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What Is the Role of the University in Creating a High-Technology Region?

Heike Mayer

IN The past thirty years, high-technology industries have become popular among economic development planners because they feel that these knowledge-based industries contribute to regional economic success by providing rapid employment growth, relatively high-paying jobs, multiplier effects, and diversification of the local economy through new-firm creation and startup activities.

In the United States, regions such as California's Silicon Valley and Boston's Route 128, are the prototypes for successful high-technology development. Silicon Valley created 150,000 technology-related jobs between 1975 and 1990, and from 1997 to 2000 high-technology employment grew by 3.8 percent annually. This growth mobilized policymakers and business leaders in other parts of the United States and across the world to strive to transform their regions into the "next Silicon Valley". The most successful high-technology centers were fueled by continuous technological innovations, demand for high-technology products by the military and later by consumers, the rise of the venture capital industry, and, last but not least, by the support of academic institutions that created high-tech research laboratories and curricula to reflect the growth of these new industries.

Miller and Côté

The success stories of Silicon Valley and Boston cemented the belief that world-class research universities drive economic growth. In these regions, Stanford University and the Massachusetts Institute

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of Technology contributed to the growth of technology companies in three ways: they developed and attracted talent to create a specialized labor pool; they funded research that translated into new products and processes; and university administrators promoted new business formation to contribute to regional entrepreneurship.

Second-tier regions such as Austin in Texas and North Carolina's Research Triangle Park also benefited from investments in their respective higher education infrastructure. Especially during the 1990s, these regions showed impressive track records in rooting high-technology businesses. In contrast to these regions, there are cases where top-tier research universities have not influenced the creation of technology-driven industries. One could think of Seattle, Washington, or Baltimore, Maryland, or numerous cases of small towns that host world-class land grant universities. Moreover, regions such as Colorado Springs or Portland, Oregon, also established high-technology industry clusters during the same decade. These last two regions are distinguished, however, by the lack of a world-class higher education infrastructure. How have these regions rooted knowledge-based industries without a top-rank scientific research university? Have these regions merely benefited from a strong economic climate? Or did other agents provide the seeds for high-technology growth? And what exactly is the role of the research university in high-technology economic development?

In contrast to common assumptions, the literature on the evolution of high-technology regions is characterized by a lively debate regarding the role of the research university in catalyzing economic growth. The debate can be structured into three models that explain high-technology growth. The first model is characterized by successful high-technology development in regions where a world-class research university is present. Regions like California's Silicon Valley, Boston's Route 128, and North Carolina's Research Triangle Park represent this model. The second model describes regions that host research institutions such as The Johns Hopkins University or federally funded R&D laboratories. But even though these regions possess an academic infrastructure, they failed to leverage the institutions for economic development. In these cases, economic development did not result from the presence of such institutions. Thus, such case studies suggest that the presence of a research university in a region is not sufficient. The third model focuses on regions that do not have a research university but have successfully developed a high-technology industry base. Seattle's software industry,

Luger and Goldstein 1990
Saxenian 1994a

for example, did not benefit from the proximity to the University of Washington. In Colorado Springs, military facilities substituted for the presence of a research university. In Portland, Oregon, two private firms functioned as catalysts for high-tech economic development. From that, emerges the notion that a research university is not necessary to spur high-tech industries.

In contrast to the dynamic discussion in academic research, economic developers have adopted the first model in which the research university plays an important role. As a result, economic development policies increasingly focus on the university as a vehicle for economic growth. This perspective has led economic developers and higher education officials to establish science parks, technology transfer and commercialization programs, and university-based venture capital funds among other economic development policies. Even though the academic literature questions this model, policymakers and higher education officials still myopically focus on the necessity of a research university.

Castells and Hall
Feller 1990
Florida and Cohen

This paper provides a critical examination of the different ways a high-technology region can evolve and the extent to which a research university can play a catalytic role in that evolution. I briefly review the general roles universities have played in their local and regional communities. This will serve to introduce the major contributions higher education institutions make to economic development. Since technology-based economic development has become a popular concern of economic development practitioners, I will then focus my discussion on the role of the university in stimulating the growth of high-technology centers. Here, I will present a critical review of the literature and point out that universities have not always played a significant role in the creation of technology industry clusters. I will also highlight the importance of other factors in the creation and maintenance of high-tech industries and will argue that a university is neither a necessary nor a sufficient ingredient in the recipe for high-tech success. Finally, an attempt is made to clarify the role of the university in economic development and to synthesize critically the evidence and provide suggestions for further research regarding the role of the university in high-technology regional development.

Universities and Urban Development in the United States

Universities play an important role through their contributions to local economic development, real estate development, and

community development. The most relevant to this review is the role of the university in spurring economic development which can be traced to the establishment of the land grant university system in 1862. The movement was a response to the demands for higher education to be more practical and utilitarian and facilitated the university's orientation towards local industry through training, knowledge provision, and extension services. Rosenberg and Nelson describe how close linkages with local industries facilitated the institutionalization of engineering and applied sciences and how in turn these new academic disciplines created technological advances and innovations that spurred economic growth in the United States. Today's land grant universities are still focused on providing services to their local communities (especially in agriculture and forestry as well as other extension-oriented services), but they have changed their orientation to include other scientific fields (for example the life sciences) and have found new ways of helping the regional economy through the introduction of such entrepreneurial efforts as incubators, specialized research centers, and technology transfer programs. Luger and Goldstein describe these additional roles of the university as a response to the pressures of globalization and economic competitiveness and the urge to involve universities in local and regional economic development through the creation of startup companies and the facilitation of an innovative knowledge environment.

Lucas

Rosenberg and Nelson

Lazzeroni and Piccaluga
Rosenberg and Nelson
Smilor et al. 1993

Luger and Goldstein 1997

Besides the shift from traditional involvement with agriculture industries, universities have always played an important role as economic agents themselves. Universities are important customers for necessary supplies; they often are the major employer in a community; their student body provides a steady stream of customers for local shops and restaurants; their sports and entertainment activities are important stimulants for local tourism activity; and their expansion activities have influenced physical capital and infrastructure investments. These functions have been assessed primarily in consulting and research reports about the economic impact of the institutions. Such studies often serve higher education officials in their policymaking and internal management processes. Austrian and Sadowski's economic impact study of Cleveland State University is one example of an economic impact study. Other efforts such as Illinois' assessment of its higher education institutions, Boston's study of its eight research universities, or San Diego's examination of direct and indirect effects of the UC system have expanded their definition of impact to include innovation and commercialization activities.

Luger and Goldstein 1997

Resek et al.

The Association of Independent Colleges...
Lee and Walshok

Often these studies are efforts to demonstrate the university's impact on state economic development and could be regarded as public relations or lobbying efforts. For an example see North Carolina's study. Academic studies of the economic impact of universities have accompanied these reports and a critical review of these studies is presented in Beck et al. R.Thanki offered a valuable overview of such impact studies in the United Kingdom in a 1999 article in *Regional Studies.*

Thanki

Huron Consulting Group

More recently, attention has been shifted to the role of the university as an urban developer. The studies that emerged in this field emphasize the influential part universities play in developing the land around them. Perry and Wiewel's edited volume presents a wide range of case studies that examines the expansion of the university campus into their neighborhoods and their role in inner city revitalization. Their edited volume goes beyond a mere description of these cases by analyzing the collaborative relationships between universities and their surrounding communities, the political struggles involved, aspects of making deals, and critical ethical questions. Other studies have highlighted the benefits that occur both to the community and the university from their efforts at neighborhood transformation and revitalization. In her historical account of the efforts of particular universities (University of Pennsylvania and Georgia Tech) to transform their surroundings into high-technology communities, O'Mara links the real estate and land development role to that of an economic development agent.

Perry and Wiewel

Deitrick and Soska
Marcuse and Potter
Coffey and Dierwechter

Cummings et al.
Weber et al.

Rodin

In a third role, the university is increasingly seen as a partner for community development and social change. The literature in this area focuses primarily on aspects of civic engagement of the university with the goal of transformative social change. Such studies can be found in journals of higher education, community development and urban planning (for an example see the 2000 special issue of the journal *Cityscape* on community outreach partnerships), and the nonprofit sector. Studies in this tradition emphasize the connection between student learning and civic engagement with the community through two-way relationships. For a good overview of university-community partnerships, see Cox.

Brisbin and Hunter

Ostrander

The three roles described above emphasize that the university cannot be viewed in isolation of its environment. In the book *The University and the City*, editor Thomas Bender highlights this notion and the case studies persuasively show how the university is an integral part of the urban environment. Institutions of higher

education are increasingly seen as change agents in urban development and planning and within the field of economic development, a perspective of the university as an "engine of economic growth" has emerged. This perspective is especially dominant in discussions on high-technology economic growth and the role universities play in creating knowledge-based regional economies.

High-Tech Growth with Universities

The high-tech economies of Silicon Valley, Route 128, and Research Triangle Park have become the prototypical examples of how regional economic development leverages existing higher education institutions. Saxenian describes how MIT's and Stanford's close partnerships with high-technology industries benefited regional economic growth. In Silicon Valley, Frederic Terman, Dean of Engineering at Stanford University, spearheaded a variety of efforts to transform Stanford University into an economic growth engine. Terman envisioned close relationships between industry and university, encouraged and supported Stanford graduates in establishing their own companies, and leveraged the Stanford Industrial Park as a real estate strategy for economic growth. In Boston, MIT functioned as an early hub for electrical engineering research and government contract work. Luger and Goldstein point to the prominent role that North Carolina's research institutions played in the planning and development of Research Triangle Park. The theory of the university has also been applied to second-tier, high-technology regions. In the case of Austin, Texas, the university (University of Texas) played a pivotal role in promoting home-grown companies (some of them as university spin-offs) and in attracting large technology firms from outside. In a later article, two of the same authors contend that "if such a research university is not in place, and has not attained an acceptable level of overall excellence, then a technology center is not likely to develop very rapidly."

Saxenian 1985
Saxenian 1994a
Williams
Luger and Goldstein 1990
Smilor et al. 1989
Smilor et al. 1993

Brooklyn, New York's MetroTech complex is a case where a university played a key role in creating a technology complex in an urban setting. In the mid 1970s, the Polytechnic University, in partnership with the City and State of New York, developed a concept for an urban knowledge park for Brooklyn. The park was a response to the threat of job loss to neighboring states,

Bugliarello 1999
Bugliarello 1993
Bugliarello 1996

urban decay, and declining student enrollment. Unique about this case is that the example not only highlights how a university plays an important role as an agent of the urban revitalization of a 16-acre park, but it also illustrates how vibrant university-industry partnerships can be created through specialized technology centers. The Center for Advanced Technology in Telecommunications and Distributed Information Systems (CATT), for example, works closely with the city's telecommunications, information technology, and financial services industries. In doing so, the university plays a key role in providing its expertise to New York's industry clusters, thereby making them more competitive. MetroTech is an early example of how science and technology programs can influence a region. The project resulted from ideas and concepts developed from a study of the role of engineering schools in Illinois, which

Bugliarello and Simon

was sponsored by the National Science Foundation. The NSF study highlighted a variety of areas where engineering colleges can contribute to regional economic development. It is interesting to note that this was a very early study and that its ideas have been implemented especially in response to the role of the university in creating regional and national competitiveness.

In all these regions, a university's contribution to the development of a local technology industry is attributable to three factors: labor, knowledge creation, and entrepreneurship. First, they supplied the region with a specialized technical workforce that was hired by the emerging technology companies. Second, universities spearheaded knowledge creation efforts. During World War II, for example, MIT became the leading center for military research. Under the leadership of Vannevar Bush, MIT established the Radiation Laboratory, which was the "first large-scale interdisciplinary and multifunctional R&D organization at

Saxenian 1994b

a U.S. university." Stanford University emerged as an important post-World War II research institution and established the Stanford Research Institute in the 1950s. The Institute was charged with conducting applied and practical research.

Third, these research universities fostered entrepreneurship. MIT and Stanford most notably functioned as incubators for new companies. Faculty and students left academia to establish their own businesses and this entrepreneurial activity furthered economic growth in these regions. Companies such as Shockley Semiconductors and Hewlett-Packard can trace their roots to

Lecuyer Packard

Stanford University. A 1997 BankBoston study presents data on

BankBoston

MIT-related startup companies. According to this study, more than 4,000 companies across the nation can trace their roots to

MIT. The majority of these firms are located in the Boston area. The literature on university startups is limited, however. Studies of academic entrepreneurship focus on the most prestigious institutions, such as MIT or Stanford University, but more comprehensive studies have yet to be undertaken. In general, the methodology illustrating this category has used the case-study approach. In addition, these case studies have incorporated a historical perspective that tended to be biased towards the catalytic role of the universities in the initial phases of regional high-technology development.

These prominent examples of high-technology development have led to more theorizing about research universities and their impact on regional economies. Luger and Goldstein conceptualize the role of public universities in regional economic development. They argue that such institutions contribute to regional economic growth in a variety of ways. Specifically: universities develop human capital, create basic knowledge through research, transfer existing know-how, apply knowledge to the creation and commercialization of new products or processes, make capital investments, provide regional leadership, co-produce the region's knowledge-based infrastructure, and lastly, create a favorable economic environment.

Luger and Goldstein 1997

These university spillover effects contribute to the creation of high-technology regions. Other studies confirm this claim. Miller and Côté, for example, acknowledge a set of necessary conditions that need to be in place to develop a high-technology region. They include: availability of state-of-the art technical knowledge, presence of an incubator that spawns high-technology startups, and an entrepreneurial environment. Castells argues that scientific and technical labor is a basic production factor in high-technology industries because those businesses rely on information and technical know how. Industry cluster theory, pioneered by Michael Porter, emphasizes the critical role higher education institutions play as input factors. Others have refined the importance of universities in industry clusters and argued that not just science and technology disciplines contribute to the success of clusters, but also other academic areas and the general breadth of a university. The actual role of universities in workforce development and whether universities create local labor markets are questions for debate. Some theorize that a labor pool is in most cases not indigenous, but is "recruited either directly by rapidly expanding firms or indirectly through the agency of local universities." In sum, the necessary seeds for growing a high-technology region

Paytas et al.

Markusen et al. 1986

are believed to be a specialized labor pool, cutting-edge knowledge that can be commercialized into new products, and entrepreneurs who start their own businesses. The theory of university primacy in industry development argues that research universities create these seeds and thereby act as engines for economic growth.

Failure in the Presence of Universities

Some academic studies challenge the theory of universities acting as engines of economic development. These studies have focused on the failures to replicate the Silicon Valley model. Scholars have examined regions that have not been successful in leveraging existing research universities. Combined, these studies suggest that a research university is not sufficient for growing a high-technology region. Moreover, they posit that a supportive local environment must be in place to complement the research university and absorb its spillover effects.

Efforts to replicate the success of Silicon Valley have a long history. By the mid-1960s, Frederick Terman, Stanford's provost and dean of engineering, traveled to several regions in the United States and abroad in an effort to replicate the Silicon Valley model. Terman believed that Silicon Valley could be copied in other regions if the right kind of university was in place. He tried to set up higher education institutions that resembled Stanford University in places as far-flung as northern New Jersey, Dallas, and outside the United States in South Korea. But Terman's attempts failed because he overemphasized the importance of the research university and did not fully appreciate the relationship between the research university and the local environment. Terman's approach ignored that industry and an academic infrastructure symbiotically grew up together in Silicon Valley.[1] Moreover, Terman failed because most of these places did not have a local environment characterized by a regional network-based industrial system able to absorb the seeds created by the research universities. A study by Leslie of New York's capital region and efforts around Rensselaer Polytechnic Institute (RPI) confirms this assessment. Regional leaders in the mid-1970s undertook a series of efforts that were aimed at imitating Silicon Valley's success. Leslie states that "yet for all they accomplished in transforming RPI, they could not overcome the regional disadvantage that kept them from competing effectively with emerging high-technology centers in other parts of the country. [. . .] Without a strong

[1]*Interestingly, several historical accounts of Silicon Valley's evolution focus not only on its higher education infrastructure as an economic engine, but also on early electronics companies such as the Federal Telegraph Company, which got started in 1909 and quickly became the nation's largest wireless firm (Malone). Most historical accounts of Silicon Valley begin with 1955 when William Shockley founded Shockley Transistor Corporation in Palo Alto (Sturgeon).*

Leslie and Kargon

industrial base to capture and hold the innovations [. . .], RPI ended up exporting its best ideas and best graduates to other places, including Silicon Valley itself." This case stands in contrast to the aforementioned example of the urban knowledge park created in Brooklyn. Studies like Leslie's take a historical case study approach and focus on the efforts on behalf of the universities to establish themselves as economic engines.

Leslie

These failures underline the importance of the economic environment in which a research university is embedded. In the case of Silicon Valley and Route 128, this environment emerged in parallel with the research university. The regional economy provided work opportunities for Stanford graduates. Incoming venture capital supported the commercialization of knowledge that originated from the university and contributed to increased entrepreneurial activity. And corporate activity that emerged even prior to Stanford University's rise as the preeminent higher education institution provided a fertile industrial base. In short, Silicon Valley developed a supportive regional economy in which university efforts could become fertile. Some scholars, as will be discussed below, call such an environment an innovation milieu.

Sturgeon

Camagni
Castells

By being able to develop this environment, the importance of a research university might have declined as a source for continuing high-technology growth. Castells and Hall, for example, point out that

> Silicon Valley became a self-sustaining innovative milieu of high-technology manufacturing and services, generating its own production factors: knowledge, capital, and labor. Universities [. . .] continue to be critical in providing the labor market with well-trained engineers and scientists. However, their role as sources of R&D has substantially declined in comparison to the endogenous research capacity of the industry. . ..

The theory of the university as an engine of high-technology growth is further challenged by evidence from regions that have not been successful in leveraging existing higher education institutions. Baltimore and Cleveland are examples of urban regions not capitalizing on the presence of a research university.

Feldman presents research findings of a case study for the Baltimore region, which hosts one of the nation's most prominent medical research institutions, The Johns Hopkins University. According to Feldman, the region was not able to develop an innovation infrastructure around The Johns Hopkins University

Feldman 2001

and, consequently, the local environment did not capture the benefits available through its proximity to this major research university. Several important characteristics of a high-technology region were missing in the case of Baltimore: it lacked a critical mass of technology-intensive firms where innovation could be developed and commercialized and it lacked large plants that focused on R&D. Feldman argues that the large branch plants located in Baltimore do not generate innovations and new startup companies. The region also lacks specialized producer services and an entrepreneurial culture that encourages researchers to start their own businesses. The latter finding points to the lack of a local environment or innovation milieu capable of absorbing the spillovers from Johns Hopkins. In later work, Feldman and her co-authors argue that the greater Washington, D.C. region emerged as a high-technology region because federal downsizing provided an external impetus while subsequent entrepreneurial activities ensured the growth of the region.

Feldman and Francis 2001
Feldman and Francis 2003

While the studies mentioned above primarily rely on case studies and historical sources, another study employed a more quantitative approach to examine whether universities have made a difference in regional economic development. Fogarty and Sinha examined patent citations and presented evidence for failed university engagement in the Cleveland, Ohio region. When Cleveland was faced with severe industrial decline, state and local policymakers committed significant investment to improve university-industry relationships. Fogarty and Sinha describe efforts to enhance these relationships that ranged from federally sponsored science and technology centers at existing research universities to technology transfer and commercialization programs. The investments, however, did not induce local economic development. Cleveland's local economy was not able to absorb the academic spillover effects, and important technological breakthroughs produced in Cleveland's research labs quickly diffused to other regions, namely Silicon Valley and Boston. They conclude that older industrial regions especially cannot generalize from the experiences of Silicon Valley.

The cases discussed in this section illustrate that hosting a world-class research university and investing in university-based programs are not sufficient for creating economic growth. To leverage these institutions, regions must develop a regional economic infrastructure or innovation milieu that is able to absorb the academic spillover effects. Fogarty and Sinha concluded that "R&D spillovers associated with the new technology will become a source of long-run economic benefit only if the local industry

Garnsey

R&D network draws from the technology, if commercialization occurs locally, and if the region's industries capture the technology through diffusion and investment."

The importance of a local innovation milieu is supported by findings of a national study of spatial patterns of academic research and innovation activity (as measured by research expenditures) by Varga. Varga demonstrated that the most developed high-technology agglomerations (measured by levels of high-tech employment) absorb the university effects most efficiently. Over time, these high-technology regions may have developed a local environment or innovation milieu that is responsible for absorbing the university spillovers.

Successful High-Tech Development without a University

The literature describes a third group of high-tech regions that is characterized by successful high-technology development in the absence of a research university or where regional economic development did not build on existing academic institutions. These cases present counterfactuals and challenge the theory of the university as a necessary condition for high-tech growth. These studies use Markusen's methodology "studying regions by studying firms"and focus not only on the university's role but also on the role of firms and other institutions such as military establishments. As the case studies show, these regions compensated for the lack of a university by hosting firms, private research laboratories, or military facilities that acted as catalysts for high-tech growth.

Markusen

In the case of Colorado Springs, the region had no research university or skilled labor force. Instead, military facilities built the basis of regional economic development and high-tech growth. Labor was imported mainly from California and Boston and was attracted by the rapidly expanding military facilities. Local leaders pushed for an improved higher education system and "forced the state" to set up a university. The authors concluded that "university involvement has followed the creation of the complex, not the other way around."

Gray and Markusen

Markusen et al. 1991

Markusen et al. 1991

A case where a region's higher education infrastructure did not influence high-technology growth is Seattle. Although Seattle hosts the renowned University of Washington, the aerospace and software industry cluster developed independently of this institution. Instead, large employers such as Boeing and

Gray et al. 1999
Gray and Markusen

Microsoft were the catalysts for high-technology growth. Boeing and Microsoft, for the most part, did not rely on the university for developing knowledge and recruiting talent. The researchers state that large firms such as Microsoft "recruit nationally and internationally for employees and researchers."

Gray et al. 1999

Gray et al. 1996

Gray et al. study the Seattle region as a hub-and-spoke industrial district. They argue that two firms, Boeing and Microsoft, function as the anchors in the regional economy with relationships to competitors, suppliers, and customers outside and inside the region. Boeing acts as the hub for the aerospace industry in the region and, despite waves of layoffs, the company is still the region's most important employer. Until the early 1990s, Boeing maintained an oligopolistic market position and vertically integrated organizational structure. Competitive pressures and uncertain markets, however, forced the company to restructure. Boeing tried to improve coordination between its functional divisions, increase communication between the firm and its customers and suppliers, and implement concurrent design and manufacturing procedures. In the late 1990s, the company also initiated substantial layoffs (more than 20,000 workers). Even though only a small set of Boeing's suppliers (15 percent) were locally based, some of them were spin-offs or start-ups. In addition, Boeing is working more intensively with these local suppliers.

The study shows that the corporate restructuring process influenced the regional economic structure. The study also found that Boeing "has been a powerful agent in shaping regional economic infrastructure and labor pools. Thus, its role as a regional hub is perhaps its most significant contribution to the economy beyond its sheer size and direct employment." Boeing attracted other firms that wanted to take advantage of the region's skilled labor pool, specialized business services, and other amenities.

Gray et al. 1999

Boeing also functioned as an important catalyst for the creation of Seattle's software industry cluster. Boeing Computer Services (BCS) employed about 6,000 people and primarily served Boeing's internal needs for software development. The authors of the study state that BCS helped to establish a regional pool of computer specialists. Microsoft located in the region in 1981 and evolved into a hub for the software industry and functioned as an incubator for software startups.

Another compelling case in which high-technology development occurred in the absence of a university is Portland, Oregon. My own research has shown that the region used firms as "surrogate universities." Portland, also known as the "Silicon Forest," hosts a

Mayer 2005a
Mayer 2005b

significant cluster of electronics manufacturing firms that specialize in semiconductor manufacturing, output devices like printers and displays, measurement instruments, computer manufacturing, and software. Portland's academic infrastructure has not influenced the high-tech industry to a great extent, and the two major universities in the state are located about 50 and 100 miles south of the city. The evolution of the Silicon Forest benefited greatly from two private firms, Tektronix and Intel.

The home-grown Tektronix started in 1946 and quickly became a world leader in manufacturing oscilloscopes. By the mid 1980s, the company employed more than 24,000 workers worldwide and about 15,000 locally. During the 1980s and 1990s, market pressures and the entrance of new competitors forced Tektronix to restructure. As a result, the firm laid off employees, divested business units, and refocused on its core functions. Tektronix' corporate crisis, however, influenced the regional economy greatly. Tektronix served as an incubator for over 90 direct and indirect startup companies. In 1976, Intel decided to establish its first branch plant outside of California in Portland. Initially the plant produced memory chips but over time the facilities evolved into a complex research and development location where Oregon-based inventors at times generated more patents than their California counterparts. Intel not only influenced the creation of 57 startup companies, but also attracted outside supplier and competitor companies.

While Tektronix and Intel functioned as surrogate universities for the Silicon Forest, their mere presence and influence on firm activity in the region was not sufficient. Parallel to business formation, the region was also able to create an environment that was highly conducive for entrepreneurship and innovation. This "innovation milieu" consisted of the presence of related and competing firms, support services, policies and programs encouraging continued investments in research-intensive corporate activities, the creation of locally based industry groups and trade associations, and a high quality of life that ensured that workers stayed in the region even if they were laid off.

In the cases discussed above, economic actors other than research universities created the conditions for high-technology growth. Military facilities and firms built a skilled labor pool and served as incubators for new startups. As the studies show, the regions substituted the research university with firms and military facilities in the realms of labor and entrepreneurship. Urban planning practitioners and scholars interested in the role of the university in high-technology economic development would need to take this

alternative model into account and pay more attention to the role of corporations or laboratories in spurring high-technology growth.

Degrees of University Engagement

As the discussion shows, world-class research universities are neither necessary nor sufficient in growing high-technology regions. The critical inputs for high-technology growth—labor, knowledge, and entrepreneurs—can also be generated by firms, research laboratories, or military facilities. Combined, the studies reviewed above show that universities are only one of many possible engines of growth and that other economic actors can function as surrogates. Therefore, the theory of the research university as an engine for high-technology growth needs to be revised, and researchers and practitioners have to take into account that there are many ways to high-technology regional development. This is a hopeful message, especially for those regions that are not well endowed with world-class research universities. Economic development practitioners and planners in those regions would be well advised to examine their industrial base and see whether they host institutions other than universities that can facilitate regional high-technology development.

The studies also show that a research university is not sufficient for regional high-technology growth. To create a high-technology cluster, the spillover effects have to fall on fertile soil. This fertile soil is the local environment or the innovative milieu, in which high-technology firms emerge, applicable knowledge is created and spills over in the form of commercial applications, and in which the specialized local labor pool is maintained and grown. Some scholars have argued that regions have to have an "absorptive capacity" that is responsible for holding on to knowledge spillovers. The aforementioned studies of failed growth in the presence of a higher education infrastructure clearly highlight that these regions were not able to retain university spillovers. In addition, recent research emphasized the critical link between a region's innovation capacity and its ability to support entrepreneurship. Camp argues that the most successful regions are the ones that are in a position to link knowledge creation and innovation to entrepreneurial activity. The lesson that a university is not a sufficient criterion for economic development is important for practitioners. Regions that are focusing on university-based economic development need to also pay attention to the environment in which these institutions function.

Cohen and Levinthal

Camp

TABLE 1
University Engagement and High-Technology Economic Development

	Degree of University Engagement	
Nature of High-Tech Economy	*Strong and/or pro-active university involvement*	*Weak and/or reactive university involvement*
High-tech service economy	***San Diego, California (biotech, telecommunications)*** Walcott (2002) Walshok et al. (2002) ***Brooklyn, New York (information technology and financial services)*** Bugliarello (1993, 1996, 1999)	***Washington, D.C. (IT services)*** Feldman (1994, 2001, 2003, 2005) Haynes et al. (1997) Warf (1993)
High-tech manufacturing economy	***Austin, Texas (semiconductor)*** Smilor et al. (1989) Garnsey (1998)	***Portland, Oregon (semiconductor, test & measurement, display)*** Mayer (2005) ***Seattle, Washington (aerospace)*** Gray et al. (1996, 1999) ***Colorado Springs, Colorado (telecommunication, test & measurement)*** Gray et al. (1999) ***Phoenix, Arizona (semiconductors, aerospace)*** Cortright and Mayer (2001) ***Denver/Boulder, Colorado (data storage manufacturing, measuring instruments)*** Lyons (1995)
High-tech service & manufacturing economy	***Silicon Valley, California*** Saxenian (1994) Adams (2003) Williams (1998) O'Mara (2005) ***Boston's Route 128*** Saxenian (1994) BankBoston (1997)	**More research needed about this model of high-tech development**

If the university is neither sufficient nor necessary, then what exactly is the role of the university in high-technology development? In sum, the role of the university is varied and ranges from strong proactive engagement to weak and primarily reactive involvement. Table 1 summarizes the literature and proposes a typology of university engagement in high-technology development. The typology takes into account that high-technology regions differ regarding their industrial nature. Some regions specialize in high-technology services while others specialize in high-technology manufacturing. Regions like Silicon Valley and Boston characterize more complex economies that consist of high-tech services and manufacturing. An additional dimension regarding university engagement is added. Here we need to distinguish between strong and/or pro-active university involvement and weak and/or reactive university involvement.

Boucher et al. propose a similar typology that addresses different levels of degrees of engagement of universities with their regional environments. Their model takes the size of the region, the number of universities involved, the scale of higher education institutions, and the type of the university (whether it is an old, traditional university or one that is new and focused on technology development). They propose four tiers: Single-player universities in peripheral regions, multi-player universities in peripheral regions, traditional universities in core regions, and newer technology-oriented universities in core regions. Each is distinguished by the degree of its engagement, the ways in which it engages, and by its purpose. When applied to high-technology regions, Boucher et al.'s typology offers additional dimensions such as the type of university and the number of universities present in the region. Such a view presents fruitful avenues for additional research on the role of universities in high-technology development.

Conclusion

Economic development practitioners are increasingly looking to higher education institutions for support in their economic development efforts. University-based economic development is now a popular tool within the wider array of technology-based economic development approaches. It differs from past economic development practices such as business attraction and incentive strategies in so far as it embraces the importance of knowledge and innovation to economic development. In that sense, economic

Berglund and Clarke
The State Science and Technology Institute

developers are now incorporating ideas from new growth theory. New growth theory, which highlights the importance of knowledge and using universities as engines of economic growth through the creation of knowledge, underscores this importance. However, this review of the literature cautions practitioners in focusing solely on the university. As the model of failed development in the presence of universities has shown, the regional environment's ability to absorb a university's spillover effects is as important as the institution itself.

Cortright
Romer

Planning practitioners often have high hopes that universities can be engines of knowledge-based economic development. This is understandable because globalization, the emergence of a knowledge-based economy, and changes in corporate innovation from a closed to an open innovation model have elevated the importance of the contributions universities can make to the economic progress of a society. The academic literature, however, cautions practitioners not to consider universities as "engines of economic growth," but to consider them as important underlying components or part of the regional knowledge-creation infrastructure. Florida and Cohen argue that the conventional metaphor of the university as an "engine" of regional economic development is misapplied. The university's economic role is much more complicated, subtle, nuanced, and complex than such mechanistic thinking allows. Instead of thinking of the university as an engine of economic development, it is more appropriate to conceptualize it as a pivotal component of an underlying infrastructure for innovation on which the system of knowledge-based capitalism draws.

Chesbrough 2003
Chesbrough 2006

Florida
Florida and Cohen

Florida and Cohen

Critics of a more active role of universities in economic development have argued that it distracts universities from their core missions, that it leads to increased imitation among universities regarding their efforts in economic development, that it is expensive, and that it reflects an outdated linear or science push model of innovation and economic development.

Cooke and Morgan
Feller 1990
Feller 2004

Despite such cautionary notes, universities remain important institutions in regional economies. Universities are able to attract talent to a region and positively influence an area's employment growth rates and science and technology workforce employment. The provision of talent has been highlighted by high-tech industry executives as one of the most important functions of institutions of higher education. Universities are also important sources of innovation and knowledge that can be used by industry. This function is especially important in the light of continued decline of

Beeson and Montgomery

Gibbons

Rees and Debbage

Chesbrough 2003
Rosenberg and Nelson

corporate research and development. Rees and Debbage, however, found that university research and not the university as an institution *per s*e is important to industry. This indicates that industry values research and can access it through a variety of channels. For some industries—in particular, biotechnology and life sciences—university researchers and their knowledge have been critical in the founding of new companies.

Zucker et al.

In this critical review of the role of the university in high-technology regional development, I deconstructed the dominant theory of the university as a driver of economic development. I highlighted that universities are important support institutions in regional economic development. Future research needs to determine different ways of university engagement in economic development. We know little about the role of the university as a support organization. It would be interesting to examine university engagement in those regions that have weak higher education institutions. How are universities responding and adapting to their changing environments? Is industry engaged in establishing a more pro-active university culture? If so, what strategies are universities and firms using in building university-industry relationships? Do traditional licensing, technology transfer, and commercialization programs work? Or are there more effective approaches that are more in line with a region's industrial structure and the emerging open innovation model? We also need to fill the gap in examining regions that have a diverse high-technology industrial base (services and manufacturing) but are missing strong higher education institutions (see empty cell in Table 1). On the other hand, a better understanding of how university engagement matures over time would help us understand the evolution of university-industry relationships of regions like Silicon Valley and Boston Route 128. In Silicon Valley, for example, regional leaders have become concerned about their ability to link universities to industry and they have formed the Bay Area Science and Innovation Consortium (BASIC) to discuss these issues. More research is needed on the question whether university engagement changes as an industry matures and evolves. The field would also benefit from comparisons of different high-technology regions. Such comparisons would enable us to better assess what kind of university engagement can be beneficial given certain economic circumstances. Moreover, comparative studies would help economic development practitioners to customize their approaches to university-based or technology-based economic development.

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Lester

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