech and ICT clusters arose in Metro Washington, whereas, urbanization/suburbanization was the result of the rise of Silicon Valley and Research Triangle Park. Thus, pure agglomeration characteristics pre-dated the rise of the Biotech and ICT clusters. However, due to the concentration of high intellectual capital, social networks were established trough interest/advocacy groups and technology councils. • RESEARCH TRIANGLE PARK: Though following a different route than the other three studied science cities, Research Triangle Park, nevertheless, also began with the social networking of several individuals that were interested in developing an idea for a research park centered within the geographic proximity of three closely-located North Carolina universities (Duke University, the University of North Carolina, and North Carolina State University). The original social network later expanded to bring in new members as the process progressed from the idea stage, to the fund-raising/attracting investors stage, to a shift in concept and change in direction, and finally to the implementation stage. Within the McCann et al. typology, the social network aspects of Research Triangle's R&D cluster has given way to the Agglomeration Economies type of cluster.

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