A Strategic Overview of the Silicon Valley Ecosystem: Towards Effectively "Harnessing" the Ecosystem

8. University-Industry, University-Government Ties

Kenji E. Kushida

Universities are a critical component of the Silicon Valley ecosystem, serving as a multifaceted focal point for the exchange of human capital, ideas, technologies, and more. As such, Japanese companies that can effectively make use of universities for the variety of functions they can offer stand to benefit and become more effectively integrated into the Silicon Valley ecosystem. To do so, the first step is understanding the role of universities.

The relationship between the government, universities and industries is often misunderstood as unidirectional, with the government encouraging innovations at universities by providing funding and the universities producing new ideas that are commercialized by industry. The reality observed in Silicon Valley, however, is more complex and multi-directional. The efforts for innovation are more often driven by individual researchers at universities rather than the government agencies or university administration, and initial ideas for innovation often comes from industries.

The university-industries ties that contribute to the Silicon Valley ecosystem are multifaceted, diverse, and not easily captured by a single set of metrics. This in itself has caused much confusion for actors wishing to learn about Silicon Valley, not only from those outside the US, but in US media portrayals as well. This is partly because of the close relationship between the multifaceted university-government ties that anchor much of the university-industry ties.

The core research universities are Stanford University and the University of California. Among the University of California schools UC Berkeley and UC San Francisco Medical Center are within the broader Silicon Valley ecosystem, with UC Davis also playing an important role, particularly in agricultural science. Other universities in the area include Santa Clara University, San Jose State, San Francisco State, University of San Francisco, and numerous community colleges. Each plays different roles in the Silicon Valley ecosystem, but here we focus on Stanford and UC Berkeley.

We should start with the overall US national context of US-industry ties, which most analyses begin with. There is a pervasive image that funding often flows from the government and industry into major research universities, which then patent commercializable technologies and inventions through a technology licensing office, which then spins out the intellectual property into the commercial sector, deriving major revenue for the university. The image of this system as successful has led to policies by government around the world imitating this system. As we will see, this image is misleading; university-industry ties in the US are far more complicated, and this simple model in and of itself is not as successful as it may seem from the outside. The major successful research universities in Silicon Valley are have far more complex and multidimensional relationships to industry. Therefore, simply copying this image of a "technology licensing office-centric university-industry coordination model" is not likely to succeed elsewhere.

8.1. The US Technology Licensing Model: Bayh-Dole

The US technology licensing model was legislated in 1980 with the Bayh-Dole Act, also known as the Government Patent Policy Act of 1980. It was passed in the context of grave concerns about the economic competitiveness of the US as its economy suffered from recessions and stagflation following the oil shocks beginning in 1971. The Bayh-Dole Act allowed the ownership of an invention from federal research funding to reside with the university, small business, or non-profit organization. Previously, ownership was required to go to the federal government. Given the government's $75 billion or so budget assigned to research in the 1970s, this was a game-changer, providing strong economic incentives to commercialize the products of research. [1]

However, the Bayh-Dole Act was *not* a strategic industrial policy in the sense that there was widespread political support. In fact, a very fragile political coalition of interests narrowly passed the measure despite the Carter administration's initial opposition.[2]

After the Bayh-Dole was enacted, research universities almost all established technology transfer offices aimed to become a central hub for patents from universities to be discovered and used by industry, and to negotiate licensing arrangements. The degrees to which these were successful are mixed. We will introduce specific Stanford examples below, but a few notable points should be emphasized.

8.2. Multifaceted University-Industry Ties

First, s*imply counting of academic patents or licensing revenues are poor measures* of the "performance" of universities in developing or transferring technologies and knowledge to industry. This is because of the *multifaceted and bidirectional* nature of industry-university interactions and knowledge flows that are observed in virtually all case studies of successful university-industry collaboration. In the area of university entrepreneurship, the data is extremely

[1] Stevens, A. J. (2004). "The Enactment of Bayh-Dole." Journal of Technology Transfer **29**: 93-99.
[2] Ibid.

problematic, and significantly undercounts a variety of forms of academic entrepreneurship and influence of universities on startup ecosystems.[3]

The university-industry relationships are multi-faceted and complex, but can be revealed through case studies. University patents are only one mechanism of transfer from universities to industry. Others include the following: licensing, generating academic spin-offs, collaborative research, contract research, consulting, ad-hoc advice and networking for practitioners, as well as teaching, joint publications with industry, staff exchanges, and joint student supervision.[4] Almost all of these mechanisms of coordination occur outside "the technology transfer office centered coordination" model.

Industry visitors spending time in universities, and university faculty and researchers taking sabbaticals or other time to spend in company labs are common mechanisms of bidirectional exchange.

In an analysis of the origins of Silicon Valley, historian Lécuyer notes the critical importance of the bidirectional ties between university and industry. He shows how Stanford researchers relied heavily on technologies and manufacturing process technologies developed in Silicon Valley to advance their own research. Only by having close relations with cutting edge industry, whose personnel they could invite to Stanford as collaborators, were Stanford researchers able to make technological innovations of their own, while training engineers to become the workforce of the newest technologies.[5] Stanford and UC Berkeley provided much of the basis for Silicon Valley, but *they could not have done so without feedback loops from Silicon Valley helping them stay at the forefront of industry*.

This is a point echoed by Martin Kenney and his collaborators in a book analyzing the role of University of California schools in their respective economies, such as Silicon Valley, San Diego, Los Angeles, Santa Barbara, and Davis (and Napa Valley). The industry environment surrounding the university was critical in shaping how the universities could contribute to local economic development.[6] This emphasizes the point that university-industry ties are not a one-way street with university technologies harvested by industry, but that successful universities depend on effective ties with the surrounding industry.

In fact, while developing Stanford into a world-class research university in the 1950s, Dean Fredrick Terman explicitly made efforts to take problems that were facing industry, which could possibly lead to major breakthroughs if theoretical problems were solved, and encouraging faculty to take those theoretical problems as research agendas within the university.[7] Subsequent breakthroughs in solid-state physics and other areas drove the revolution from vacuum tubes to

[3] Grimaldi, R., M. Kenney, D. S. Siegel and M. Wright (2011). "30 years after Bayh-Dole: Reassessing academic entrepreneurship." Research Policy **40**: 1045-1057.
[4] Ibid.
[5] Lécuyer, C. (2006). Making Silicon Valley : innovation and the growth of high tech, 1930-1970. Cambridge, Mass., MIT Press.
[6] Lécuyer, C. (2014). Semiconductor Innovation and Entrepreneurship at Three University of California Campuses. Public universities and regional growth : insights from the University of California. M. Kenney and D. C. Mowery. Stanford, CA, Stanford University Press**:** 20-63.
[7]

semiconductors, placing Stanford as a core of Silicon Valley at the center of the computer revolution from the 1960s onward.

UC Berkeley, the other core of Silicon Valley, was the first UC campus to enter semiconductor research, with a former Bell Labs engineer establishing the first integrated circuits laboratory at any US university.[8] Faculty interested in semiconductors took sabbaticals in Silicon Valley firms, transferring innovative designs to industry, facilitating the hiring of students by local startups, and licensing intellectual property. Electronic design automation firms including Synopsys and Cadence Design Systems grew out of these efforts.[9]

Box 1: Examples of multifaceted University-Industry ties

Stanford student A was an excellent undergraduate student in computer science, who went on to work for a major IT firm after graduation. The IT firm was introducing path breaking new IT services—an online app store. Former student A was part of the team that developed the app store, and through his close ties to a professor from his undergraduate days, he was invited to offer a one term course at Stanford in computer science on how to write apps for the app store—the first such course at a university level. Former student A motivated a large number of students who became his students, and when he left the major IT firm to start his own company, a news aggregation app, many of those students came with him to work at the startup. In this way, a student who went into industry brought experience to the classroom, cultivating the next generation of students who then followed him to his own startup. Expertise and people flowed in both directions.

At the senior level, a highly decorated American economist, Hal Varian, who had an undergraduate degree from MIT a PhD from UC Berkeley, and a longtime appointment at Berkeley, became the chief economist of Google. He had spent a sabbatical at Google while it was still a small company. He was so enamored with the possibility that the wealth of information could provide that he eventually decided to become part time at the university, building a new research agenda as chief economist at Google with the wealth of data they have to offer. His path breaking work on auctions is often cited as a critical influence in building Google's successful auction-embedded advertising model, in which prices for ads are determined by a variant of an auction model. In Varian's own words, he was having so much fun at Google that he retired from the university, becoming full time at Google. This was not a cushy post-retirement position, but an influential position at the forefront of theory, which allowed him to interact with some of the best young minds coming out of school, as well as those from other areas of industry.

[8] Donald Pederson received a PhD from Stanford University in electrical engineering in 1951, working for Bell Laboratories until 1955, when was hired by UC Berkeley's department of Electrical Engineering and Computer sciences.

[9] Lécuyer, C. (2014). Semiconductor Innovation and Entrepreneurship at Three University of California Campuses. Public universities and regional growth : insights from the University of California. M. Kenney and D. C. Mowery. Stanford, CA, Stanford University Press**:** 20-63.

8.3. Stanford's Technology Licensing Office

Stanford University, at the heart of Silicon Valley, provides some sobering data about their technology licensing office, commonly considered the most successful among universities. Put simply, Stanford cannot rely on royalties for university operating expenses. The Office of Technology Licensing was established in 1970, and since then, over 10,000 patent and invention disclosures have come to the office, with approximately 4200 licenses. Of those, about 1200 are active. While approximately $1.66 billion has been generated by royalties—which sounds like a very large number—it turns out that over $1.0 billion came from only three big inventions. In short, three out of ten thousand were big winners, generating 2/3 of all income over the course of 44 years. Only 33 cases generated over $5 million, with 87 generating $1 million or more in royalties. In 2014, there was approximately $108 million in royalty revenue; 644 inventions generated income, but only brought in royalties of over $100,000, with 6 cases bringing in $1 million or more. The *legal expenses* were a staggering $9.8 million, just under 10% of the revenue.[10]

These amounts may seem large, but put in perspective, Stanford University's total operating budget for FY 2012-2013 was $4.4 billion. It received $1.27 billion in sponsored research, with 84% of that coming from government sponsors. The industry affiliate programs, of which the campus has 56, generated $193 million. The university's endowment was $17 billion, and pre-specified returns from investments of the endowment can be used toward operating expenses.[11]

The corporate affiliate programs are scattered throughout the university, which includes 7 schools: Business, Earth Sciences, Education, Engineering, Humanities and Sciences, Law, and Medicine. Many of the corporate affiliate programs include the ability for corporate sponsors to send researchers into university labs. Engaging in joint research with PhD students can give them access to valuable employment recruitment opportunities. For professors, having corporate affiliate sponsors can help employ PhD students in their lab. (It is important to note that for a vast majority of PhD students, their admission into the PhD program includes guaranteed funding that will pay their tuition and a stipend for living expenses—meaning that they are able to make an independent living while attending graduate school.) This can enable a virtuous cycle of professors engaged in important areas of research getting a large number of corporate affiliate sponsors who can fund a large number of PhD students, which in turn enables the professor to do more research in the area, thereby attracting more corporate sponsors.

Yet, income from licenses and patenting is clearly not the primary reason Stanford and UC Berkeley engage in these activities and encourage technology transfers to industry. The value lies in the long-term relationships with industry that ensure that faculty and research are defining cutting edge new technological trajectories. This gives faculty competitiveness for the next round of federally funded research, which is actually the main portion of the university's research

[10] Stanford Technology Licensing Office Presentation, November 2014.
[11] http://facts.stanford.edu

income, as covered in the next section.[12] Strong university-industry ties can also anchor relationships that can lead to philanthropic gifts. In 2001, for example, Stanford received a $400 million gift from Hewlett-Packard; its total gift income from FY 2012 was over $1 billion.

Strong industry university ties can also lead to new private-public partnerships, such as the $500 million, ten year contract between BP and primarily UC Berkeley, which led to the creation of a new Energy Biosciences Institute.

8.4. Government – University Ties

The government played a critical role in the establishment and growth of the research universities of Stanford and University of California at the heart of Silicon Valley. Even beyond their historical legacy, government continues to provide a very large portion of research funding for these universities. What is critical to note, however, is that the research budgets are allocated through multiple different agencies, with evaluations of grant approval based on blind peer-reviewed boards comprised of scientists and other members who do not necessarily work at the agencies providing funding. In other words independent advisory boards evaluate the merits of proposals, which are competitive, and those winners are awarded on a project basis rather than central bureaucracy allocations of budgets to particular institutions. Even the University of California system has a majority of its operating budgets for research come from competitive rather than guaranteed state funding sources. For many disciplines, therefore, faculty members' ability, or potential ability, to apply for and successfully receive large government grants can play a role in hiring and tenure decisions.

UC Berkeley was California's first public university, founded in 1868. It has enjoyed considerable strength in basic research. Its faculty, alumni, and researchers have a combined 72 Nobel prizes total, and Berkeley scientists are responsible for 6 elements in the periodic table (including the humorously named berkelium, and lawrencium, discovered in the Lawrence Berkeley labs.) During World War II it was responsible for managing the national laboratories, including Los Alamos, which produced the atomic bomb, with Robert Oppenheimer and Edward Teller as faculty members.

Stanford's ascent as a top US university occurred largely during the Cold War, through a re-orientation that entailed aggressively pursuing government research budgets and forging strong ties with industry. Until the university experienced a financial crisis in the early postwar era, it largely kept its distance from government research, leaving that to public universities such as UC Berkeley. There was a sense that private universities should not be participating in the war effort. However, when Fredrick Terman, a mechanical engineering professor who later became dean of the engineering school and provost, and is largely credited with transforming Stanford.

Terman reoriented the faculty hiring and composition to recruit top talent and encouraged their research in a way that would attract federal funding, while remaining industry relevant. His conception was to build "steeples of excellence." Since the government grants were competitive,

[12] Lenoir, T. (2014). Inventing the entrepreneurial university: Stanford and the co-evolution of Silicon Valley. Building Technology Transfer Within Research Universities: An Entrepreneurial Approach. T. J. Allen and R. P. O'Shea. Cambridge, UK, Cambridge University Press**:** 88-128.

so the science had to be evaluated by blind peer-reviewed processes by other scientists, so hiring the very best people was critical to getting the major government grants. He also focused on building large PhD programs rather than a focus on practical engineering training. At the same time, Terman focused on hiring faculty that were interested in theoretical problems that would be of interest to industry. *The key concept was obtaining federal funding for scientific research that was simultaneously relevant for industry*. This was *not simply outsourced corporate contract research,* where companies narrowly specified what they wanted from the university, in effect making it a lower cost corporate R&D lab. The questions had to be basic, and considerable effort went into establishing a working relationship pin which firms trusted the faculty and university to use their sponsored research funds at their discretion, without micromanagement. The insistence on centrality of the research mission of faculty led Terman to reject contracts for applied research that did not fit the mission of increasing research prowess.[13]

The key conception of Terman, who is often credited primarily with successfully building industry ties, was that his visions was to anchor Stanford in government grants. Others on the board of Trustees and president of the university were actually more interested in building ties with university, but for Terman, whose vision became the Stanford model, *industry funding was not the primary way to build up the university*. It was instead the way to build a competitive university that could thrive on government funding, especially during the Cold War context.[14]

To expand research staffing, Terman pioneered a system of "salary splitting" rather than increase salaries of faculty already hired. This entailed paying half the salary of a new faulty member from grants and contracts, with research associates and others involved in sponsored project to be covered entirely from contract funds.[15]

Stanford has continued along the trajectory set by Terman, and for FY 2014, 87% of 1.27 billion out of 4.4 operating budget was from government sponsored research. The majority of government funding has gone to the medical center, with Department of Health and

Figure 1. Stanford's Sources of US Government Research, FY 2014

Government Agency	% of US Government Research
Department of Health and Human Services (DHHS)	65.3
Department of Defense (DOD)	14.2
National Science Foundation (NSF)	11.1
Department of Energy (DOE)	3.8
National Aeronautics and Space Administration (NASA)	3.5
Other	2.1

Source: Stanford University

For UC Berkeley's sponsored research funding, which totaled 738.5 million in 2013, the federal government accounted for 66%, at 486.3 million, and industry at 3%, with 22.9 million

[13] Ibid.
[14] Ibid.
[15] Ibid.

(not including the BP contract). The state of California contributed only 10%, with $73.7 million, showing the national stature of Berkeley. The composition of the government funding sources is shown below.

Figure 2. UC Berkeley's Sources of US Government Research, FY 2013

Government Agency	% of US Government Research
Department of Health and Human Services (DHHS)	25.3
Department of Defense (DOD)	4.3
National Science Foundation (NSF)	20.3
Department of Energy (DOE)	10.8
National Aeronautics and Space Administration (NASA)	32.5
Other	7

Source: UC Berkeley

Much of the difference in proportions between UC Berkeley and Stanford is accounted for by the medical school at Stanford; between 2012, Stanford's life sciences, which includes the medical school, comprised of just under $538 million out of the university's $903 million total research expenditure. Engineering was 132 million, with non-science and technology amounting to $48 million.[16] Within the University of California system, expenditures at the UC San Francisco Medical Center account for a majority of the entire research expenditures system wide.

Box 2: A note on Stanford endowment and funding

In 2012-2012, Stanford University's total assets were $25.7 billion, of which Stanford's endowment makes up $18.7 billion, the second largest of any private US University, surpassed only by Harvard. Approximately 75% of the endowment is designated for a specific purpose by the contributing donor. Every year, the Stanford Management Company oversees Stanford's financial and real estate assets which produce investment returns that are either used to support annual operating expenses, or reinvested in the endowment. This company employs financial professionals and is completely separate from any academic department or professors. The endowment payout is as follows: instruction and research 30%, student aid 23%, unrestricted 22%, faculty related 20%, library 2%, other 4%.

The largest source of University funding is the income earned from Stanford's endowment, making up 21% of overall funds. Closely following is sponsored research, which constitutes 19% (Harvard 21.6%). Student income pays 16%, health care and services 15%, SLAC 9%, expendable gifts 6%, other income 10%, and other investments 4%. The expenditure of these funds is concentrated mainly on salaries/benefits and operating expenses which represent 59% and 31% respectively.

[16] Stanford financial report

8.5. Academic Entrepreneurship

Academic entrepreneurship is a focal point for much of the discussion around the Silicon Valley ecosystem that other areas try to emulate. Counting the number of academic startups is therefore a tempting measure of university performance in this area. However, as seen above, the patterns in which universities have an impact on industry can be multifaceted. In a similar fashion, what to count as "academic entrepreneurship" is difficult.

The first point to remember is that in the US overall, the average and median age of entrepreneurs is approximately 40. This means that many are professionals who have gained deep knowledge in large firms, and often have PhD degrees from universities. The image of college students starting successful businesses right out of school—perhaps not even finishing their degree—certainly exists, such as Mark Zuckerberg of Facebook (or Bill Gates of Microsoft), but they are less prevalent than one might expect. Google's founders, for example, were PhD students at Stanford. The original Silicon Valley success startups, Fairchild Electronics, followed by firms such as Hewlett Packard, then Sun Microsystems, Cisco, and others, were all founded by Stanford graduates that had PhDs or had been professional researchers for some time.

Counts of academic startups usually do not include simply all graduates of a school. Data for all graduates of the school is still being compiled by researchers and are not readily available. However, given that it is very possible that graduates of Stanford or UC Berkeley have utilized interpersonal networks and skills that later enabled them to become entrepreneurs that suggest that the important effects of universities are understated by counting companies started directly out of universities. For example, Stanford alumni that are founders or CEOs of major firms include the founders of Nike, Silicon Graphics, Sun Microsystems, Cisco Systems, The Gap, Trader Joe's Dolby Labs, McCaw Cellular, Netflix, Wipro Technologies, Mozilla Firefox, IDEO, Paypal, WebEx, Youtube, Whatsapp, Instgram, Snapchat, Flipboard, and presidents of blue chip firms such as Time Warner, Pfizer, eBay, and others. Many of these notable individuals then return to Stanford to give talks or make monetary gifts. They provide stimulus for students to go start their own companies—at some point, even if not directly out of graduation—and they also can provide employment opportunities through recruiting activities at Stanford, where is a connection. Students who graduate and then work for such firms can then become entrepreneurs or follow new entrepreneurs once they gain experience.

UC Berkeley was ranked as third in Forbes' most entrepreneurial research universities in the US for 2014. The ranking was based on their entrepreneurial ratio, measured as the number of alumni and students who identified themselves as founders and business owners on LinkedIn against the schools total graduate and undergraduate student body. (The top was Stanford, and MIT was second.)[17] Pitchbook, an M&A, private equity, and venture capital database, created a

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[17] http://www.forbes.com/sites/liyanchen/2014/07/30/startup-schools-americas-most-entrepreneurial-universities/

list of schools whose alumni founded VC-funded companies, between 2010 and the third quarter of 2013. Stanford led with 190, with UC Berkeley as second, with 160.[18]

Located at the core of Silicon Valley, neither Stanford nor Berkeley has numerical targets or explicit incentives for faculty to become involved in entrepreneurship. Entrepreneurship is instead viewed as a way to retain high quality faculty, and it is supported. Being involved in entrepreneurship can also be a way to maintain a strong connection with working on cutting edge areas and help with faculty's teaching and research. The Stanford Faculty Entrepreneurship seminar explicitly raises the point that technology transfer through the Office of Technology licensing may be best for some areas, but for others, non-exclusive licenses or openly publishing results might be the best route.[19]

[18] http://www.geekwire.com/2013/top-universities-producing-vcbacked-entrepreneurs/

[19] Lenoir, T. (2014). Inventing the entrepreneurial university: Stanford and the co-evolution of Silicon Valley. Building Technology Transfer Within Research Universities: An Entrepreneurial Approach. T. J. Allen and R. P. O'Shea. Cambridge, UK, Cambridge University Press**:** 88-128.