

Universities and innovation ecosystems: a dynamic capabilities perspective

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Abstract

Universities play an important role in innovation ecosystems. In addition to developing human capital and advancing technology, they are increasingly expected to participate as economic development partners with industry and local, state, and national governments. Models such as the “Triple Helix” have been advanced to frame the assessment of interactions among academia, industry, and governments that may foster economic development. Such models highlight the boundary-spanning roles of universities and provide a predetermined list of actions universities could take to strengthen their ecosystem. Unfortunately, the flexible and entrepreneurial management of universities required to make this model work has virtually been ignored in the academic literature. We propose the dynamic capabilities framework to guide how universities might manage their innovation ecosystems. We use this framework to analyze the role of the university throughout the ecosystem lifecycle. These concepts are then illustrated with three case studies of universities that have engaged with partners in local economies to launch new industries, fostering entrepreneurship, and revitalize neighborhoods.

JEL classification: M13, D24, L31, O31, O32

1. Introduction

The concept of an “innovation ecosystem” is the latest in a list of similar concepts—including “innovation districts,” “innovation clusters,” and “national innovation systems”—that reference geographically located innovation at a national, regional, or local level. Local and regional ecosystems typically incorporate a key knowledge-generating institution, such as a university, academic medical center, or science park. The research university inhabits an innovation ecosystem which is typically defined to embrace the full set of agents, institutions, activities, and culture that support (or undermine) technological and business innovation that be assisted by a university’s resources and behaviors. Understanding the factors that influence the vitality of campus innovation ecosystems is a main goal of a considerable body of studies of innovation (e.g., Kenney, 1986; Zucker, Darby, and Brewer, 1998; Shane, 2004). The effects of decisions by universities, governments, and firms that impact the vitality of an innovation ecosystem are of considerable interest to many constituencies.

Traditionally, the role of research universities has been to educate students and conduct basic research, often with spillover benefits for industry (Mowery *et al.*, 2004). Etzkowitz and Leydesdorff proposed the Triple Helix as a

descriptive and prescriptive model that highlights a third role of universities: regional economic development, in concert with industry and government (Etzkowitz and Leydesdorff, 2000). This model embraces resource assembly projects, such as the development of science parks, and assisting in the launch of new enterprises from incubator facilities (Etzkowitz, 2002). Michael Porter's influential "recipe" for creating a regional cluster recognized the following roles for the university: identify local demand drivers, build a science park on or near a research university, provide incentives for chosen firms in a particular industry to locate there, strengthen local institutions, and attract venture capital (Porter, 1990). University technology transfer offices have been extensively studied, and best practices are fairly well understood, if not always practiced (Phan and Siegel, 2006).

Unfortunately, much of the advice provided in this area is free of context. Success stories in one region may not work for less-favored regions, where the capabilities of the university or of nearby entrepreneurs and firms may be relatively weak. It is also true that innovation ecosystems evolve. The roles of universities may differ, depending on the stage of an innovation ecosystem. Greater emphasis now needs to be placed on the role universities can play in fostering startups (Siegel *et al.*, 2003; Siegel and Wessner, 2012) and strengthening the innovation ecosystem more generally.

A university can serve as an ecosystem orchestrator, applying its intellectual, reputational, and financial capital strategically to establish and maintain a strong ecosystem. To do this well requires strong dynamic capabilities.

Our thesis is that the Dynamic Capabilities framework provides a useful framework for thinking about ecosystems management, since it helps frame the issues and prioritize the countless competing demands on university resources. The cultivation of strong dynamic capabilities by the university and its leaders will help to sustain and enhance campus innovation ecosystems. A strong leadership team can play a catalyzing and sustaining role if an ecosystem is to develop and renew itself over time—especially when other potential actors in the public and private spheres are not initially engaged.

More specifically, this article illustrates how universities can actively stimulate growth and renewal in their regional innovation ecosystems in ways that support their other core missions of education and research.

The remainder of this article is organized as follows. First, we briefly outline (a) the role of universities in innovation ecosystems and (b) the Dynamic Capabilities framework that we will use to analyze this role in more detail. We then use the Dynamic Capabilities perspective to explore how the role of universities in the innovation ecosystem might change over the ecosystem's lifecycle. We then apply this perspective to three case studies of universities engaging with local economies for launching new industries, fostering entrepreneurship, and revitalizing neighborhoods. The article concludes with a brief summary and discussion, plus suggestions for future scholarship.

2. Innovation ecosystem and the university

Innovation ecosystems evolve. Silicon Valley in the 1960s, for example, was less congenial to entrepreneurship than it is today (Bresnahan *et al.*, 2001). Successful innovation ecosystems are able to adapt to (and, sometimes, bring about) changing circumstances in the broader business and regulatory environment. Outcomes in any one period depend on multiple factors, including the suitability of the prevailing legal framework, the absorptive capacities of local firms, and a university's ability and willingness to engage with the private sector (Lester, 2005). Innovation ecosystems can be undermined by shifting circumstances, such as disruption by technology or trade of the ecosystem's anchor companies. But clearly some innovation ecosystems, such as Silicon Valley and Boston's Route 128 corridor, have shown that they can repeatedly reorient their activities over time.

While innovation ecosystems can emerge and grow organically, the process can also be spurred and then managed through conscious intervention. When elements of an ecosystem are present yet failing to coalesce, resources must be orchestrated by a strong player willing to take the lead. This could be a mayor or governor, a corporate executive at a potential anchor firm, or a campus leader.¹ In this article, we focus on how faculty and administrators at research universities can contribute to building or revitalizing their ecosystems through engagement and leadership.

A healthy ecosystem consistently converts technology and other inputs into enterprise development, survives disruptions such as unforeseen technological change, and creates niches to increase diversity (Iansiti and Levien, 2004).

1 For example, North Carolina governor Luther Hodges recognized the need to diversify and expand North Carolina's economy, so he worked with three universities (Duke, NC State, and UNC-Chapel Hill), corporate partners, and government to establish North Carolina's Research Triangle Park.

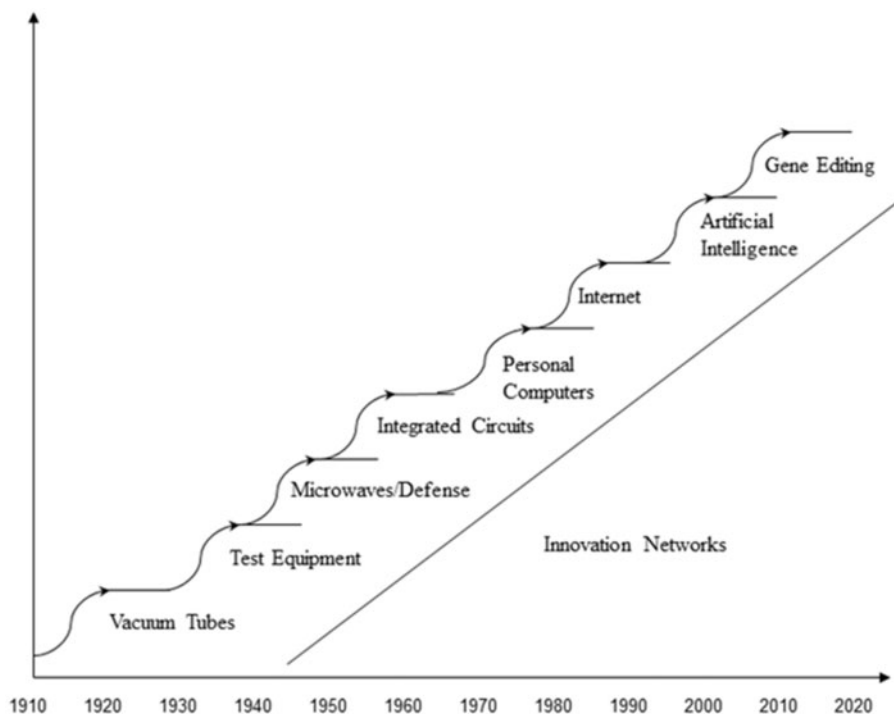


Figure 1. The waves of innovation in Silicon Valley.²

Indeed, what is so special about Silicon Valley is that it has ridden successfully through multiple technological waves (see Figure 1). While some participants have fallen away, many Silicon Valley companies have evolved to participate in and to shape new waves of innovation (Moore, 1996). Without such renewal, a regional ecosystem will languish or collapse.

A good innovation ecosystem will have an attractive living environment, large numbers of creative and competent engineers, building entrepreneurs, a supportive entrepreneurial milieu, easy property development approvals for structures suitable for new ventures, and easy access to major airports and other transportation arteries (Florida, 1999). Quality housing and other amenities for top talent are also a high priority. Cultural offerings, such as theaters, concerts, and museums (some of which may be provided by the university), stimulate the creative powers and human passion of talented individuals (Balderston, 1995). In recent years, entrepreneurs and skilled workers have increasingly been choosing high-density urban districts that offer rich cultural amenities as well as an array of business services (Katz and Wagner, 2014). In short, a strong university and vibrant local neighborhoods are mutually reinforcing. Examples include Kendall Square in Cambridge around MIT, Westwood next to UCLA, and downtown Berkeley next to UC Berkeley.

Universities can be central to the growth or decline of their ecosystems, especially when they typically loom large in their local economies. In 1996, more than 1900 universities in the core of US cities spent a total of about \$136 billion on salaries, goods, and services.³ Major universities such as University of Pennsylvania (Penn), New York

- 2 S. Blank, "Silicon Valley: Past, Present, Future," presentation for the Always On & Stanford Technology Ventures Program Summit at Stanford (July 28, 2010). Available at: <https://www.slideshare.net/sblank/silicon-valley-past-present-future-always-on-july28-2010>
- 3 Initiative for a Competitive Inner City (ICIC), *Leveraging Colleges and Universities for Urban Economic Revitalization: An Action Agenda* (Boston, MA: CEOs for Cities, 2002), p. 7. Available at <https://community-wealth.org/sites/clone.community-wealth.org/files/downloads/report-ceos1.pdf>

University (NYU) and Columbia University in New York City, Arizona State University in Phoenix, and Vanderbilt University in Nashville, Tennessee, rank among the top employers in their cities.

However, the functions of the university within an innovation ecosystem are not deterministic, and perhaps are not even indispensable. Bresnahan *et al.* (2001) argued that having a good university is not essential in the formation of regional industrial clusters, because regions can source necessary skills from large firms or distant institutions. Stanford did not build Silicon Valley on its own. Intel cofounder Gordon Moore portrays Stanford's role in the formation of Silicon Valley in a balanced way, noting: "We do not hold Stanford University to have been essential to the formation of Silicon Valley. . . . The defining characteristics of Silicon Valley business modes and models, and the sustained, rapid, technology-based growth were neither started nor made fundamentally possible through the presence of this university" (Moore and Davis, 2001: 11). Regional actors built the infrastructure needed in Silicon Valley, and talent was drawn from all over the United States (Florida, 1999). The local presence of a university is desirable but not necessary for the emergence and growth of an ecosystem.

3. The dynamic capabilities framework

Large research universities bear many similarities to for-profit enterprises: budgets that can amount to billions of dollars, an array of stakeholders with conflicting goals, and unpredictable regulation. They are also engaged in vigorous competition with rival institutions for students, faculty, grants, donations, and government favors. Consequently, Dynamic Capabilities, a framework developed for the strategic management of the enterprise, can be usefully applied in the university setting (Teece, 2018b). It is fundamentally a framework to guide an organization or institution endeavoring to achieve and maintain evolutionary fitness.

Dynamic capabilities are an organization's "ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece *et al.*, 1997). The most important categories of dynamic capabilities have been grouped for pragmatic reasons into capabilities to (1) sense and shape opportunities and threats, (2) seize opportunities, and (3) maintain competitiveness through enhancing, combining, protecting, and, when necessary, reconfiguring the organization's intangible and tangible assets (Teece, 2007: 1319). Strong dynamic capabilities help an organization to be innovative, successful, and resilient, particularly in the presence of technological and political turbulence and deep (unforecastable) uncertainty (Teece and Leih, 2016).⁴ Universities face uncertainty on many fronts, such as rapid and unforeseen developments in government funding and online teaching platforms, and global competitor for talent.⁵

Dynamic capabilities are rooted partially in organizational routines and partially in managerial decision making (Teece, 2014). They are embedded in tacit organizational culture, yet are guided and shaped by the cognition of individual managers. This gives them a dual nature, because routines and culture are path dependent and therefore slow to change, while managerial frames and strategies can be transformed relatively quickly. Thus, transformation of a low-performing organization frequently involves a new leader taking over the reins and slowly shifting the organization's culture while looking for easy wins to raise confidence and boost morale. For example, the arrival of a new president at Yale (Richard Levin, the 22nd Yale president) influenced the development of a biotechnology cluster surrounding the university in the 1990s (Leih and Teece, 2016: 191). Despite the important roles leaders can play, the organization will be vulnerable if the sensing, creative, and learning functions are left to the cognitive traits of a few individuals (Teece, 2007: 1323). As Knight observes, with uncertainty there is "a necessity to act upon opinion rather

- 4 Risk can be quantified using probabilities, including conditional probabilities. There is a well-understood management toolkit for risk management. Uncertainty cannot be quantified. With uncertainty, the unknowns are unknowable, which requires very different management responses. Dynamic capabilities are helpful for dealing with deep uncertainty because they enhance organizational creativity and resilience.
- 5 Former Stanford President John Hennessy says technology's impact on universities is real and growing; E. Bothwell and C. Havergal, "Moocs can transform education—but not yet," *Times Higher Education* (2016). Available at: <https://www.timeshighereducation.com/features/massive-open-online-courses-moocs-can-transform-education-but-not-yet>. Education can be delivered by using a variety of tools, such as web-based platforms, eBooks, mixed reality, virtual worlds, and immersive technology; A. Pena-Rios, V. Callaghan, M. Gardner, and M.J. Alhaddad, "Remote Mixed Reality Collaborative Laboratory Activities: Learning Activities within the InterReality Portal," in *Proceedings of the 2012 IEEE/WIC/ACM International Joint Conferences on Web Intelligence and Intelligent Agent Technology v.3* (2012): 362–366.

than knowledge” (Knight, 1921: 268). The problem is not just about knowledge asymmetries and incentive problems but also about filtering and interpreting information about evolving technologies and marketplaces (Teece, 2007: 1323).

Strong dynamic capabilities are slow to build and must be maintained and, periodically, renewed because routines, by their nature, gradually become less well adapted as circumstances change. The creation of strong capabilities typically involves decentralizing authority, fostering a collaborative organizational culture, and propagating a shared vision. These characteristics are particularly relevant to the university setting, where authority is inherently fragmented between the faculty and the administration.

The Dynamic Capabilities framework can help managers strengthen their understanding of how technology, organization, and strategy are interrelated in complex settings. The construct was originally outlined in the 1990s by Teece and his graduate students (Teece and Pisano, 1994; Teece *et al.*, 1997). It has been further elaborated on and used by scholars in many disciplines, including strategic management (e.g., Helfat *et al.*, 2007), entrepreneurship (e.g., Zahra *et al.*, 2006), marketing (e.g., Day, 2011), and information technology management (e.g., Sambamurthy *et al.*, 2003). It has gained traction with managers facing complex challenges (Easterby-Smith *et al.*, 2009).

Almost all firms have some dynamic capabilities, but in many cases, they are weak, leaving an organization myopic, as its leaders flounder in the face of uncertainty and make ad hoc, crisis-driven decisions. In (limited) very stable circumstances, weak dynamic capabilities may carry only a small penalty; but in cases where uncertainty and technological ferment are rife—including the worlds of higher education, entrepreneurial startups, and a growing number of industries facing disruption—the cost of strengthening dynamic capabilities is well worth incurring.

Dynamic capabilities are usually underappreciated in the campus setting. The capabilities approach has recently been applied to the internal management of the university (Leih and Teece, 2016). In this paper, we propose a normative model in which proactive sensing, seizing, and transforming processes undertaken by the university can produce better outcomes for an entire ecosystem.

A key managerial function in the Dynamic Capabilities framework is “asset orchestration” (Teece, 2007). In an ecosystem context, asset orchestration requires persuasion and consensus building around a strategy for action and investment aimed at joint prosperity and growth. Specific activities might include holding conferences to build momentum behind early successes, bringing stakeholders together to launch a business incubator program, or managing a joint lobbying effort to obtain necessary legislation.

For example, the first major venture capital firm, American Research and Development (ARD), was founded in 1946 by Georges Doriot, the former dean of the Harvard Business School, along with Karl Compton, the former president of MIT. ARD was launched with a focus on MIT technology-based startups. ARD also worked with a handful of like-minded New England business leaders, with the purpose of using the firm to help revitalize the regional economy (Hsu and Kenney, 2005).

Although we focus here on the university’s capabilities, the ecosystem’s private firms and policymakers have dynamic capabilities as well. The stronger the dynamic capabilities of each organization are, the more resilient the network as a whole will be.⁶ On the other hand, strong capabilities in the university alone will likely not be enough to create a strong ecosystem until, at a minimum, key local firms have been induced to start strengthening their own dynamic capabilities.

We next turn to a more granular view of the dynamics of innovation ecosystems and proactive university managers.

3.1 The ecosystem lifecycle: a dynamic capabilities view

As mentioned earlier, ecosystems grow, decline, and can be reborn. A university’s evolutionary “fitness” at any point in time are shaped by the specificities of the regional innovation system in which it is embedded. The ecosystem can also be shaped by the university.

The university’s collaboration with industry has different requirements depending on whether the industry is emergent or mature (Audretsch and Feldman, 1996; Freitas *et al.*, 2013). Similarly, Fini *et al.* (2011) argue that

6 In a similar vein, Teece (2007: 1319) notes that: “Enterprises with strong dynamic capabilities . . . not only adapt to business ecosystems, but also shape them through innovation and through collaboration with other enterprises, entities, and institutions”

Table 1. Stages of innovation ecosystems and university functions

Initial stage	Development stage	Renewal stage
Innovation ecosystem characteristics		
<ul style="list-style-type: none"> • Few enterprises • Rare interactions between the members of the ecosystem • Low identity 	<ul style="list-style-type: none"> • Supporting agencies and organizations become active participants • Communication channels formed for exchanging knowledge in the ecosystem • Inter-firm and professional networks become well established 	<ul style="list-style-type: none"> • Stagnation of established sectors • Patenting activity shifts toward new domains
University functions		
Attractors	Consolidators	Change agents
<ul style="list-style-type: none"> • Stronger regional focus on student recruitment and graduate retention • Support faculty entrepreneurship and co-location of new and existing firms near the campus 	<ul style="list-style-type: none"> • Support startup incubators • Develop niche technologies • Host networking events, business plan contests for students • Create industrial liaison programs 	<ul style="list-style-type: none"> • Perform outreach with emerging technologies • Pursue promising avenues of research • Improve attractiveness of surroundings for skilled workers
Key dynamic capabilities		
Sensing (e.g., Carnegie Mellon University)	Seizing (e.g., University of California, Berkeley)	Transforming (e.g., University of Pennsylvania)
Selected key decisions by universities		
<ul style="list-style-type: none"> • Identified key fields for new research programs • Placed new emphasis on research and entrepreneurship • Provided infrastructure for collaboration with private technology companies 	<ul style="list-style-type: none"> • Fostered generation of new ventures • Enhanced level of communication and cooperation among ecosystem participants • Built linkages between university and local firms 	<ul style="list-style-type: none"> • Developed a strategy that transforms its external environment • Led local initiatives to revitalize its neighborhood • Reoriented its culture

regional settings' idiosyncrasies should be considered for universities to develop effective spin-off support policies (p. 1113). However, a dynamic capabilities perspective posits that interactions between a university and its environments are coevolutionary. The university's adaptation to its ecosystem can alter both the fitness and the fitness landscape of the other organizations in its ecosystem (Kay *et al.*, 2018: 11).

We hypothesize that campus innovation ecosystems evolve through at least three phases: an initial liftoff stage, development and stability, and eventually decline and (ideally) renewal. Table 1 summarizes these stages and how the role of a university varies across them, which we elaborate in this section.

The dynamic capabilities required at each stage are somewhat different. For example, in early stage ecosystems, key activities might include evaluating the capabilities of local firms, developing a talent pipeline, and elaborating on a shared vision. In a growing ecosystem, the most salient issues for the university may be how to keep the university aligned with the evolving needs of the private sector and how best to capture more of the value being created. For purposes of illustration, in the remainder of this section we emphasize the critical nature of a specific set of capabilities at each stage. In reality, though, an organization will be simultaneously engaged in sensing, seizing, and transforming most of the time.

3.1.1 Initial stage: university as attractor (sensing)

During its initial stage, an innovation ecosystem exhibits low density, a limited identity, and few linkages. Firms and other actors begin to cooperate on key activities. To be successful, the ecosystem must build a critical mass of companies, entrepreneurs, talent, and investment—a process that can take years and is not a guarantee of success. During this stage, a university can help create preconditions by ensuring a research and outreach presence in promising technological fields with regional potential. Agrawal and Cockburn (2003) argue that a university can play the role of an “anchor tenant” that attracts corporate research and development to a region lacking multiple nodes of

Box 1. Criteria for the “Saviors of Our Cities” universities⁷

Inclusion on the list is based on ten criteria that have been designed to accommodate scale in terms of the size of the institution in geography, student population, endowment, and the population of the immediate neighborhood or city. Some, by necessity, include subjective impressions based on 20 years of professional experience. The criteria are:

1. The institution’s longstanding involvement with its urban community.
2. The real dollars invested through its foundations and annual budgets.
3. Its catalyst effect on additional partners for social and economic change.
4. Its presence in terms of payroll, research, and purchasing power.
5. Faculty and student involvement in community service.
6. Engagement in neighborhood initiatives.
7. Its impact, through K-12 partnerships and other programs, on local student access and college affordability.
8. The qualitative esprit of the institution in its engagement.
9. The quantifiable increase in positive recognition of the institution as demonstrated by a rise in applications by prospective students and resources raised through alumni giving for community projects and local scholarships.
10. Recognition of the impact of the institution within its communities gathered from interviews with educators and public officials throughout the country.

knowledge generation (Agrawal and Cockburn, 2003). This requires that university and departmental leaders develop an understanding about which technologies and ideas have future ecosystem potential and help bring funding to them.

In this early stage, universities can contribute to both produce and attract the human capital necessary for innovation. By having talented faculty and students, universities can help to generate new knowledge within the innovation ecosystem. In Richard Florida’s field research, executives revealed that their location decisions are based less on tax incentives or infrastructure and more on the availability of highly skilled people (Florida, 2002).

University leaders can play a pivotal role in at least two ways. First, they can engage faculty and industrial partners to identify promising medium- to long-term technologies and provide support for research in those areas. This “sensing” exercise, once initiated, should be continuous.

With skilled leadership, the university can also take a direct role in orchestrating local assets to attract potential ecosystem partners. The former dean of engineering and provost at Stanford, Frederick Terman (often called the father of Silicon Valley), played an outsized role in shaping the development of the local innovation ecosystem. In 1939, he gave advice and personal funds to help his students Bill Hewlett and David Packard establish Hewlett-Packard (Leslie and Kargon, 1996). By 1946, when he became dean of Engineering, Terman understood the vast potential of solid-state electronics and encouraged the administration to leverage government research funding to deepen the university’s knowledge base for potential collaboration with industry (Leslie, 2000).

Terman also encouraged Stanford faculty to be entrepreneurial and interact with the private sector, partly to compensate the limited financial support at Stanford available at the time for research. This was meager compared to leading East Coast universities (Kenney and Goe, 2004). In 1954, he initiated the Stanford Honors Co-op, which allowed companies in Silicon Valley to send their engineers to Stanford graduate engineering programs (Huffman and Quigley, 2002). Terman also helped to shape the Stanford Industrial Park, which provided space for firms to co-locate new companies. By 1965, the park hosted 42 tenant companies that provided employment for about 12,000 people (Feder, 1999).

Terman’s forward thinking and many initiatives provide a challenging example of strong sensing and seizing within an innovation ecosystem, as it moves from its initial stage to a period of development. His holistic approach is characteristic of the systems-based dynamic capabilities framework (Tece, 2018a).

In this stage of an ecosystem, a common language and culture may emerge. The ecosystem may have a number of firms and other actors that begin to cooperate around a core activity and realize common opportunities through their

⁷ Hazelkorn (2011).

linkages. Linkages (informal forms of inter-organizational networking and cooperation) are part of the social context in which new knowledge is generated in the ecosystem. Formal and informal systems and norms of collaboration will become established.

3.1.2 Development stage: university as consolidator (seizing)

Once the foundations are laid, an ecosystem may see an increase in employment, an expanding number of linkages, and a growing number of startups. This development stage calls for more deliberate efforts by local leaders to support and expand the local ecosystem's assets.

A key characteristic of successful innovation ecosystems is that knowledge flows in all directions. In studying the networks in California's Silicon Valley, Anna Lee Saxenian emphasized that it is not simply the concentration of workers' knowledge but also the communication among individuals within and across innovation ecosystem groups that helps innovative activity (Saxenian, 1990). Universities can help orchestrate the free flow of information throughout the innovation ecosystem by establishing connections through targeted conferences and other outreach mechanisms. The campus itself is also a neutral, noncommercial zone where ideas and insights can be shared, discussed, and debated.

Another key role is fostering entrepreneurship by organizing programs such as entrepreneurial boot camps, university incubators and accelerators, and coaching (Mian, 1996; Rothaermel and Thursby, 2005; Clarysse *et al.*, 2007). Courses offered at business schools, such as entrepreneurship and marketing, are important for assisting venture formation and survival (Shane and Delmar, 2004). Universities can also help to access on campus and off campus tangible, intangible, and financial resources that help commercialization and societal impact.

For the university, the "seizing" of opportunities involves steering venture capital toward a new enterprise and/or facilitating faculty leaves of absence to help launch a new venture. A university can also offer guidance through its technology transfer office to potential acquirers of patented technology.

Kendall Square in Cambridge is an example of a vibrant innovation ecosystem around a major anchor university (MIT). Starting in the 1950s, MIT actively deployed university-owned land to support university–industry partnerships and leverage its unique strength, helping grow an internationally significant life sciences/pharmaceutical cluster (Katz and Wagner, 2014).

A more recent example is the Northeast Ohio Polymers Cluster.⁸ Universities helped the region establish a particular niche in flexible electronics. PolymerOhio, a public–private–university technology center, serves as a networking and information hub. Kent State University's Liquid Crystal Institute, the University of Akron's College of Polymer Science & Polymer Engineering, and Case Western's Center for Applied Polymer Processing all contribute to the cluster's knowledge stock. The University of Akron's technology transfer program, for its part, ranks among the nation's best (Muro and Fikri, 2011).

In the development stage of an ecosystem, a critical mass needs to be reached. Relations with complementors outside and inside the ecosystem are strengthened. The resultant ecosystem may include a large number of firms, acknowledgment of the ecosystem's advantages, and robust levels of innovation.

3.1.3 Renewal stage: university as change agent (transforming)

Any stable system will be challenged when the circumstances to which it was well adapted start to change. The issue for managers and boards of directors is how long it takes before the change is noted and a response formulated. A declining ecosystem will adversely affect the local community. Neighborhoods can experience periods of population loss, economic decline, and decay in living conditions due to shifts in demand, offshoring, global competition, and other factors. Universities too often see themselves as separate from their cities and/or townships until matters reach crisis. Institutions such as the Penn have had to battle urban blight. Expanded employment, affordable housing, and new retail opportunities are part of the solution (Katz and Wagner, 2014). Yale and Northwestern are examples of universities that have confronted similar issues, although perhaps not with the same degree of success. Some

8 See National Research Council, *The Flexible Electronics Opportunity, Board on Science, Technology and Economic Policy* (Washington, DC: The National Academies Press, 2015).

efforts, such as that of Johns Hopkins in Baltimore, failed to engage with local residents and are unlikely to achieve the desired results (Rich and Tsitsos, 2018).

Universities have the potential to catalyze improvements in the quality of the environments surrounding the campus. Low crime rates and a high quality of life are required to attract talented people.⁹ Given that many universities have significant real estate investments, some schools have made strategic investments (with the help of donors) in urban neighborhoods to stimulate economic development (more on that later).

For an ecosystem to perform well over time, it must (co)evolve with markets and technologies. That means that members of the ecosystem must update and renew their own resources and capabilities, which is a difficult task. Some innovation ecosystems decline and disappear, while a few undergo successful transformation and ride new waves of innovation.

Universities can help lead ecosystem transformation. Transformation often requires incumbent firms to latch onto and contribute to the development of new technology paradigms—something that is difficult for a single firm to do on its own. As such, universities can serve as effective gateways to transform organizations and institutions within the campus ecosystem. Universities can serve as a source of refocusing on promising opportunities to prevent a declining ecosystem from becoming obsolete. They can reorganize research addressing new developments in technology and reconsider the ways in which they exchange knowledge. Indeed, Kanter found that a number of universities in Massachusetts have helped the state develop the capability to continuously move from old to new industries (Kanter, 2012). In some cases, universities have made key investments in new off-campus facilities as a way to create a focal point for innovation activities. Examples include UC San Francisco's biotechnology campus in the city's Mission Bay neighborhood (2003), Duke University's Clinical Research Institute in downtown Durham, North Carolina (2013), and the Cornell Tech campus on Roosevelt Island in New York City (2015) (Katz *et al.*, 2015). The University of Rochester and the Rochester Institute of Technology also helped the region develop higher technology opto-electronic devices, such as lasers, semiconductors, and photonics (Mattoon, 2006).

A successful renewal can lead an ecosystem to a new growth path. Typical ingredients include a period of identifying promising fields, developing a strategy, and assembling the necessary human resources in support of a new shared vision.

3.2 The university, dynamic capabilities, and the innovation ecosystem

We now take a closer look at three case studies that reflect sensing, seizing, and transforming by university leaders with respect to their local innovation ecosystems.

To analyze the complex interorganizational relationships of the ecosystem and the related management requirements within the university, we adopted a case study approach. Our process began with a review of the academic literature and other documentation regarding university ecosystems. We considered a number of university ecosystems, including Cornell University (including Cornell Tech in New York City), Massachusetts Institute of Technology, and Stanford, as potential cases. We excluded cases such as Cornell that are too new to generate clear guidance as to "what works." We analyzed three cases in depth: Carnegie Mellon University (CMU), the University of California (UC), Berkeley (UCB), and the Penn. Each has achieved some success as a hub of innovation and is relatively understudied, compared to the usual examples of MIT and Stanford. We examined available historical, academic, and archival material, including local press sources, on the three universities in order to trace the historical and institutional context in which each ecosystem has evolved.

Our process was iterative. Studying the cases shaped our thinking about the role of universities and university leadership in ecosystems, which in turn helped us decide where to focus further attention. Our goal was not to create a set of comprehensive cases. In this article, each case is used to illustrate one aspect of the ecosystem relationships as we've theorized them.

9 In 2009, the New England Board of Higher Education (NEBHE) released a list of twenty-five "best-neighbor" urban colleges and universities that strengthened the economy and quality of life of their neighboring communities and became "Saviors of Our Cities" (see Box 1).

For insight into the related leadership and management issues, a particularly valuable resource was the archive of oral interviews with UC faculty, administrators, and regents. This was supplemented with informal discussions with UCB and Stanford leaders, along with written material from leaders at CMU and Penn. Participation in various conferences on ecosystem-related topics has also been helpful.

We augmented these interviews by using local business databases, as well as patent and publication data as appropriate, and reports and published sources concerning the local economy, local universities, and other local institutions. As described in [Table 1](#), the data include assessments of key decisions and initiatives by universities, the execution of particular initiatives by universities, network linkages and partnerships, amounts of VC investments, and the number of graduates who stayed local. Some local performance measures we considered include unemployment rates, the number of startups, and VC funded entrepreneurs, partnerships and physical environments conducive to fostering innovation.

3.2.1 Sensing: CMU and robotics in Pittsburgh

The first stage of an innovation ecosystem is the emergence of an industry that has no technological antecedent in the regional economy—that is, it entails the local creation of an entirely new (at least to the region) industry. A high degree of uncertainty characterizes the business environment at this stage.

Because of the nature of academic research, the seeds for this must be planted well ahead of time. Hence the need for university and departmental leaders to engage in sensing activities that assess internal and external signals about scientific and technological developments that hold promise for the future, then ensure that sufficient financial and faculty resources are available for exploring the most attractive possibilities.

From 1972 to 1990, while Richard Cyert was president, CMU in Pittsburgh saw its funding for advanced technology and applied research increase from \$13 million to \$123 million ([Lubove, 1996](#)). Cyert also encouraged private firms to participate in university programs. In 1978, with corporate funding, CMU established the Robotics Institute, which has become a key component in its advanced technology empire.¹⁰ The center gained attention in 1983 when a CMU robot was used to explore the contaminated nuclear facility at Three Mile Island. In 1999, the *Wall Street Journal* dubbed the city “Roboburgh,” a nickname that remains in use. The Institute has attracted multinationals like Bosch, Disney Research, and Delphi to Pittsburgh, and has spawned self-driving car startups that maintain a local presence, most notably Aurora Innovation, Argo AI (now majority-owned by Ford), and Ottomatika (acquired by Delphi) ([Bitar, 2017](#)).

CMU is also strong in biotechnology, as is the other major local research institution, the University of Pittsburgh (Pitt). CMU has expertise in computing, software, and artificial intelligence, while Pitt develops medical technology. Both institutions also have a good record of moving technologies out of the lab and into the market.

These long-gestation investments have proven to be the saving of Pittsburgh. For decades, the town’s industry was dominated by a thriving steel sector. The city went into decline in the 1970s and 1980s when the domestic steel industry collapsed, and tens of thousands of jobs vanished. The city hit bottom in 1985 when Gulf Oil merged with Standard Oil of California to form California-based Chevron, leading to the loss of nearly 1500 white-collar jobs (and a payroll of \$54 million) that were moved to California or cut ([Sweeney, 2013](#)). The loss of other major Pittsburgh-based corporations, such as Rockwell International and Westinghouse brought more job losses. Pittsburgh’s unemployment rate reached 17.1% in 1983, and the city seemed stuck in a downward spiral ([Domrzalski, 2014](#)).

In the 1980s, Pittsburgh’s leaders recognized that the city needed new economic engines. The universities stepped up, placing new emphasis on research, boosting entrepreneurship, and commercializing discoveries. In 1993, Robert Mehrabian, then president of CMU (1990–1997), drafted a 20-page report that called for an overhaul of the area’s economic development structure.¹¹ A large committee was subsequently formed to develop specific strategies and implement the plan.

CMU also made significant institutional innovations to support the development of its innovation ecosystem. In 2013, reflecting on his sixteen years as CMU president, Jared Cohon identified three things that CMU did to help Pittsburgh’s economic transition ([Pan, 2013](#)):

¹⁰ *Ibid.*, p. 45.

¹¹ *Ibid.*

- Altered the technology transfer policy to make it easier for professors to start new companies
- Built a Collaborative Innovation Center to attract and support established technology companies working with the university
- Collaborated with Pitt to provide support to startups.

These initiatives led to the creation of hundreds of startups and saw major technology companies such as Intel and Apple open collaborative labs on the CMU campus.

Pittsburgh has transformed from its industrial past into an active hub for technology, education, healthcare, and finance. No steel manufactured in the city today, and former mills are now technology parks. Pittsburgh's tech and education sectors account for some 80% of the high-wage jobs in the city (Thrush, 2014). A 2011 report from the Census Bureau showed that during the previous decade Pittsburgh had been one of the top ten metropolitan areas in the country for "brain gain" among the college educated, reversing years of decline (Futrell, 2011). Robots are just the most visible piece of this striking turnaround.

While Pittsburgh's eventual comeback was attributed to ingredients such as a major environmental cleanup and federal funding, an important asset was undoubtedly the human capital housed at CMU and Pitt (Thrush, 2014). This, in turn, was due to the forward-looking decisions taken years earlier by decision makers at CMU and Pitt.

3.2.2 Seizing: UC Berkeley and the creation of entrepreneurial infrastructure

Universities have a range of tools with which they can help an innovation ecosystem to grow. Funding exciting research is one step, but turning that into commercial products and services in a way that benefits the economy requires the provision of suitable infrastructure. Otherwise, benefits will not materialize. This section analyzes the steps that UC Berkeley has taken to improve the entrepreneurial infrastructure of the city of Berkeley, California.

When companies and entrepreneurs find an inhospitable city government, their failure rate is higher and they tend to locate elsewhere. Taxes, retail customers, and future opportunities that could otherwise aid the city go elsewhere, too. Moreover, technology jobs generally have large "multiplier" effects. That is, for every job created in the high-tech sector, more than four jobs are then created in other sectors. By comparison, new manufacturing jobs are associated with the creation of fewer than two other positions (Raguso, 2012). For the university, an increase in the number of successful nearby startups can also bring advantages, from more interactions with students to closer ties with successful alumni.

The UC, Berkeley is a top university for producing venture-capital-backed entrepreneurs, but it was not always so. Two decades ago, faculty and students acting as entrepreneurs ran the risk of being stigmatized, rather than encouraged, by the campus community. With respect to startup activity, Berkeley faculty faced skepticism from their colleagues. UC Berkeley's culture valued basic research above applied fields, with the feeling that it was somehow more in keeping with the university's public status (Kenney and Goe, 2004).

This has, for the most part, given way to a far more entrepreneurial spirit. In 2015, Forbes ranked UC Berkeley third among America's Most Entrepreneurial Universities, behind only Stanford and MIT. From 2010 to the third quarter of 2013, UC Berkeley ranked second worldwide (behind Stanford) with 160 graduates receiving venture capital funds (Lau, 2013). According to the latest data from the UC Berkeley vice chancellor for Research, over two hundred companies have been founded under intellectual property licenses from UC Berkeley and have attracted more than \$1.6 billion in venture capital funding.¹² Many more UCB-connected startups have not required a license for their ideas.

Former chancellor at UC Berkeley Nicolas Dirks describes the changes at Berkeley:

DIRKS: Of course there is skepticism at Berkeley, and this skepticism was in part enabled by the regular support we received from the state in the days before budget cuts became a regular feature of that support. Attitudes have changed, and not just because of the different funding environment. Many of our faculty and students are now as captivated as their peers at Stanford by opportunities to move ideas outside the university, both to the market and for the public at large. Our discoveries are routinely designed for applications, whether in the domain of new and cheaper medicines, or new and more effective products, from anti-malaria drugs to early earthquake warning systems. And I dare say the market is seen differently as well these days, both at the university and in the East Bay. I'll give you an example of the culture change around here. A few of our COE graduates set up a

12 University of California, Berkeley, "Innovation and Entrepreneurship Highlights," Berkeley Research. Accessed November 28, 2017, at: <https://vcresearch.berkeley.edu/innovation/highlights>

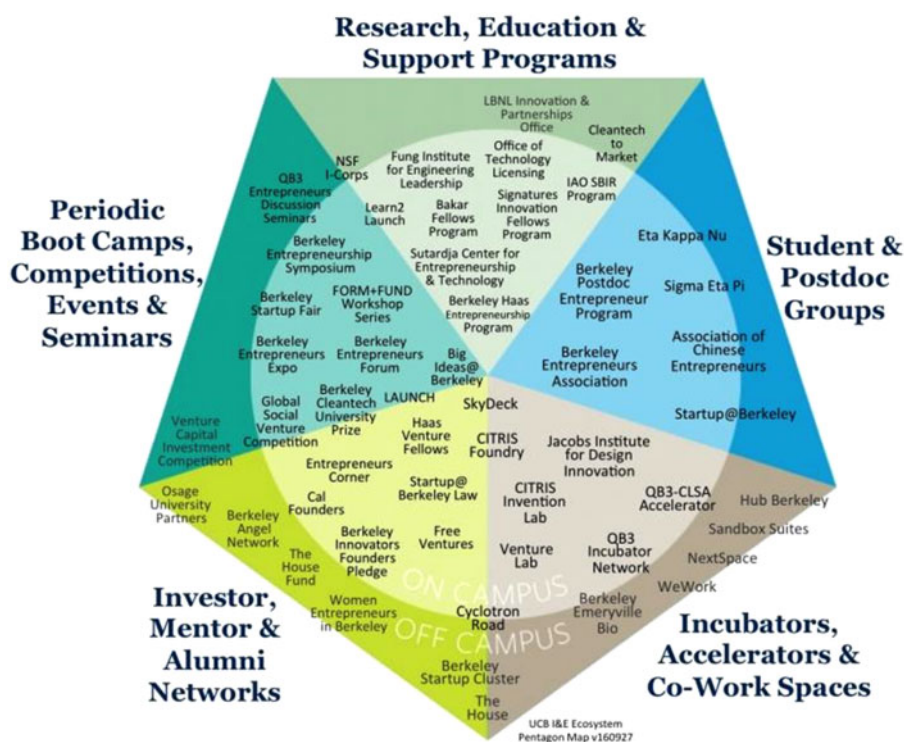


Figure 2. UCB's local innovation ecosystem.¹³

very successful new video games company, and we named the football field at Memorial Stadium after them. Interesting, there was no complaining about this from the faculty. Now we have Kabam! field, at Berkeley! It is gratifying now to see all the startups emerging from Amp Lab (e.g. Data Bricks), from Citris, from QB3, to mention just a few examples.

Do you know that Berkeley has more VC backed startups than any other university except for Stanford? This is a different institution now. And yet there is a difference between Berkeley and our peers in an important respect, and it has to do again with the kind of culture of public service. Many of the ideas that people want to commercialize are ideas for products and services that have real importance for the public. People at Berkeley see their discoveries and their ideas often as most successfully being translated to the marketplace outside if it will be a real public benefit. And I think that's been one of the strengths of this place; but I also think it's become a kind of wedge for a new culture of entrepreneurship. If you can actually serve the public through entrepreneurship, then everyone here will agree it's a good thing for Berkeley to do.

UC Berkeley's entrepreneurial ecosystem consists of an alphabet soup of dozens of programs, arrayed among five categories in [Figure 2](#), that cover everything from entrepreneurship education and mentoring to multiple accelerators and on-campus venture funding. Local innovation is strengthened by the rich panoply of events and programs on and off campus, open to students, faculty, and alumni. A "front door" into the network of activities has been created in the form of a website (Berkeley Gateway to Innovation, or BEGIN) pointing to the key programs.¹⁴

The ecosystem support activities shown in [Figure 2](#) are extensive and decentralized, but that doesn't mean there is no coordination. For example, SkyDeck, a UCB-connected startup accelerator, is a collaboration between the

- 13 Berkeley IPIRA, "Entrepreneurship Ecosystem," Intellectual Property and Industry Research Alliances. Accessed November 28, 2017, at: <https://ipira.berkeley.edu/entrepreneurship-ecosystem>
- 14 BEGIN: Berkeley Gateway to Innovation, University of California, Berkeley. Accessed November 28, 2017, at: <http://begin.berkeley.edu>

College of Engineering, the Haas School of Business, and the Office of the Vice Chancellor for Research (Cohen, 2016).

To build a pipeline from campus-based innovation to local commercial development, the university provides an infrastructure that contains three core elements. First, UC Berkeley fosters the generation of new ventures. The Berkeley-Haas Entrepreneurship Program (anchored in the Lester Center for Entrepreneurship) has evolved from offering one-off entrepreneurship lectures to providing a more comprehensive range of hands-on classes, mentoring, access to seed funding, a student-run business plan competition, and more (Snyder, 2017). Many of these programs also bring local actors together through conferences and special events.

Second, the university has taken steps to enhance the level of communication and cooperation among established firms, startups, and knowledge providers. In 2011 the College of Engineering, the Haas School of Business, and the Office of the Vice Chancellor for Research established SkyDeck Berkeley, a business accelerator located in downtown Berkeley. It aims to provide entrepreneurs with the tools to start and grow their businesses and access the resources of the university. To qualify for the program, companies must have a scalable business plan, a technology or product, and established customers or users. Once admitted, residents can stay 6 months with the option to reapply in 3-month intervals. Though still a young organization, SkyDeck's ecosystem of startup teams, serial entrepreneurs, technology veterans, and early stage investors has produced a first crop of successful companies.¹⁵

Third, the university enhances its local innovation ecosystem with programs to build thicker network linkages between the university and local firms, including multinationals, such as GM and Siemens, that have a presence in the region. The Electrical Engineering and Computer Sciences department has created a system for paid corporate partnerships that allow firms special access to faculty and students through projects and recruiting events.

Linkages with local alumni are also being upgraded. The Haas School organizes a number of events with alumni employed in the Bay Area, and an alumni-run Berkeley Angel Network provides a pool of potential investors for early stage UCB-connected enterprises.

Yet, despite the world-class intellectual assets in its environments, the city of Berkeley has traditionally not been good at localizing the impact of innovations developed at the campus and at Lawrence Berkeley Lab, which many would characterize as a lost opportunity to benefit from homegrown assets (Cohen, 2011). The city of Berkeley lacks suitable office space, which limits scalability. And the city still struggles to shake off its anti-business reputation.¹⁶ The older industrial spaces of West Berkeley could be attractive to technology startups, but the city has persisted in zoning this space in a way that limits its utility for new (non-industrial) ventures.

However, attitudes toward entrepreneurs in city government have decidedly improved. The city's leaders have begun to realize that Berkeley has not adequately capitalized on the economic benefits of innovations originating from UC Berkeley. It has recently made efforts to make the city a better place for technology startups (Raguso, 2014). As of 2014, the city had more than 300 startups.¹⁷ Unfortunately, many Berkeley graduates merely incubate their business in Berkeley and then move elsewhere. The attraction of Silicon Valley, Emeryville, and, in recent years, San Francisco is hard to overcome.

The university-city partnership around the innovation ecosystem has just begun. The adversarial relationship that has simmered between the university and the city is decades old and is still not entirely obliterated. However, as the city realizes that innovation brings benefits and that startups can have positive social impact, and improve the tax base, the city's inhospitable land use and other policies are beginning to change, albeit slowly, and not without zig zags.

3.2.3 Transforming: Penn and the revitalization of West Philadelphia

Innovation ecosystems need to evolve and adapt to changing environments over time. Although much is beyond their control, surrounding communities are generally amenable to renewal efforts.

15 Bay Area Council Economic Institute, *UC Berkeley: Stimulating Entrepreneurship in the Bay Area and Nationwide*, (2014), p. 8. Available at: http://www.ucop.edu/innovation-alliances-services/_files/econ-rpts/UCB-Stimulating-Entrepreneurship-2014.pdf

16 For example, Xerox's first choice for its western research lab was Berkeley, but it was discouraged by conservatives within the city, and Xerox's historic lab (known as PARC) was located instead in Palo Alto.

17 Ibid.

Innovation can benefit from a safe, stimulating environment that encourages talent to think in creative ways. A positive urban environment provides cultural capital such as museums, nearby outdoor activities, high-quality K–12 schools, and cutting-edge academic and commercial research (Florida, 2002). A negative environment, ridden by crime, poor schools, and limited cultural life, will make it far harder to stimulate innovative activity.

University infrastructure development practices have emerged as important ingredients in improving nearby innovation spaces that have gone into decline (Perry and Wiewel, 2005). Universities are often among the largest landowners and employers in their cities, which gives them a central position in the local economy, for good or ill. Here, we present a case widely regarded as a successful university-led example of urban renewal.

The Penn is a private university located in Philadelphia. While Penn has continued to grow and transform into a top research university, Philadelphia has evolved in a different direction. The competitive position of older cities like Philadelphia declined as the American economy became less reliant on its manufacturing base (Rodin, 2007). The campus was surrounded by economically depressed West Philadelphia, a high-crime district with a large homeless population. The housing stock was deteriorating, and local schools were failing (Kromer and Kerman, 2004). Members of the university became increasingly aware of the threat that the situation posed to Penn's future viability, but their local initiatives up to then had been piecemeal and too small to make a significant difference.

In 1994, Judith Rodin assumed the presidency of the university. She believed strongly that mutual advantage would result from a successful local improvement initiative, and she led the development of an integrated strategy that covered housing, retail, and K–12 education for the local residents and the university community (Rodin, 2004a). Stabilizing the neighborhoods around the university would also create an environment suitable for expanding research and development partnerships with the private sector.

Penn understood that to be competitive in attracting students and faculty, it needed to recognize itself as the keystone of a larger ecosystem that needed to provide physical environments conducive to fostering creativity and innovation. As Rodin put it a decade later:

Only one entity had the capacity, the resources, and the political clout to intervene to stabilize the neighborhood quickly and revitalize it within a relatively short time period. And that was Penn. Outside developers were certainly not beating on our doors. And local government didn't have the resources. If Penn didn't seize the initiative to revitalize the neighborhood itself, no one else would (Rodin, 2004b).

The university mobilized both intellectual and financial support for the plan, requiring internal as well as external transformation. Rodin reported that “we had to reorient our administrative culture to work holistically toward simultaneously transforming the university and the neighborhood” (Rodin, 2007).

Penn administrators devised strategies for leading and financing the university's neighborhood initiatives in collaboration with the community. The university-led effort created a true “University City” (a designation that remained from a 1950s-era redevelopment effort) by encouraging residential development that would attract talent and faculty members, while offering anti-displacement reassurances to the local residents.¹⁸ It supplemented this neighborhood effort with local education initiatives that included the creation of a public elementary school known as Penn Alexander that receives financial and academic support from the university.

University City is today a recognized innovation hub, with Penn and Drexel University as anchor institutions with a high proportion of high-wage employment. The number of patents issued to University City institutions grew 110% from 2006 to 2016.¹⁹ Comcast recently decided to build its major new Innovation and Technology Center in the district (Katz *et al.*, 2015).

A successful ecosystem becomes a magnet. From 2004 to 2010, the share of graduates who were not initially Philadelphia natives and who chose to remain in the region rose from 29% to 48%.²⁰ Penn is the largest private employer in the city of Philadelphia, and education is the largest industry in the Philadelphia area.²¹ The result seems to

18 *Philadelphia Inquirer* (March 19, 1960), cited in Rodin (2007), p. 33.

19 University City District, *The State of University City, 2016*, p. 6. Available at: http://www.universitycity.org/sites/default/files/documents/The%20State%20of%20University%20City%202016_0.pdf

20 Campus Philly, *From Student to Resident: Findings from Campus Philly's 2010 student retention survey*. Available at <http://campusphilly.org/wp-content/uploads/2011/10/fromstudenttoresident.pdf>

21 In the greater Philadelphia metropolitan area, education and health services had the largest employment gain from February 2016 to February 2017, adding 29,400 jobs. Bureau of Labor Statistics, “Philadelphia Area Employment –

create a win-win situation for both the university and the ecosystem, because new businesses create new jobs and a new tax base, which can fund better local business services. At the same time, the university can provide a better environment for faculty to interact with the participants of its innovation ecosystem and build strong bridges for applied research and future endowment.

4. Discussion

This article examines the leadership roles that universities can adopt as part of a capabilities-based life-cycle model of innovation ecosystems. We described how innovation ecosystems move through different developmental stages and how these stages can be viewed from a Dynamic Capabilities perspective. Case studies of three universities engaging with their local economies were analyzed from a Dynamic Capabilities perspective to illustrate how universities can actively stimulate growth and renewal in their regional economies in ways that support their other core missions of education and research.

Previous studies have often viewed the role of universities as monolithic. In the national systems of innovation perspective, the role of universities is relatively passive, with regional agglomeration resulting naturally due to the knowledge spillovers from their research (Nelson, 1993). It is increasingly being recognized that the Triple Helix interactions of academia, industry, and government must be coordinated and aligned if innovations are to be moved effectively out of the lab and into the world (Etzkowitz and Leydesdorff, 2000). This points to the increasing importance of dynamic capabilities in the context of universities.

An important element missing in the literature has been an understanding of the roles of the university as part of an innovation ecosystem in which the university is embedded. We have analyzed interactions between universities and their urban surroundings as their ecosystems evolve. University–local innovation ecosystem interactions are coevolutionary and strongly shaped, for good or ill, by past relations, by the growth or decline of relevant industries, and by current university leadership.

4.1 Dynamic capabilities of universities and innovation ecosystem lifecycles

Our preferred theoretical lens for analyzing the activities of the university in its complex setting is the Dynamic Capabilities framework. Strong dynamic capabilities are needed if a university is to be a good partner (or manager) in an innovation ecosystem. This includes the entrepreneurial ability to identify emerging new fields and invest in research around them, build partnerships to create and maintain ecosystem infrastructure, and help to bring about an alignment of interests among stakeholders.

Research universities with strong dynamic capabilities are in a good position to provide strategic leadership for the ecosystem. They are well positioned to drive the development of new scientific and industrial fields that corporate research is increasingly reluctant to explore. This is inherently an entrepreneurial function.

Although capabilities have a strong basis in organizational routines and culture, the cognition of individual leaders and managers is also important (Helfat and Martin, 2015). One way culture manifests itself is in how the university sees its role with respect to its urban environment. A research university may be world-class in certain fields and see itself as separate from the concerns of a nearby city, only to find later that this was a grave mistake. Public universities, especially land-grant universities, have a strong economic development mandate, which sometimes helps overcome internal resistance to efforts to engage with the local region. It also resonates with many governors and state legislatures. Each university will differ from others based on its particular history and circumstances.

Campus leaders in the grip of fixed mental models may feel constrained in how and to what extent their university should drive the development of its ecosystem(s). For example, a recent study in the UK examined how the different self-images of two research-intensive universities influenced their relationships with the local region (Holstein *et al.*, 2018). In one case, relations between the university and key regional players were strained, and the university viewed itself as having an international perspective. In the other case, the university maintained tighter regional links, which were closely connected to its past civic engagement. Role definition differences such as these have implications for how easily a given university will be able to reach out to its community to develop a healthy ecosystem.

While engagement with the local economy adds extra burdens for university managers, the potential rewards are great. A vital local economy provides the foundation for a cycle of attracting new talent, which further increases the university's resource base and attractiveness to other talent.

To perform the required tasks well, senior campus leaders must create and implement an organizational culture and vision that accepts improvisation, rewards creativity, and embraces change. They must also proactively orchestrate assets both within and outside the direct control of the campus in a manner that is sensitive to local needs and market opportunities. Engagement with the local economy requires building trust by adhering to principles of reciprocity and transparency (Weber *et al.*, 2005). Penn's effort to revitalize West Philadelphia and UC Berkeley's drive to encourage the local implantation of university-connected startups satisfy this requirement.

A key finding is that the university's role in the local innovation ecosystem also depends on the given stage of the innovation ecosystem. The initial stage, development stage, and renewal stage are each associated with a different set of university's roles and capabilities. This finding suggests a more context-specific view of the university's role in the innovation ecosystem.

4.2 Policy implications

As mentioned above, dynamic capabilities are also relevant for policymakers. In addition to making their own organizations as innovative, resilient, and responsive as possible, policymakers need to assess partner organizations in dynamic capabilities terms. For example, the amount of autonomy afforded a keystone university should vary positively with the entrepreneurial skills of the university's leadership. Decision-making autonomy may be especially important if the university's research programs are active in fast-changing fields. On the other hand, if the university's leadership is unfocused or distracted by one or more crises, regional policymakers can seek to fill the gap either by seeking their replacements or by finding executives at private firms to serve as ecosystem leaders. Government policies can be successful only when they mesh with the rest of the ecosystem. Throwing money at poorly designed or undermanaged programs for a business incubator or some other public-private collaboration will not improve a bad situation.

Policies also need to take into account the specific stage of ecosystem development. In an early stage ecosystem, for instance, workforce development or infrastructure investment might be appropriate. Changes in university technology transfer policies to promote startup creation for faculty and students are also advised at this stage. At later stages, tax credits that support technology commercialization and new business formation might prove most useful.

4.3 Future research

Our study also raises unexplored questions for future research. Note that our approach has been strictly conceptual and qualitative. In future research, we hope to craft specific testable hypotheses and then test these hypotheses empirically. That means determining precisely how to define and measure key constructs and data collection procedures.

More specifically, a more in-depth understanding of the nature of universities' leadership and asset orchestration efforts is required. We have provided examples of several universities bringing diverse organizations together and guiding urban revitalization. A university's asset orchestration function can also include ensuring the provision of missing or desirable assets and identifying complementarities among other ecosystem members (Teece, 2012).

We also need to understand how to better manage the total resource portfolio of a university. This would involve identifying strategies to capture value from its ecosystem contributions that go beyond traditional technology-licensing modalities, while not undermining support for basic research, student education, or institutional independence.

5. Conclusion

Preserving and strengthening the university's positive societal impact requires an understanding of how innovation ecosystems complement, rather than subtract from, the core academic enterprise as well as the regional economy. Stanford and MIT are clear examples of how to do this effectively, and UC Berkeley has made important strides in the right direction. An increasing number of universities are demonstrating that supporting the innovation ecosystem,

including new enterprise development and external partnerships, when managed correctly, can be fully consistent with cherished academic values, while at the same time strengthening the university's resource base. This is especially true for public universities which are experiencing declining state financial support and thus are compelled to be more innovative and entrepreneurial.

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References

- Agrawal, A. and I. Cockburn (2003), 'The anchor tenant hypothesis: exploring the role of large, local, R&D-intensive firms in regional innovation systems,' *International Journal of Industrial Organization*, 21(9), 1227–1253.
- Audretsch, D. and M. Feldman (1996), 'Innovative clusters and industry lifecycle,' *Review of Industrial Organization*, 11(2), 253–273.
- Balderston, F. E. (1995), *Managing Today's University: Strategies for Viability, Change, and Excellence*, 2nd edn. Jossey-Bass: San Francisco, CA.
- Bitar, E. (2017), 'Why Pittsburgh is Ideal for Robotics Businesses,' *Robotics Business Review*, <https://www.roboticsbusinessreview.com/events/pittsburgh-ideal-robotics-businesses/>.
- Bresnahan, T., A. Gambardella, and A. Saxenian (2001), "'Old economy" inputs for "new economy" outcomes: cluster formation in the new Silicon Valley,' *Industrial and Corporate Change*, 10(4), 835–860.
- Clarysse, B., M. Wright, A. Lockett, P. Mustar, and M. Knockaert (2007), 'Academic spinoffs, formal technology transfer and capital raising,' *Industrial and Corporate Change*, 16(4), 609–640.
- Cohen, M. (2016), 'Strategies for developing university innovation ecosystems,' *Les Nouvelles*, 51(3), 184–190.
- Cohen, M. (2011), 'Localizing the commercialization of UC Berkeley innovations: a justification, strategy & plan to take the campus to the third tier of innovation ecosystems,' *Intellectual Property & Industry Research Alliances Office*, UC Berkeley, White Paper, p. 3, <https://ipira.berkeley.edu/sites/default/files/shared/docs/Local%20Innovation%20Ecosystem%20Development%2024%20excerpts.pdf>.
- Day, G. S. (2011), 'Closing the marketing capabilities gap,' *Journal of Marketing*, 75(4), 183–195.
- Domrzalski, D. (2014), 'What we can Learn from Pittsburgh's Economic Revival,' *Albuquerque Business First* (February 28), <http://www.bizjournals.com/albuquerque/news/2014/02/28/what-we-can-learn-from-pittsburghs.html>.
- Easterby-Smith, M., M. A. Lyles, and M. A. Peteraf (2009), 'Dynamic capabilities: current debates and future directions,' *British Journal of Management*, 20(s1), S1–S8.
- Etzkowitz, H. (2002), *MIT & the Rise of Entrepreneurial Science*. Routledge: London, UK.
- Etzkowitz, H. and L. Leydesdorff (2000), 'The dynamics of innovation: from national systems and "mode 2" to a triple helix of university-industry-government relations,' *Research Policy*, 29(2), 109–123.
- Feder, B. (1999), 'Stanford start-ups: Provost's revamping of university courses built the regional economy,' *San Jose Mercury News* (December 23).
- Fini, R., R. Grimaldi, S. Santoni and M. Sobrero (2011), 'Complements or substitutes? The role of universities and local context in supporting the creation of academic spin-offs,' *Research Policy*, 40(8), 1113–1127.
- Florida, R. (1999), 'The role of the university: leveraging talent, not technology,' *Issues in Science and Technology*, 15(4), 67–73.
- Florida, R. (2002), *The Rise of the Creative Class*. Basic Books: New York, NY.
- Freitas, I. M. B., R. A. Marquesc, and E. M. de Paula e Silva (2013), 'University–industry collaboration and innovation in emergent and mature industries in new industrialized countries,' *Research Policy*, 42, 443–453.
- Futrell, J. (2011), 'Wall Street Journal: Pittsburgh's a Top 10 Metro Area for "Brain Gain,"' *ImaginePittsburgh* (September 23). <http://explore.imaginepittsburgh.com/now/tag/brain-gain/>.
- Hazelkorn, E. (2011), *Rankings and the reshaping of higher education: The battle for world-class excellence*. Palgrave Macmillan: Houndmills, Basingstoke, United Kingdom.
- Helfat, C. E., S. Finkelstein, W. Mitchell, M. Peteraf, H. Singh, D. J. Teece, and S. G. Winter (2007), *Dynamic Capabilities: Understanding Strategic Change in Organizations*. Blackwell: Oxford, UK.
- Helfat, C. E., and J. A. Martin (2015), 'Dynamic managerial capabilities: review and assessment of managerial impact on strategic change,' *Journal of Management*, 41(5), 1281–1312.
- Holstein, J., K. Starkey and M. Wright (2018), 'Strategy and narrative in higher education,' *Strategic Organization*, 16(1), 61–91.
- Huffman, D. and J. Quigley (2002), 'The role of the university in attracting high tech entrepreneurship: a Silicon Valley tale,' *Annals of Regional Science*, 36(3), 403–419.

- Hsu, D. H. and M. Kenney (2005), 'Organizing venture capital: the rise and demise of American Research & Development Corporation, 1946–1973,' *Industrial and Corporate Change*, 14(4), 579–616.
- Kanter, R. M. (2012), 'Enriching the ecosystem,' *Harvard Business Review*, 90(3), 140–147.
- Katz, B. and J. Wagner (2014), 'The Rise of Innovation Districts: A New Geography of Innovation in America,' Metropolitan Policy Program at Brookings (Brookings Institution), <https://www.brookings.edu/wp-content/uploads/2016/07/InnovationDistricts1.pdf>
- Katz, B., J. Vey, and J. Wagner (2015), 'One Year After: Observations on the Rise of Innovation Districts,' Brookings, <https://www.brookings.edu/research/one-year-after-observations-on-the-rise-of-innovation-districts/>.
- Kay, N., S. Leih, and D. J. Teece (2018), 'The role of emergence in dynamic capabilities: a restatement of the framework and some possibilities for future research,' *Industrial and Corporate Change*, 27(4), 623–638.
- Knight, F. H. (1921), *Risk, Uncertainty, and Profit*. Chicago: University of Chicago Press.
- Kromer, J. and L. Kerman (2004), 'West Philadelphia Initiatives: A Case Study in Urban Revitalization' (University of Pennsylvania), p. 6, <https://community-wealth.org/sites/clone.community-wealth.org/files/downloads/report-kromer.pdf>
- Kenney, M. and W. Goe (2004), 'A tale of two universities: entrepreneurship in the departments of electrical engineering and computer science at UC Berkeley and Stanford,' *Research Policy*, 33(5), 691–707.
- Kenney, M. (1986), *Biotechnology: The University Industrial Complex*. Yale University Press: New Haven, CT.
- Iansiti, M. and R. Levien (2004), *The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability*. Harvard Business School Press: Boston, MA.
- Lau, J. (2013), 'Study lists UC Berkeley among top universities for producing entrepreneurs,' *Daily Californian*, October 24, <http://www.dailycal.org/2013/10/24/study-lists-uc-berkeley-among-top-universities-producing-entrepreneurs/>.
- Leslie, S. W. (2000), 'The biggest "angel" of them all: the military and the making of Silicon Valley,' in M. Kenney (ed.), *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford University Press: Stanford, CA, pp. 48–67.
- Leslie, S. W. and R. H. Kargon (1996), 'Selling Silicon Valley: Frederick Terman's model for regional advantage,' *Business History Review*, 70(4), 435–472.
- Leih, S. and D. Teece (2016), 'Campus leadership and the entrepreneurial university: a dynamic capabilities perspective,' *Academy of Management Perspectives*, 30(2), 182–210.
- Lester, R. K. (2005), *Universities, Innovation, and the Competitiveness of Local Economies*. MIT Industrial Performance Center, Working Paper.
- Lubove, R. (1996), *Twentieth Century Pittsburgh: The Post Steel Era*, Vol. 2. The University of Pittsburgh Press: Pittsburgh, PA, p. 44.
- Mattoon, R. H. (2006), *Can Higher Education Foster Economic Growth?* Chicago Fed Letter. <https://files.eric.ed.gov/fulltext/ED505628.pdf>.
- Mian, S. (1996), 'Assessing value-added contributions of university technology business incubators to tenant firms,' *Research Policy*, 25(3), 325–335.
- Mowery, D., R. Nelson, B. Sampat, and A. Ziedonis (2004), *Ivory Tower and Industrial Innovation*. Stanford Business Books: Stanford, CA.
- Moore, G. and K. Davis (2001), 'Learning the Silicon Valley way,' *SIEPR Working Paper*, Stanford University: Stanford, CA.
- Moore, J. F. (1996), *The Death of Competition: Leadership and Strategy in the Age of Business Ecosystems*. HarperBusiness: New York, NY.
- Muro, M. and K. Fikri (2011), *Job Creation on a Budget: How Regional Industry Clusters Can Add Jobs, Bolster Entrepreneurship, and Spark Innovation*. Brookings, 3. <https://www.brookings.edu/research/job-creation-on-a-budget-how-regional-industry-clusters-can-add-jobs-bolster-entrepreneurship-and-spark-innovation/>.
- National Research Council (2015), *The Flexible Electronics Opportunity, Board on Science, Technology and Economic Policy*. Washington, DC: The National Academies Press.
- Nelson, R. R. (ed.) (1993), *National Innovation Systems: A Comparative Analysis*. Oxford University Press: New York, NY.
- Pan, G. (2013), 'Interview: Three keys to Pittsburgh's transformation: CMU president,' *Xinhua English News* (May 4), <http://english.sina.com/2013/0504/587751.html>.
- Perry, D. C. and W. Wiewel (eds) (2005), *The University as Urban Developer: Case Studies and Analysis*. M.E. Sharpe: Armonk, NY.
- Phan, P. H. and D. S. Siegel (2006), 'The effectiveness of university technology transfer,' *Foundations and Trends in Entrepreneurship*, 2(2), 77–144.
- Porter, M. E. (1990), *The Competitive Advantage of Nations*. Free Press: NY.
- Raguso, E. (2012), 'Berkeley for startups: Perfect or brain drain in action?' *Berkeleyside* (February 9), <http://www.berkeleyside.com/2012/02/09/berkeley-for-startups-perfect-spot-or-brain-drain-in-action/>.
- Raguso, E. (2014), 'Berkeley staff aims to grow city's "innovation ecosystem,"' *Berkeleyside* (January 28), <http://www.berkeleyside.com/2014/01/28/berkeley-staff-aim-to-grow-citys-innovation-ecosystem/>.
- Rich, M. and W. Tsitsos (2018), 'New urban regimes in Baltimore: higher education anchor institutions and arts and culture-based neighborhood revitalization,' *Education and Urban Society*, 50(6), 524–547.

- Rodin, J. (2004a), 'A partnership that's making a difference: the University of Pennsylvania's West Philadelphia initiatives,' in K. Ferraiolo (ed.), *New Directions in Civic Engagement: University Avenue Meets Main Street*, Vol. 2. Pew Partnership for Civic Change: Charlottesville, VA, pp. 32–39.
- Rodin, J. (2004b), 'Forging connections and creating transformations,' *University of Pennsylvania Almanac*, 50(27), supplement, 1–4.
- Rodin, J. (2007), *The University & Urban Revival*. University of Pennsylvania Press: Philadelphia, PA.
- Rothaermel, F. T. and M. Thursby (2005), 'University-incubator firm knowledge flows: assessing their impact on incubator firm performance,' *Research Policy*, 34(3), 305–320.
- Sambamurthy, V., A. Bharadwaj, and V. Grover (2003), 'Shaping agility through digital options: reconceptualizing the role of information technology in contemporary firms,' *MIS Quarterly*, 27(2), 237–263.
- Saxenian, A. (1990), 'Regional networks and the resurgence of Silicon Valley,' *California Management Review*, 32, 89–112.
- Shane, S. and F. Delmar (2004), 'Planning for the market: business planning before marketing and the continuation of organizing efforts,' *Journal of Business Venturing*, 19(6), 767–785.
- Shane, S. A. (2004), *Academic Entrepreneurship: University Spin-Offs and Wealth Creation*. Edward Elgar: Aldershot, UK.
- Siegel, D. S. and C. Wessner (2012), 'Universities and the success of entrepreneurial ventures: evidence from the small business innovation research program,' *Journal of Technology Transfer*, 37(4), 404–415.
- Siegel, D. S., C. Wessner, M. Binks, and A. Lockett (2003), 'Policies promoting innovation in small firms: evidence from the U.S. and U.K.,' *Small Business Economics*, 20(2), 121–127.
- Snyder, B. (2017), 'How bears breed unicorns: Inside Cal's vast startup ecosystem,' *California Magazine* (February 16), <https://alumni.berkeley.edu/california-magazine/just-in/2017-02-16/when-bears-breed-unicorns-inside-cals-vast-startup-ecosystem>. See also, Berkeley Haas Entrepreneurship Program, <http://entrepreneurship.berkeley.edu/>.
- Sweeney, J. F. (2013), 'The Pittsburgh comeback,' *id8nation.com* (May 23), <http://www.id8nation.com/after-30-years-has-pittsburgh-entrepreneurship-turned-a-corner/#sthash.lFbp44m8.dpuf>.
- Teece, D. J. (2007), 'Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance,' *Strategic Management Journal*, 28(13), 1319–1350.
- Teece, D. J. (2012), 'Dynamic capabilities: routines versus entrepreneurial action,' *Journal of Management Studies*, 49(8), 1395–1401.
- Teece, D. J. (2014), 'The foundations of enterprise performance: dynamic and ordinary capabilities in an (economic) theory of firms,' *Academy of Management Perspectives*, 28(4), 328–352.
- Teece, D. J. (2018a), 'Dynamic capabilities as (workable) management systems theory,' *Journal of Management and Organization*, 24(3): 359–368.
- Teece, D. J. (2018b), 'Managing the university: why "organized anarchy" is unacceptable in the age of massive open online courses,' *Strategic Organization*, 16(1), 92–102.
- Teece, D. J. and S. Leih (2016), 'Uncertainty, innovation, and dynamic capabilities,' *California Management Review*, 58(4), 5–12.
- Teece, D. J. and G. Pisano (1994), 'The dynamic capabilities of enterprises: an introduction,' *Industrial and Corporate Change*, 3(3), 537–556.
- Teece, D. J., G. Pisano, and A. Shuen (1997), 'Dynamic capabilities and strategic management,' *Strategic Management Journal*, 18(7), 509–533.
- Thrush, G. (2014), 'The robots that saved Pittsburgh,' *Politico Magazine* (February 4), <http://www.politico.com/magazine/story/2014/02/pittsburgh-robots-technology-103062#ixzz3mUOAu1L>.
- Weber, R., N. Theodore, and C. Hoch (2005), 'Private choices and public obligations: The ethics of university real estate development,' in D. Perry and W. Wiewel (eds), *The University as Urban Developer: Case Studies and Analysis*. New York: M. E. Sharpe Publishers, pp. 285–299.
- Zahra, S. A., H. J. Sapienza, and P. Davidsson (2006), 'Entrepreneurship and dynamic capabilities: a review, model and research agenda,' *Journal of Management Studies*, 43(4), 917–955.
- Zucker, L., M. Darby, and M. Brewer (1998), 'Intellectual human capital and the birth of U.S. biotechnology enterprises,' *American Economic Review*, 88(1), 290–306.