

REPORT

The Role of Universities in Economic Competitiveness in California

ACUP ASSOCIACIÓ CATALANA D'UNIVERSITATS PÚBLIQUES

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THE ROLE OF UNIVERSITIES IN ECONOMIC COMPETITIVENESS IN CALIFORNIA

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The Role of Universities in Economic Competitiveness in California

A Case Study for the Catalan Association of Public Universities

By John Aubrey Douglass and C. Judson King
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Executive summary

Commissioned by the Associació Catalana d'Universitats Públiques (ACUP), this report provides a case study of the University of California's (UC) role in helping to create a highly competitive economy and in a manner that may be of use in Catalonia. The report provides a discussion on the role of research universities as important players in larger innovation ecosystems, the economic impact of UC on California, specific examples of university-private sector engagement, and relevant UC policies that set what we call the “rules of engagement” that both encourage economic engagement and protect academic freedom and university autonomy.

California and Catalonia

In the size of their populations and economies, and in their public systems of higher education, there are important differences and similarities between California and Catalonia, including:

- » The Autonomous Region of Catalonia holds a similar position as an economic innovator and driver for the Spanish economy, but with a substantially smaller population. Nearly 19 percent of Spain's GDP is produced in Catalonia. Catalonia universities and businesses account for 25 percent of Spain's production of scientific research, including patents and licenses.
- » There are some similarities in issues related to income inequality and significant problems with increasing educational attainment rates in California and Catalonia.
- » At the same time, Catalonia's economy is less diverse than California's, with a smaller high technology sector and only a few large businesses. California's economy is now growing in the post-Great Recession Era with a large expansion of its technology sector, while Spain's, and Catalonia's, is still in a transition period.
- » UC is a coherent network of ten university campuses under a single governing board and with substantial management capacity under its “One University” model; it is also part of a larger pioneering system of higher education that is highly mission-differentiated system. In contrast, Catalonia's public universities are independent entities.
- » At the time of finalizing this report, and in contrast to California, Catalonia is in the midst of significant political turmoil and uncertainty in the aftermath of a referendum for independence from Spain. Although outside the scope of this report, this situation creates an unstable environment for Catalonia's universities to innovate and promote economic development.

Knowledge Based Economic Regions – A Framework for Analysis

The growing acceptance of new growth theory relates, in part, to a number of highly touted regional success stories—or what we term Knowledge Based Economic Areas (KBEAs) in this report. The United States, and California in particular, are viewed as perhaps the most robust creators of KBEAs, providing an influential model that is visited and revisited by business and government leaders, and other universities, that wish to replicate their strengths within their own cultural and political terms.

While California has a number of unique characteristics, including a robust University of California system with a strong internal academic culture and devotion to public service, the story of its historical and contemporary success as an agent of economic development is closely linked to a number of key contextual factors. These relate to the internal culture, governance and management capacity of major universities in the United States, investment patterns in R&D, the business environment, including the concentration of Knowledge Based Businesses and the availability of venture capital, the legal environment related to Intellectual Property (IP) including tax laws that promote private R&D investment, the quality of the workforce, and quality of life variables important component for attracting and retaining talent.

In most of these areas, California has enjoyed an advantage that helps to partially explain the success of the University of California as an agent of economic development.

The University of California's Economic Impact

With ten campuses, the University of California is a significant actor in California's economy and in its social and cultural life. With expenditures of about \$31.5 billion in 2017-18, much of that in the form of salaries, wages and benefits, UC annually generates more than \$46 billion in economic activity in California. In total, UC generates approximately \$14 dollars in economic output for every dollar of taxpayer money invested by the state. The following summarizes some of the key ways UC influences and shapes the California economy.

› *Geographic Presence and Public Service*

One of the key features of California's pioneering public higher education system is a conscious effort to have campuses and services distributed throughout the state, and correlating with population centers and regional economic needs.

› ***Employment***

UC is a major employer in California, with over 190,000 faculty, researchers, staff, and students employed at 10 campuses, five health centers, and other facilities throughout the state, making UC the third-largest employer in the state. UC employees are broadly distributed throughout the state with about 74 percent associated with the nine general campuses, 23 percent at the five health centers, and 3 percent at other UC facilities.

› ***Graduates and Post-Graduate Employment***

UC has more than 150 academic disciplines and over 600 graduate degree programs. At the undergraduate level, the university awards nearly one-third of California's bachelor's degrees. Across disciplines, undergraduate degree recipients tend to double their earnings between two and ten years after graduation. At the graduate level, UC confers more doctoral degrees per tenured/tenure-track faculty than the average at public American Association of Universities (AAU) peers. More than 25,000 graduates of UC's academic Ph.D. and master's programs (in fields other than engineering/computer science) have entered the California workforce since 2000.

› ***Research Impact***

UC researchers reported more than 1,700 new inventions in 2014, and during that same year, UC inventions led to over 70 startup companies in California and generated \$118 million in royalty and fee income. UC has more than 12,500 active U.S. patents from its inventions—more than any other university in the country. UC startups are independently operating companies that formed to commercialize a UC technology. The vast majority (over 85%) of these startups were founded in California. As of 2014, 430 UC startups are actively operating in California. These startups employ 5,178 people and bring in a combined \$654 million in annual revenues.

Silicon Valley near San Francisco and the San Diego/LaJolla area in southernmost California are two regions where the roles of the University of California has been particularly great for economic development. The ways in which this came about differ substantially between the two regions. In Silicon Valley, Stanford University and the approaches of Stanford Provost Frederick Terman were vital at the start. The Berkeley campus of the University of California became increasingly important as time went on, as is documented through a number of specific examples in this report. In San Diego there was a full-community effort toward reorienting and building the economy, which focused around the new San Diego campus of the University of California and other research-based institutions brought together with it on Torrey Pines mesa.

The University of California has had a large impact on several major California industries, beginning with agriculture and mining, and extending to computing and biotechnology. The biotechnology industry is now heavily concentrated in California largely because of pioneering efforts and unusually effective research structures at the UC San Francisco and San Diego campuses. Interaction between these campuses and new companies has been particularly close.

The Industry-University Research Program of the University of California and then later the four Governor Gray Davis Institutes on Science and Innovation served to bring the university and industry together on research related to wireless communications, biotechnology, nanotechnology, and information technology.

University and private sector interactions should be governed by an appropriate set of policies concerning patenting, licensing, conflicts of interest and commitment, publication, etc. The University of California has a wide array of policies that serve those purposes. The University also maintains strong traditions of shared governance and faculty review and evaluation for advancement that underlie these policies.

Key Findings – California and Catalonia

In a globalizing world, where businesses investment and activity is increasingly competitive, universities play an essential role as an KBEA anchor, providing a physical space that generates new knowledge and talent that is not transportable to another region, another nation. The University of California, along with other major research universities, including Stanford, plays this anchor role in California. Stakeholders should view Catalonia's universities as a major means for long-term economic growth and socioeconomic mobility. The following outlines six major observations related to the California experience that may be of value to Catalonia.

› ***University Autonomy and Management Capacity***

Early in its development as the Flagship University for the state of California, UC gained a high level of institutional autonomy, granted to its Board of Regents and including a prominent role for faculty in institutional management. This allowed the university to manage financial and capital (buildings and land) resources, and, most importantly,

to shape its academic programs, admissions standards, faculty advancement policies, and the role of university administrators, relatively free of government interference and influence. As noted, its “One University” model enhances UC’s management capacity; Catalonia’s public universities are independent entities. Respective of this important difference, ACUP may wish to more fully explore how to better coordinate key policies and activities of their universities in a number of areas, not just economic engagement.

› ***Internal Academic Culture that Values Economic Engagement***

A sufficient level of autonomy, and an appropriate management capacity, also provided the required environment for UC to build a performance based academic culture that focuses on faculty productivity. This includes regular campus conducted peer reviews of faculty performance, and clear institutional policies regarding the criteria that reflect the larger mission and goals of an institution. The quality, expectations, and productivity of faculty in carrying out their duties, built around peer review and with an emphasis on innovation and creativity, is one of the most important features of leading universities. This includes placing sufficient value on economic engagement *and* public service, and a qualitative review of a faculty member’s contribution in this area.

› ***Robust Sources of External and Competitively Funded R&D***

The University of California, and specifically its faculty and researchers, have long operated in a competitive environment for securing research grants, and, at the same time, relatively robust sources of external research funding. Most of this funding has come from the federal government that understands its crucial role in promoting both basic and applied research, and in shaping innovation and economic growth. UC has also benefited from policies on overhead rates that recognize the larger costs of funded research activities for the institution, including administrative staff support and capital costs, and that plays an essential role in the university’s overall financial model.

› ***Universities and Technology Transfer***

Universities need to develop policies and mechanisms to encourage interaction and collaborations with businesses and public agencies. This includes a careful consideration of the “rules of engagement” with business in which the university outlines conflict of interest policies and appropriate expectations between the academic community and the private sector. Universities operate on a basis of the free exchange of knowledge, or open science. This value needs to be retained and is, in fact, an important element in building strong innovation systems.

› ***A Supportive Political and Business Environment***

An essential component of California's innovation system, and that of any KBEA, is the interest and support of lawmakers, business interests, and more generally the public on the multiple roles universities play in socioeconomic mobility and economic growth. The business environment is also part of the political environment and includes broad and specific features: including a society supportive of risk taking, perception regarding the interest and flexibility of a university to engage with the private sector, tax policies that encourage private sector investment in university research, and the availability of venture capital.

› ***University Accountability***

Developing and sustaining a vibrant KBEA, and a positive and strategic relationship with local communities and the private sector, takes time and effort. Universities need to actively report on the overall economic impact and their collaborative roles in specific government, community and business sectors, and to seek avenues to disseminate and help explain their roles in society. Internationally, most accountability standards have been developed by ministries and are sometimes used for resource allocation. But universities need to creatively seek their own internal processes for setting their own performance standards, including their economic impact and the strength of their relationship with the private sector, and evaluating their strengths and weaknesses.

Previous studies on Spain and Catalonia's innovation systems by the OECD and the European Commission provide data and information, but only limited guidance on the internal culture and practices required of universities for promoting economic engagement. The example of California, and the University of California, may provide ideas and examples for both macro (state) and micro (institutional) policies and practices useful in the Catalonia context.

It is our sense that the unique culture of Catalonia, its present economic role in Spain and in the European Union, existing private sector strengths, and the entrepreneurial drive of its businesses and universities provide an opportunity to increase the economic and social impact of its public universities. Self-reflection, the search for best practices and new ideas, and a willingness to adopt and change are essential elements for seeking productive innovation systems. Yet the political instability, and decreased autonomy and increased authority of the Spanish central government in Madrid, may, in the short-term, limit or constrain the ability of ACUP institutions to reach their full potential.

1. Introduction – The Goals Of The Report

Research Universities continue to expand their role as creators of new knowledge and as key collaborators in regional economic development and national competitiveness. Perhaps nowhere is this more evident than in California where a group of public and private universities are ranked among the best in the world. The multi-campus University of California, in particular, has been a key actor in promoting socioeconomic mobility, producing basic and applied research, and collaborating with the private sector that have distinctly shaped the state's economy and the quality of life of its citizens.

Commissioned by the Associació Catalana d'Universitats Públiques (ACUP), this report provides a case study of the University of California's (UC) role in helping to create a highly competitive economy that may be of use to Catalonia. The purpose is to outline the part research universities play in larger innovation ecosystems, the economic and social impact of UC on California, and specific examples of university-private sector engagement and relevant UC policies that set what we call the “rules of engagement” that both encourage economic engagement and protect academic freedom and university autonomy. The intended readership is ACUP's academic community, the Catalonia government, the local business community, and other stakeholders.

In the size of their populations and economies, and in their public systems of higher education, there are important differences and similarities between California and Catalonia. With a population of nearly 39 million, California is the largest state in the U.S., nearly twice the size of the next largest state, Texas. The population of California is projected to grow to 50 million by 2050 through a combination of immigration and domestic birth rates. The state is also the largest economy in the U.S. with a gross state product (GSP) of \$2.3 trillion and would rank as the 7th largest economy in the world if it were a nation. While California is famous for its robust high technology sector, including major tech firms such as Apple, Google, and Qualcomm, and has the highest concentration of biotech enterprises in the world, it has a diverse economy that also includes agriculture, health, manufacturing and a large service sector.

Constant population growth is an important policy reality in California. UC has historically maintained a commitment to grow in enrollment and programs with the state's population and economic needs. California also has experienced a significant change in its demographics. It is now a “minority majority” state, with 60% from minority backgrounds—including Chicano/Latinos, Asians and other racial and ethnic groups.

Like other parts of the U.S., California faces challenges related to inequality and a growing chasm between the rich and the poor. Among many minority populations, educational attainment rates are low relative to other developed nations. At the same time, there is a growing need for a higher percentage of Californians to attain bachelor and graduate degrees, largely in STEM fields, necessary to meet short—and long—term labor needs.

Within this changing demographic landscape, higher education is a vital factor for improving the life of California's citizens and for maintaining and bolstering the state's large and diverse economy. The University of California is the state's Flagship university with a broad and expanding mission, and that consists of ten campuses, nine of which have comprehensive academic programs providing undergraduate and graduate education, research, and public service; UC San Francisco is the one campus devoted only to medical education and research. Berkeley was the first campus, established in 1868. To meet the needs of growing population in Southern California, in 1919 a second campus was established, what became UCLA. Other UC campuses followed including Santa Barbara in 1944, Davis and Riverside in the 1950s, and San Diego, Irvine and Santa Cruz in the 1960s. The most recent campus is UC Merced in California's Central Valley, which opened in 2005. Today, UC enrolls a total of 240,000 students, 28 percent of which are in graduate degree programs. UC also operates a large "Extension Program" that dates back to the late 1800s and provides courses and programs for professionals and to support local and regional businesses and communities.

Figure 1 – University of California's Markers of Productivity

Six UC campuses are members of the 62 member Association of American Universities. Within the U.S., no other university system matches this level of representation.

Seven UC campuses are included in the top 100 of the Academic Ranking of World Universities. The top ranked campuses were Berkeley (4), UCLA (12), San Diego (15), UCSF (17), Santa Barbara (33), Davis (48), and Irvine (48).

Five UC campuses were ranked among the top 50 universities worldwide by Times Higher Education magazine in its 2010-11 World University Rankings. UC Berkeley was rated at number 8, followed by UCLA (11), Santa Barbara (29), San Diego (32), and Irvine (49). Also among the rankings: UC Davis (54) and UC Riverside (117).

UC doctoral programs rank among the best in the U.S. in a 2010 National Research Council report that universities consider the gold- standard assessment of Ph.D. studies. The NRC reviewed 322 UC programs in science, math, engineering, social sciences, and humanities. A total of 141 UC programs were ranked among the top 10 in their fields.

UC's Board of Regents has responsibility for overseeing the management of the system, including appointing UC's president and the Chancellors for each campus. UC's "One-University" model provides coherence to the system in key policy areas, including undergraduate admissions standards, the hiring and advancement of faculty, and a UC-wide process for reviewing existing and new degree programs. UC also has a history of "shared

governance” where the Academic Senate, as the representative body of the faculty, has clearly defined responsibilities related to academic management and shared authority with administrators in specific policy areas.

UC operates within a larger pioneering system of higher education that is highly mission-differentiated system, including the ten University of California campuses, the California State University with 23 regional campuses, and 110 local California Community Colleges, plus private institutions like Stanford and Caltech. Most tertiary students (some 80 percent) are in public colleges and universities in California. The UC system in particular, with sole authority as the primary public research and doctoral granting university, is one of the most productive and highly ranked universities in the world (see Figure 1) with a long history of engagement with local economies and innovation, partly chronicled in this report.

The Autonomous Region of Catalonia holds a similar position as an economic innovator and driver for the Spanish economy, but with a substantially smaller population of some 7.5 million. Nearly 19 percent of Spain’s GDP is produced in Catalonia. Catalonia universities and businesses account for 25 percent of Spain’s production of scientific research, including patents and licenses. At the same time, the economy is less diverse than in California, with a smaller high technology sector and few large industries. Another important contrast is that California’s economy is now growing in the post-Great Recession Era with a large expansion of its technology sector, while Spain’s, and Catalonia’s, is still in a transition period.

There are similarities in issues related to income inequality and significant problems with increasing the educational attainment rates needed to fully support a Knowledge Based Economic Area (KBEA).

The Catalan higher education system consists of thirteen universities, seven of which are public, and four private. Five of the public universities have their campuses in Barcelona and the city’s metropolitan area: the Universitat de Barcelona (UB, 1837), the Universitat Autònoma de Barcelona (established in 1968), the Universitat Politècnica de Catalunya (1971) and the Universitat Pompeu Fabra (1990), and the Open University of Catalonia which has a statewide mandate. The remaining three public universities are in the three other provincial capitals in Catalonia and all established in 1990: the Universitat de Girona, the Universitat de Lleida and, in Tarragona, the Universitat Rovira i Virgili. Hence, with the exception of UB, the public universities in Catalonia are all relatively recent institutions. Public universities enroll some 142,000 students—approximately 74 percent of all tertiary enrollments.

Catalonia’s public and private universities also play a large role in the region’s economy supported by “strategic investment in research and development in Spain,” as noted in a

2010 report by the OECD. This includes a major role played by the Catalonia government to bolster the competitiveness of the region's universities in attracting both Spanish and EU funding for research. For more than 30 years, the Catalan government has had authority over its universities. Catalonia's government, for example, has established a number of high profile research centers and an agency that recruits and pays the salaries of top scientists who choose their host Catalan institute or university. These programs, and the efforts of universities in the region, allowed Catalonia to become Spain's primary science and technology hub.

However, as noted in the 2010 OECD report, "While most Catalan universities embrace regional engagement in their strategic plans, there is a narrow understanding of the third mission [public service] and regional engagement..." The report also points to "a lack of incentives for individual researchers and institutions" to help expand the activities of Catalonia universities to help shape and build the region's economy.

In both California and Catalonia, public universities are expanding their role as vehicles for socio-economic mobility and regional economic development. In a globalizing world, institutions are looking across borders for ideas and best practices.

This report provides a general framework for analyzing the conditions for universities to be active players in regional economic development and the ways the University of California has pursued this important mission. The role of UC in California's economy relates to both the development of human capital and direct participation in creating what is one of the most innovative, entrepreneurial, competitive, and productive economies.

It is important to note that this report cannot fully explore all historical and contemporary aspects of UC engagement in the economy. The following provides a series of illustrative cases studies related to specific regions, sectors of the economy such as agriculture and biotechnology, university and industry collaborative research organizations, and specific industry-based initiatives in biotechnology and energy. Just as importantly, the report provides an overview and examples of UC's extensive policies and practices that shape how faculty and the university engage in regional development built around an academic culture that understands and values this vital role of leading researchintensive universities.

2. The Dynamics of Robust Knowledge Based Economic Areas*

New Growth Theory is now a broadly accepted concept among business and university leaders, ministries and lawmakers of almost all political persuasions(see Figure 2). The shared axiom essentially states that postmodern economies and, increasingly, developing economies, are growing in their dependence on supporting “knowledge accumulation,” and encouraging the process of applying new knowledge in the marketplace. Innovation and new technologies depend increasingly on the number of people able and motivated to seek new innovations and technologies. Most importantly, modern adherents of New Growth Theory underscore the importance of investing in new knowledge creation to sustain growth.

Along with government and the private sector, research universities play a pivotal role in building the productive regional and national ecosystems necessary for globally competitive economies. Universities in particular are significant actors both in creating new knowledge and for attracting and educating talented people. The ability of business to innovate is also increasingly tied to acquiring knowledge from outside sources, including universities. Businesses generally prefer engagement with local or regional universities that have knowledge of the socioeconomic, cultural, and legal environment in which they operate, and that can produce talent suited to their business climate. Universities that are productive and economically engage thereby act as an anchor institution within regional economies.

In part, the growing acceptance of New (sometimes called Endogenous) Growth Theory relates to a number of highly touted regional success stories—or Knowledge Based Economic Areas (KBEAs). The United States and California in particular are viewed as

Figure 2 - New Growth Theory

New Growth Theory emphasizes that economic growth results from the increasing returns associated with new knowledge. Knowledge has different properties than other economic goods (being non-rival, and partly excludable). The ability to grow the economy by increasing knowledge rather than labor or capital creates opportunities for nearly boundless growth. Markets fail to produce enough knowledge because innovators cannot capture all of the gains associated with creating new knowledge. And because knowledge can be infinitely reused at zero marginal cost, firms who use knowledge in production can earn quasi-monopoly profits. All forms of knowledge, from big science to better ways to sew a shirt exhibit these properties and contribute to growth. Economies with widespread increasing returns are unlikely to develop along a unique equilibrium path. Development may be a process of creative destruction, with a succession of monopolistically competitive technologies and firms. Markets alone may not converge on a single most efficient solution, and technological and regional development will tend to exhibit path dependence.

Source: Cortright (2001) “New Growth Theory, Technology and Learning”

*Aspects of this section of the report are adopted from John Aubrey Douglass’s forthcoming book, *A Quiet Revolution: The Nexus of Science and Economic Policy*

perhaps the most robust creators of KBEAs, providing an influential model that is visited and revisited by business and government leaders, and other universities that wish to replicate their strengths within their own cultural and political terms.

The following outlines some of the important contextual variables that help explain the attributes of KBEA ecosystems in the U.S., and in California, and the important role of major universities—private and public institutions, but with a focus on the interplay of California’s public “Flagship University,” the University of California’s ten-campus system.

There are many important higher education institutions in the U.S., but public Flagship Universities (research-intensive institutions) have a special role and the largest impact (see Figure 3 and 4). Compared to private universities, they offer a more diverse portfolio of programs and forms of public and economic engagement.

Part of the reason for the distinct role of leading public universities is scale; they are much larger in enrollment and in the number of academic programs, and the volume of research output, including patents and licenses. Another distinction is their geographic distribution throughout major population areas, while elite private research-intensive universities are found in only a few states. And Flagship Universities have historical roots and a growing commitment to public service, including often very large “extension” programs that provide relevant research and training programs for farmers and business people throughout a state.

California and other key states are major innovators and economic powerhouses because of a number of market positions. These include long-term investments in research universities, robust forms of federal R&D funding, the availability of venture capital, tax policies that promote private investment in university basic research, and a political culture that has supported entrepreneurs and risk-taking. In essence, the U.S. was the first to understand and pursue the nexus of science and economic policy.

The objective of this report is to reflect on this work by economists, sociologists and others,

Figure 3 – New Flagship Universities

Public Flagship Universities play a significant role in regional and national economic development. With the demise of many private research laboratories, our nation’s universities have become the primary sources of U.S. research, discovery, and innovation.⁶ The biotech industry originated almost entirely from research universities. Countless start-ups and patent grants in a number of industries have sprung from the research clusters that have formed, in conjunction with private counterparts, around the University of California, Berkeley; University of California, San Diego; University of Michigan; University of Texas at Austin; and University of Illinois at Urbana-Champaign.⁷ Further, public research universities regularly engage with community and state governments, providing academic expertise, technical assistance, and critical education and workforce development. They are also major employers: in 2012–2013, public research universities employed over 1.1 million faculty and staff nationwide, and were among the top-five largest employers in twenty-four states.

Source: Adopted from Academy of Science Lincoln Project: *Public Research Universities: Why They Matter* (2016)

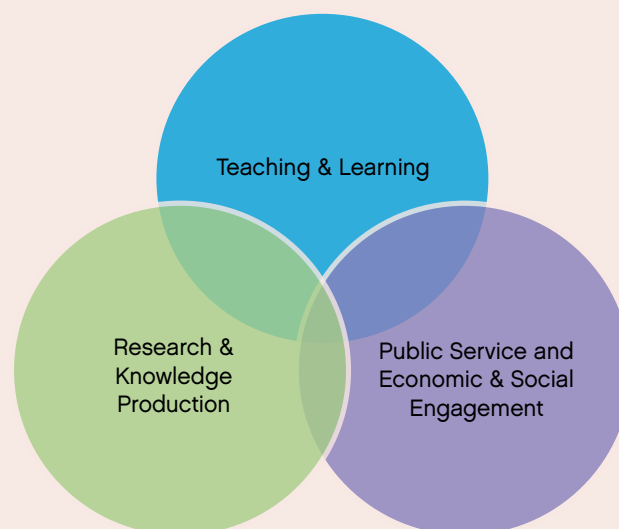
and provide a way to discuss the contextual aspects that help illustrate and highlight essential dynamics experienced in one of the most successful economies. While globalization is reshaping our understanding of economic competitiveness, regional economic productivity, and the interplay of government, business and organizations like universities, and national and regional cultures, remain primary sources of technological innovation and increased productivity. As noted by Barbara Ischinger and Jaana Puuka, and citing numerous OECD studies on the role of universities in regional economic development, “despite the ‘death of distance,’ innovation continues to cluster around specific regions and urban centers that have skilled people, vibrant communities, and the infrastructure for innovation. The competitive advantage of regions that create the best conditions for growth and development is increasing, and the gaps between regions are growing.”

2.1. Robust KBEAs – Seven Contextual Variables

Beginning in earnest in the mid-1800s, public universities in the United States were established and developed as agents of both economic and social progress, with charters that emphasized a three-part mission: Teaching, Research and Public Service (see Figure 3). In much of the world, the concept of economic engagement, and more generally public service, is a relatively new concept and identified as a “third” mission, as if it was an additional and new part of the purpose of major universities. There is a tradition of engagement with the private sector within the disciplines of engineering and the agricultural sciences, but at least historically they have been the exception.

Most of the famous state “Flagship” universities—Michigan, Wisconsin, Minnesota, Cornell, California, Washington and others—either were established or gained initial funding under the federal “Land Grant Act” of 1862. This watershed act provided allocations of federal controlled land largely in the American West to each state to sell for the fund-

Figure 4 - The Tripartite Mission of Research Universities



ing of regionally focused universities. The objective was to increase access to universities, and to have them serve local economic needs of a young nation. Universities that gained land, and hence a source of funds, were required to include programs in agriculture and mechanical arts (essentially civil and other forms of engineering training and research), but not at the expense of the liberal arts and classical subjects.

To reinforce the notion of the American university as an agent of socioeconomic change, the governing boards of these public institutions had a majority of “lay members” (i.e., not associated directly with the academic community) that represented the broader society that the university was intended to serve, including business and farming interests (see Figure 4).

California was transformed by this important federal legislation. The subsequent establishment in 1868 of California’s then sole state university at Berkeley was a direct result of the Land Grant Act. Its curriculum and subsequent research and outreach efforts were significantly focused on interacting and supporting the state’s economic needs. Agriculture and mining were the largest economic sectors in the later part of the 19th century. From these beginnings emerged universities that gauged a significant portion of their purpose and success on interaction and support of both economic development and socioeconomic mobility.

California has a number of unique characteristics and contextual factors that, as previously noted, shaped its historical and contemporary success as an agent of economic development. Figure 5 provides an outline of the variables for the most productive KBEAs. The following description provides a brief overview of each of these variables and how they influence or play a role in California.

2.1.1. Universities – Autonomy/Governance; Internal Quality Assurance and Self-Improvement; Academic; Culture Supportive of Economic Engagement

The levels of autonomy, the governance structure, and internal academic culture of research-intensive universities, play a major role in influencing their engagement with economic development and socioeconomic mobility. This includes a sufficient level of institutional autonomy to make decisions and form collaborations with private sector firms and with local government entities and NGOs. It also includes the need for an internal academic culture in which faculty and researchers value and are rewarded for pursuing research and collaborations that range from working with established firms, to supporting and participating in start-ups, and developing curricula that directly benefit regional labor needs.

Figure 5 - Key Contextual Variables For Knowledge Based Economic Areas (KBEA)



Universities in the United States, public and private non-profit, have common governance features that relate to their very earliest development as corporate entities, chartered by state governments that have authority over higher education institutions. In the U.S., there is no national equivalent to ministries responsible for higher education. The federal government primarily sets policy related to student financial aid (direct grants for low income students and loan programs for all qualified lower and middle class students), R&D funding through agencies such as the National Science Foundation, and regulatory controls related to these allocations and to national antidiscrimination policies. State governments charter all institutions and generally have provided management authority to universities via their governing boards, with expanding accountability schemes sometimes linked to university funding.

As a result, public and private universities have governance structures that lend themselves to significant management capacity when compared to universities in many other parts of the world. This includes some form of a Governing Board, an Executive Leader (e.g., “president”) and a formal body of the faculty who share management responsibilities under a model of “shared governance,” with different traditions and levels of cooperation within different universities.

Governing boards include members from the larger society that the university serves. They are sufficiently autonomous from national ministries, and government in general, to set broad institutional policies and hire and fire their top university administrator. Depending on its legal authority and the process for selecting members, the board provides a crucial combination of public accountability and, at the same time, a buffer with respect to the occasional political vacillations of ministries and other forms of political pressure that may not benefit the university's mission and public purposes.

In the U.S., states differ with regard to the amount of independence and authority that public-university boards have. California is one of three states where its Flagship public university has a large degree of constitutional autonomy, meaning independence from legislative control. The other two are Michigan and Minnesota.

If properly constituted in their membership and responsibilities, governing boards act as a conduit and forum for major policy decisions that balance the academic values necessary for the internal life of universities while responding to the external needs and multiple demands of stakeholders. (See Appendix 1 for an example of the general principles for a university governing board's operation, developed by the Association of Governing Boards based in the United States.)

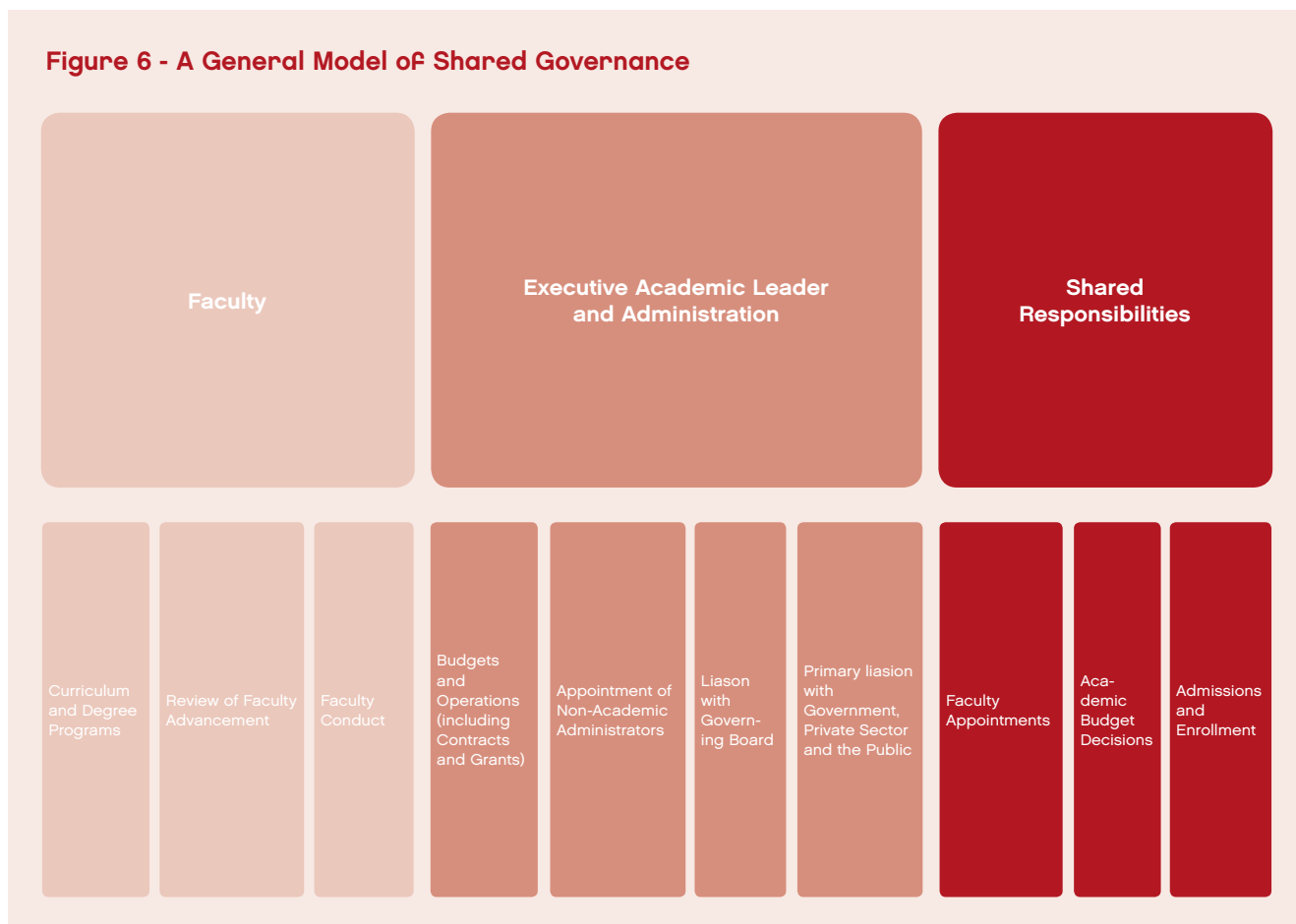
Most major universities also have an affiliated "Foundation" or "Development" corporation with a board to solicit donations, gifts and funds that are managed outside of the legal framework and restrictions of the university itself. This provides a means to generate additional income for targeted projects, like buildings and scholarships, and sometimes to provide operating funds. But a foundation is very different from the larger policy and financial accountability role of an effective governing board that optimally would charter and regulate a university's foundation.

Governing boards retain ultimate responsibility and full authority to determine the mission of the institution within the constraints of state policies and government funding mandates. But they must do so with regard for the higher education needs of their states or regions, in a deliberative manner that includes the advice of the president (or equivalent title, like rector), who in turn should consult with the faculty and other constituents.

To help navigate the proper balance in authority, universities should define the roles of administrative leaders and faculty in university management under a model of "shared governance" summarized in the following and in Figure 6:

- › Academic administrators should, generally, have the primary decision-making authority in all issues related to the institution’s budget, and effective management of university operations that support academic activities. They should act as the primary liaison with governing boards, government authorities, and other stakeholders. Executive leaders can also provide a strategic vision for universities and ideas for new initiatives, yet always in a consultative manner with university faculty and other members of the academic community.
- › A representative body of the faculty (such as a “faculty senate”) should have direct or shared authority regarding all academic activities of a university, including oversight of academic programs and curriculum, a strong advisory capacity to the university’s rector or president over faculty appointments, determination of admissions standards and practices where there is institutional discretion, and consultative rights for major budget decisions related to academic programs.

Figure 6 - A General Model of Shared Governance



The University of California, a multi-campus system with ten campuses, provides an example of policies on shared governance that arguably are one reason for its status as one of the great university systems in the world. In addition, UC's particular legal status as semi-autonomous from state and federal government control has allowed the institution to develop strategies and processes for engaging with the private sector, and for allowing faculty and university research staff to create enterprises, subject to appropriate controls set by the university itself.

At the same time, it is important to note that the model (Figure 6) is not typical of many of top private research universities in the United States: governance organization and behaviors vary greatly. Often, an organizational challenge for a university is to more clearly outline the roles of academic administrators and faculty, and students and governing boards or ministries. In many parts of the world, these roles are sometimes dictated by national laws or by ministerial policies that, arguably, limit the management capacity of universities.

2.1.2. R&D Investment Patterns – Public and Private Funding

In the area of R&D investment, the U.S. has had three major market advantages relative to other economies. First, the high proportion of R&D investment by the private sector; second, the relatively high investment rate in basic research beginning in the early 1960s; and third, the fact that funding is dispersed among universities and its researchers largely on a competitive, peer-reviewed process. Absolute levels of R&D expenditures are important indicators of a nation's innovative capacity and are harbingers of future growth and productivity. But equally important is the source, how the R&D is invested, and the geographic concentration of R&D activity.

Since 1953, U.S. R&D expenditures as a percentage of national GDP have ranged from a minimum of 1.4 percent to a high of 2.9 percent in 1964. In 2013, the ratio was 2.72 percent. In the 1960s, the majority of R&D investment was by the federal government. Since then, however, the private sector has become the majority R&D funder, mostly in the development side, yet now increasing its investment in basic research in areas such as biotechnology. Non-federally financed R&D, the majority of which is company-financed, increased from 40 percent of all R&D in 1968 during the peak of U.S. investment in R&D relative to GDP, to nearly 70 percent in 2013.

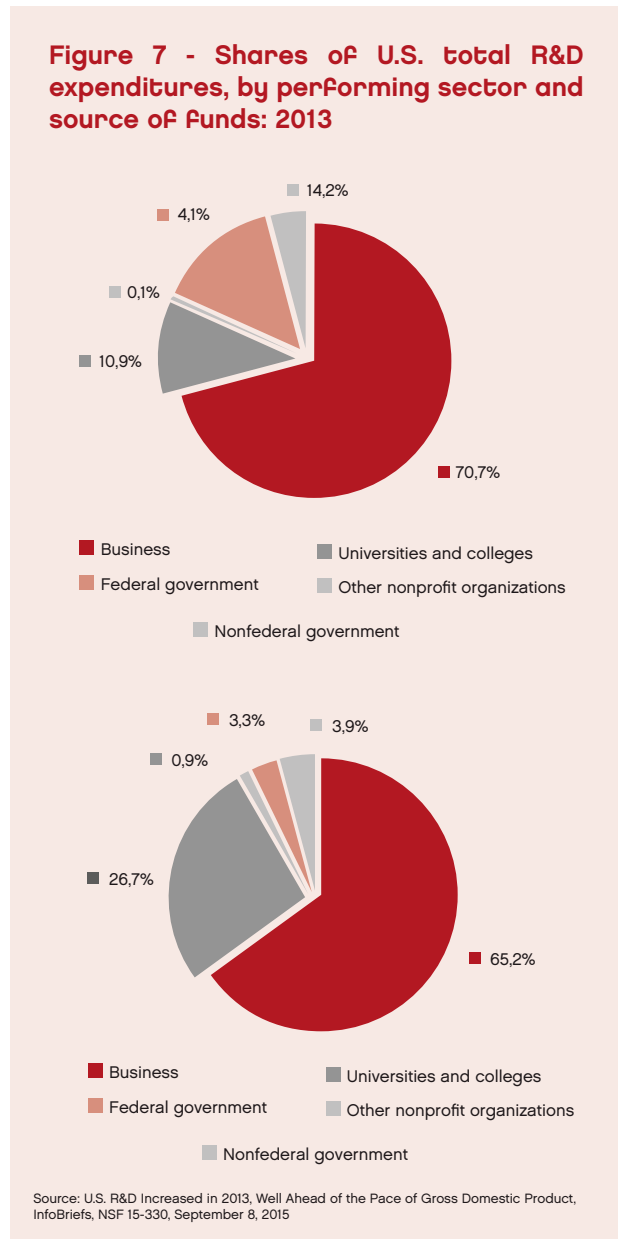
Research and development performed in the United States totaled \$456.1 billion in 2013, with spending concentrated geographically in about ten states. As noted, the business sector continues to be the largest performer of U.S. R&D. Domestically business R&D accounted for \$322.5 billion, or 71 percent, of the \$456.1 billion national total (see Figure 6).

Most of the private sector R&D investment occurs in only five states, reflecting their concentration on high-tech industries and robust research intensive universities: California, Washington, Texas, Massachusetts, and Michigan, accounting for almost half the nation’s company-paid R&D. The top 10 states—adding New Jersey, Illinois, New York, Pennsylvania, and Connecticut—produced 70 percent of the R&D that U.S. companies financed. Pharmaceuticals and medicines, the largest R&D industry, accounted for 17 percent of the national total.

The higher education sector is the second-largest performer of U.S. R&D. Universities and colleges performed \$64.7 billion, or 14 percent, of U.S. R&D in 2013 (see Figure 7). Over the 20-year period 1993–2013, academia’s share in U.S. R&D has ranged between 11 percent and 15 percent annually.

Universities and colleges remain the primary providers of the nation’s basic research, accounting for approximately \$41.2 billion out of a total of \$80 billion. Most of that funding is via a competitive review process that provides wide latitude for researchers to determine areas of science that are most promising. Relatively little funding has been directed toward specific industry needs, for example. At the same time it is important to note the high concentration of federal and private funding for university R&D in about 50 top institutions, and the importance of having highly competitive and quality universities in general for promoting regional innovation systems.

As noted, the business sector is also increasingly investing in and carrying out basic research, particularly in biotechnology. About 17 percent of all basic research is performed by the private sector in the United States. The federal government, through its national laboratories



and engineering centers, performed 15 percent; other nonprofit organizations performed 13 percent. Unlike other economic competitors, a substantial amount of university and other funding for basic research, the building block for long-term technological innovation, comes from the private sector.

2.1.3. Business Environment – Concentration of Knowledge-Based Businesses; Openness to Risk-Taking; Access to Venture Capital

Venture capital is a primary source of funding for high-tech (HT) businesses. The U.S. remains the single largest source of venture capital, representing a major market advantage unmatched by any other major developed nation. The lack of an equity investment culture, complexities related to intellectual property and legal processes for investing in new businesses, and market volatility are factors that hinder the development of early-stage financing in many OECD countries.

Total U.S. venture capital investment hit \$48.3 billion in 2014, its highest level since 2000 and an increase of 61 percent over the previous year in terms of dollars. The number of individual venture capital investments, or deals, were up as well, but by a more modest 4 percent to 4,356 deals in 2014, indicating the growth of deal size and the presence of a number of “megadeals”—many in California.

In the United States, a continuum of capital providers, including angel investors and public and private venture funds, helps diversify risk and ensures a steady flow of quality deals. These networks—together with the use of staged financing instruments linked to performance, provision of technical and managerial support, and easy exits on secondary stock markets—have contributed to the survival and growth of portfolio firms.

The number of venture capitalists with financial and technical expertise is limited in many countries and has not generally matched the rapid growth in risk capital supply across the OECD. Some countries, including Canada and Sweden as well as Israel, fill this experience gap by attracting venture investors from abroad.

In many countries, structural, regulatory, and fiscal barriers act to constrain the development of a dynamic venture capital market and business environment. A 2007 study on venture capital notes that, around the world, almost 20 percent of all venture deals take place across national boundaries, an increase of 250 percent over the preceding five-year period. The authors observe that this trend has been accelerated by the practice of “venture licensing,” the replication of proven business models in new markets.

Although the U.S., Europe, and Israel remain key in the industry, practices like these are expected to lead to an increasing focus on emerging markets in the coming years.

While the U.S. remains a major source of high-tech innovation and job growth, among the various states there are differences in the geographic dispersion of mature KBEAs, particularly in the generation of new high-tech businesses and centers of venture capital. Similar to the overall rates of R&D investment, California has the largest concentration of venture capital and venture deals; in 2014, some 56 percent of all U.S. venture capital investment was in California, mostly occurring in the San Francisco/Bay Area, Los Angeles, and San Diego. The top five states in venture capital investments represent 75 percent of all investments (see Figure 8).

One study indicates that larger firms with over 1,000 employees are the most likely to collaborate with universities and other public research institutes (nonprofits). Further, most if not all of these firms are already engaged in R&D activity, sometimes via contracting research activity, and have therefore successfully built a capacity to absorb and use public-generated research.

Another study indicates that university-based start-ups are largely concentrated in states with the largest economies and with the largest levels of venture capital.

These patterns of R&D activity all point to the importance of a vibrant metropolitan environment for providing the ecosystem for the most productive KBEAs.

Figure 8 - Top 5 U.S. States Receiving Venture Capital Investment

	Bussines Deals	Amount Invested
California	1,804	\$27,151,513,000
Massachusetts	396	\$4,678,599,700
New York	203	\$1,920,793,100
Pennsylvania	189	\$774,665,400
Texas	187	\$1,506,448,000
<hr/>		
Sub-Total Top 5	2,779	36,032,019,200
US Total	4,356	\$48,348,586,400
Top 5% of US Total	64%	75%

Source: National Venture Capital Association/PricewaterhouseCoopers

2.1.4. Legal Environment – Intellectual Property Laws; Tax Laws that Promote R&D; Tax Laws for Gifts/Funding of Universities; Foreign Investment Laws

While there is a long history of UC faculty involvement in the development of agriculture (wine, citrus, major vegetable crops) and high-technology based sectors (computing, communications, biotech), a factor that has enhanced this activity is the 1980 Bayh-Dole Act. This federal legislation changed the landscape of intellectual property law. Universities

gained ownership rights for inventions and resulting patents funded through federally funded research—as noted, the primary source of basic research funding which is performed largely in research universities.

In part because it has been one of the most prolific generators of intellectual property, the U.S. has created a relatively elaborate and generally protective set of laws that, in turn, have influenced economic development. Two major developments help to decipher the proliferation of intellectual property and its influence on the American market.

First, as noted, the Bayh-Dole Act of 1980 opened the doors for universities and, in turn their faculty and researchers, to own patents on inventions developed through federally funded research and to issue licenses on them. Prior to 1980, patents and licenses generated by federally financed research remained, with few exceptions, under the ownership of the government in Washington, the result of a Cold War approach to intellectual property that focused much of the federal R&D investment on defense-related technologies.

The Bayh-Dole Act is credited with providing an important market force for encouraging universities, and their faculty and graduate students, to be more entrepreneurial, an intellectual property model later replicated by other national governments, beginning with the UK during the Thatcher administration. Bayh-Dole generated a revised worldview for both the university and business sectors by encouraging tech-transfer, and arguably an exaggerated sense of potential profits for researchers through return of portions of royalties to inventors. This national initiative, along with the funding of new federally funded university-business centers in engineering, had another effect: state governments, and to a lesser extent municipal governments, looked for new ways to harness their universities to support and grow their tech-based businesses and to compete for growing federal funding.

Another major shift in intellectual property laws was shaped by the legal system, and specifically the emergence via the courts of a more liberal determination of what could be a patentable discovery or idea. Remarkable discoveries in the life sciences, fed in part by long-term investments in basic research, created unique requests for patents and licenses. In 1980, the same year the Bayh-Dole Act was passed, the U.S. Supreme Court upheld a lower court decision providing an extremely broad definition of “patentable material,” including the patenting of organisms, molecules, and research techniques related to new biotechnology fields.

Patenting by academic institutions in the U.S. has increased markedly over the last two decades—from 1,800 in 1992 to 8,700 in 2012—resulting in their share of all patents doubling from 1.8 percent to 3.4 percent. The top 200 R&D-performing institutions dominate among

universities and university systems receiving patents, with 98 percent of the total patents granted to universities between 1997 and 2012. Among these institutions, 19 accounted for more than 50 percent of all patents granted to the top 200 (some of these were multi-campus systems, like the University of California and the University of Texas). The University of California system received 11.3 percent of all U.S. patents granted to universities over the period, followed by the Massachusetts Institute of Technology, with 4.2 percent. Biotechnology patents accounted for the largest share (25 percent) of university patents in 2012.

Research on innovation systems state indicate that the number of patents and licenses may be of less importance than the increased circulation of faculty and researchers, including graduate students, between the academy and the private sector. Universities now allow faculty to engage with the private sector, sometimes taking leaves of absence and then returning to their teaching duties. The networking and free flow of labor and, to some degree, ideas, is one of the major characteristics of robust KBEAs, feeding and sustaining these ecosystems.

Other countries implemented policies similar to the Bayh-Dole Act by the early 2000s, giving their academic institutions (rather than inventors or the government) ownership of patents resulting from government-funded research. To facilitate the conversion of new knowledge produced in their laboratories to patent-protected public knowledge that potentially can be licensed by others or form the basis for a startup firm, many U.S. research institutions established technology transfer offices, research parks, and incubators, a topic for later in this report.

Shifting the ownership rules for government-funded intellectual property has clearly encouraged greater investment by capital markets and resulted in research collaborations in the U.S. to a degree not yet fully replicated in similar developed economies. Furthermore, actual ownership of technology is necessary if corporations are to make large investments, such as for clinical trials and Food and Drug Administration approval, in order to bring the inventions to market. One historical U.S. advantage in shaping investment patterns and promoting risk-taking relates to tax policy at the federal, state, and, increasingly, local level as well. The U.S. has long engaged in using taxation not simply to generate revenue, but to shape economic behavior, a characteristic relatively new to many other economies. For example, bankruptcy laws in the U.S. have been the most liberal of any major developed economy, reflecting a political culture that essentially promotes entrepreneurship, recognizes the high rate of failure among all types of businesses, and spreads the risk so that a business failure does not mean permanent ruin.

The U.S. tax system has included “tax credits,” encouraging businesses to invest in technology and increasingly in R&D (see Figure 9). This in part accounts for the high rates of private investment in R&D (about 70 percent of all U.S. R&D expenditures).

An important shift to further encourage private investment occurred around the time of the 1980 Bayh-Dole Act, with the establishment of the Research and Experimentation (R&E) tax credit as part of the Economic Recovery Tax Act of 1981. It has since been extended and modified several times and was last renewed through 31 December 2013 by the American Taxpayer Relief Act of 2012. From 1990 to 1996, companies claimed between \$1.5 billion and \$2.5 billion in R&E credits annually; since then, annual R&E credits have exceeded \$9 billion.

Historically, state and local taxation systems varied significantly in the U.S., including a sales tax in some states, or an income tax model like the federal system, or both. Few provided significant tax credits or other incentives for R&D investment. But over the past three decades, states and local government have become much more engaged in shaping tax policy to attract desirable businesses, including high technology enterprises, and to generate investment in both university and business-based research.

2.1.5. Workforce - High-Quality/Professional; Mobility; Access to Global Labor Pool; Pathways to Citizenship

The U.S. has reaped tremendous advantages by its early commitment to mass higher education. Over most of the last century, more Americans went to college and graduated, with many entering graduate programs, than was the case for citizens of any other nation in the world. Adding to the nation’s supply of talent has been a relatively open-market approach to attracting academics and researchers. In the 1930s, the U.S. provided a haven for preeminent scientists escaping Nazi Germany and World War II. The emergence of a large network of high-quality, sometimes prestigious, universities that would hire foreign nationals as professors and researchers contrasted sharply with many, if not most, nations where university faculty held or hold civil service positions, and in which national governments limited the hiring of non-native talent.

Particularly after World War II, and beginning in earnest during the 1960s, the presence of foreign students in U.S. universities also grew dramatically, supported sometimes by the national governments, and increasingly by offers of student financial aid by American universities in graduate programs such as engineering where, today, foreign nationals are often more than 50 percent of the total students in any given program.

In previous decades, students who came to the U.S. for both undergraduate and graduate programs largely stayed in the U.S. and entered the job market. Their presence has dramatically influenced HT innovation and the growth of that sector in the U.S. economy. For example, one study indicates that nearly one-third of all the successful start-ups in Silicon Valley were started by foreign nationals, most of who gained their training in American universities.

Foreign nationals from Asia became the largest single source of talent coming to the U.S. for education, largely in graduate programs in science and engineering. Bolstered by Chinese national government initiatives, students from China became the largest single source of foreign students in the U.S. beginning in the early 1990s. The overall growth in all foreign nationals entering U.S. graduate degree programs in that period also reflected a shortfall in the training of “native” U.S. students in STEM fields, and the push by HT economic sectors to get the talent they needed via U.S. universities, and by successfully advocating more liberal visa policies for highly educated immigrants.

This pattern of attracting and then retaining talent is beginning to erode for two general reasons. First, the U.S. and other developed economies with mature higher education systems are finding that a growing number of foreign nationals educated in science and engineering fields, and professionals that have long contributed to science and technology innovation and businesses, are returning to their native economies as they mature, buttressed by national policies to attract top scientific talent. Second, the overall market for higher education, one of the primary means of attracting

Figure 9 - US R&D Tax Credits

Source: American Association of Universities

The federal Research and Development Tax Credit (“R&D tax credit”) is a business tax credit for qualified research expenses that can be deducted from overall corporate income taxes. This includes:

- Qualified research expenses include: certain labor and wage costs for performing research activities “in-house;” certain supplies used in conducting research; and a percentage of costs associated with “contract research expenses.” The credit only applies to research performed in the United States.
- The traditional R&D tax credit provides a 20 percent credit for qualified research expenses that exceed the taxpayer’s base amount (determined by reference to the taxpayer’s research expenses during the mid 1980s and the taxpayer’s recent gross receipts). In lieu of the traditional credit, taxpayers may elect to claim the Alternative Simplified Credit (ASC). The ASC provides a 14 percent credit for qualified research in excess of 50 percent of a company’s prior three-year average qualified research expenses.
- Under certain circumstances, businesses can also claim a credit if they fund qualified research at another organization such as a university or other research organizations. In such instances, a business can claim only 65 percent or 75 percent (as compared to 100 percent for in-house R&D expenditures) of qualifying expenditures toward the tax credit. The 75 percent rate applies only to qualified research organizations (such as universities or research consortiums), which are tax-exempt entities organized primarily to conduct scientific research and which are not private foundations.

talent, is both growing and shifting with further development of university systems in the EU and elsewhere.

The United States continues to enjoy a distinct but decreasing advantage in the supply of human capital for research and other work involving science and engineering. In absolute numbers, the United States still has the largest population of science and engineering researchers, but China (which almost tripled its number since the mid-1990s) and other parts of the world, in particular Northern Europe, are catching up and will soon surpass the U.S.

The number of international students in national higher education systems (defined as those students with citizenship or residency in another country) has grown from around 1.8 million in 2000 to over 4 million in 2014. Over that period, most EU nations have either retained or expanded their market share of international students; countries such as Australia and New Zealand have also grown in their market share. Meanwhile, even in the midst of a significant expansion in the number of students seeking higher education outside of their home countries, the share of international students attending U.S. universities and colleges has declined marginally.

The U.S. does retain a strong international draw at the graduate level, and particularly in engineering, the sciences, and business management. A high percentage of Chinese students wishing to study abroad still come to the U.S.. Nearly 30 percent of all international Chinese students enroll in a U.S. university or college. And some 24 percent of all international doctoral-level students in the U.S. are foreign nationals. But, as an indicator of shifts in the global talent pool, there is now an even a higher percentage in the EU and in Australia which, combined, draw 28 percent of the global pool of doctoral students.

There is then the question of the relative quality of the international student pool, and the quality and reputation of the graduate programs they enroll in—all rather difficult factors to evaluate. The U.S. remains a world leader in the prestige and, arguably, the quality of its advanced graduate programs. Yet there is growing evidence that students throughout the world no longer see the U.S. as the primary place to study; that in some form this correlates with perceived quality and prestige in the EU and elsewhere; and, further, that the trajectory of growth in international students may mean a continued decline in the U.S. market share of international students.

Attracting talent from abroad is an important component of the U.S.'s high technology advantage. Educating a more robust native population should be an equally, if not more, important goal. A factor that will influence the U.S.'s market position, and the general socioeconomic health of the nation, is the relative decline in higher education attainment

rates of Americans when compared to other developed economies. This phenomenon relates to a decline in the quality of pre-college education in the U.S., especially in the public sector.

2.1.6. Quality of Life – Metropolitan Advantage; Housing and Transportation; Education; Pollution; Crime

A growing body of research suggests that quality of life (QOL) is becoming an increasingly important consideration in modern business location decisions, particularly for high-tech firms that are less tied to traditional location factors such as transportation costs, proximity to raw materials, and cheap labor. A recent study on new business formations notes that, “Quality-of-life factors appear to be able to explain roughly a third of new-business formations“ in the U.S. in metropolitan areas where the bulk of business activities occurs.

QOL is also an important variable for productive research-intensive universities and for supporting KBEAs. Attracting and retaining talented people is highly dependent on an environment that promotes creativity, excellence and entrepreneurship, including affordable housing, cultural amenities, convenient transportation, health care, good quality schools, job opportunities for spouses/partners, low pollution, and safe neighborhoods and city streets. Add to this other variables related to open societies: freedom of speech and racial tolerance, gender equality and non-discriminatory practices related to sexual preferences.

A faculty recruitment study at Harvard asked a sample of more than 2,000 doctoral students and almost 700 first- and-second-year faculty members at top American universities to rank the importance of such factors as salary, location, chances of tenure, department quality, and institutional prestige when weighing different offers. Both groups ranked geographic location and quality of life as their first priority, followed by the “work balance” between teaching and research. Salary and institutional prestige were ranked toward the bottom of the list. The tenure factor was ranked somewhere in the middle.

Collaborative efforts of regional or city governments, universities and the private sector have led to a variety of strategies that link many of the KBEAs variables noted. These include:

- › Defining a region based on common needs. It should be durable enough to have a home location.
- › Finding a region’s unique competitive niche.
- › Programs for developing and assisting high-growth entrepreneurs.

- › Creating clusters in the region around core business niches. Newly identified synergies can benefit adoption of new technologies, worker training and business models.
- › Improving and leveraging local amenities—parks, recreational facilities, social services, etc.
- › Investing in people, community leaders and local workforce alike, including life-long learning.
- › Enriching the region's supply of equity capital. The public and private sectors can play very different and important roles.
- › Tapping technologies suited to the region. These might include: production agriculture that includes renewable energy and new bio-based materials from crop plants; advanced manufacturing, and high-skill services based on information technologies that are not location-dependent.
- › Investing in 21st-century infrastructure. This includes quality-of-life infrastructure such as community centers, education and distance education options, and well-designed public and recreation areas as well as telecommunications infrastructure, for example.
- › Reinventing regional governance to make decisions as a region instead of as independent jurisdictions.

Universities have a special responsibility to extend their expertise to helping improve the QOL in the regional area in which they operate—on their own, or in collaboration with other higher education institutions, local government and business.

2.1.7. Political Environment - Political Leadership; University Funding (Operational and Capital); Leveraging Federal/EU Funding

Among the general public, and most importantly among major political leaders in the U.S., the tenets of New Growth Theory, as noted previously, are growing in influence. With declines in older manufacturing and consumer goods' industries, high technology and service industries are widely viewed as the sources of near- and long-term economic competitiveness. This worldview is, of course, shared by many other developed economies, such as the EU. The difference is that the U.S. has had a longer history of essentially believing that HT innovation and economic activity will, in some form, be the crux of its future economy, and this belief influences R&D investment rates.

There is abundant empirical evidence of the central importance of high-tech innovation, including highly productive regional economic areas such as Silicon Valley and the San

Francisco Bay Area for IT and biotechnology, San Diego in communication technologies (like Qualcomm), and Boston for biotechnology. But there has also emerged a rhetoric influenced by these success stories, including the desire to replicate in some form a seemingly universal formula for success, which is fueled by an optimistic enthusiasm and sense of competition that often drives policymaking.

Still, the bright light of a technology- and knowledge-based economy remains the focus of much public investment. The major change in the U.S., with similar trends in other parts of the world, is the movement of policymaking and public investment intended to promote high-tech innovation and encourage university-business collaboration from national policymaking to the regional (or state) and local levels. State governments have increasingly becoming active promoters of generating and supporting KBEAs. Yet the source of public R&D funding has traditionally been the purview of federal (national) governments. Hence, many state and local initiatives intended to build university-business collaborations two decades ago, for example, were in large part pursued to capture federal funds. This motivation remains, but increasingly states are simply investing their own money in basic research efforts in areas such as stem cells and nanotechnologies.

Political interest, enthusiasm, and the sense of political competition—for example, copying the practices of competitor states or local regions, or beating them to new policy initiatives—are in some form prerequisites to building KBEAs. Arguably, although with many nuances, the U.S. has a high political interest in and desire to promote KBEAs and HT innovation.

3. UC's Research Portfolio and Economic Impact on California*

With ten campuses, the University of California is a major actor in California's economy and in its social and cultural life. With expenditures of about \$31.5 billion, much of that in the form of salaries, wages and benefits, UC annually generates more than \$46 billion in economic activity in California.

UC faculty and researchers secure nearly nine percent of all academic research and development grants coming from Washington. The federal government alone accounts for nearly 30 percent of UC's total revenues, far exceeding the investment by the state. In total, UC generates approximately \$14 dollars in economic output for every dollar of state taxpayer money invested.

In addition, because of the success of its teaching, research and public service operations, UC is the state's third largest employer and is a major source of start-up business and other economic activity. These figures do not take into account the growth in the economy due to commercialization of inventions and innovations stemming in part or totally from UC.

The following provides an overview of the various ways UC impacts the state's social and economic health, including the research portfolio, geographic presence and role in natural resource management, employment, degree programs and employment patterns of its graduates, and the impact of its research activity.

3.1. UC's Research Funding Portfolio

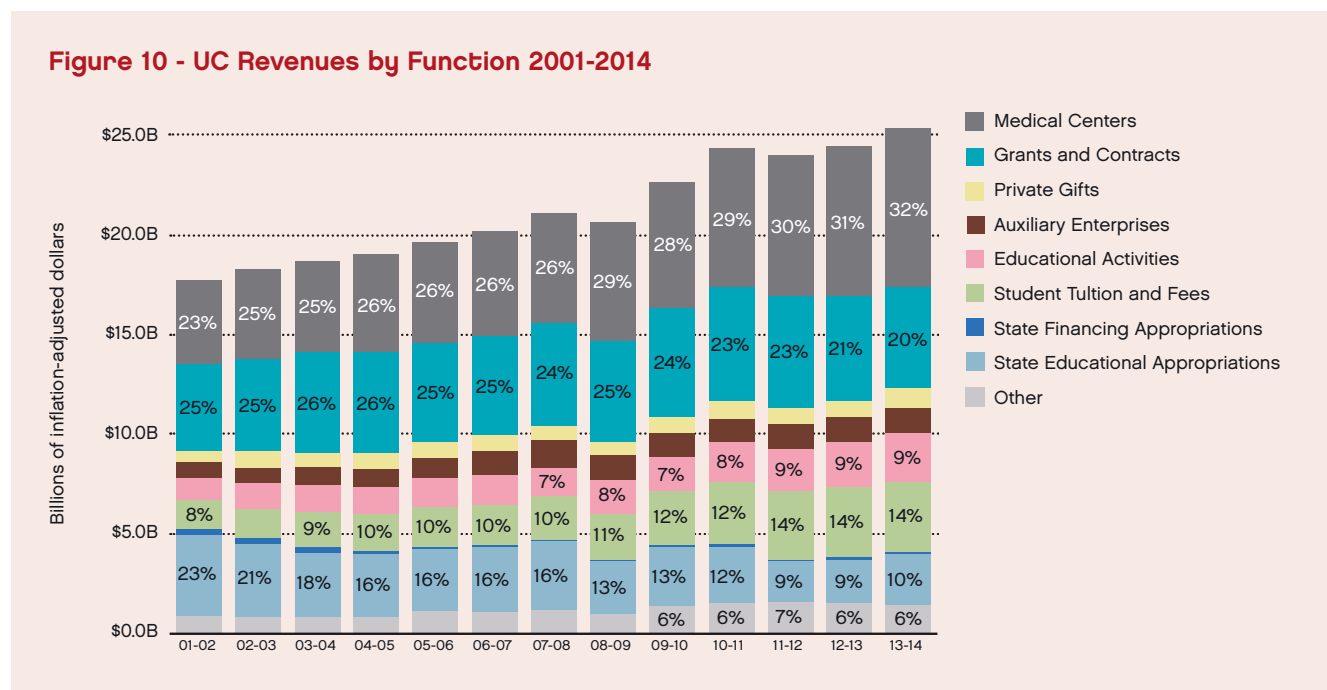
In the midst of a significant decline in state funding for the University of California, faculty and professional researchers have increased research funding. As shown in Figure 10, in 2013-14 research grants and contracts represented some 20 percent of UC's total budget. This does not include research funding provided internally by the university via various forms of cost sharing and some funding from the State of California and other government sources. Including these funding sources, research expenditures in 2013-14 totaled \$5.3 billion, representing about one-fifth of UC's total expenditures.

*This section of the report are largely adopted from the University of California 2015 Accountability Report and Final Report The University of California's Economic Contribution to the State of California, Prepared for The University of California Office of the President, Prepared by Economic & Planning Systems, Inc. September 12, 2011.

Most funding for research comes from federal agencies, including the National Institute of Health, the National Science Foundation, the Department of Energy, NASA and the Department of Defense. However, private, nongovernmental support is a growing component of UC’s research enterprise, funding research in health, life sciences, high technology, data science, materials engineering, education and many other fields. Private support accounts for about 23 percent of research awards—12 percent from corporations and 11 percent from nonprofit organizations. This leaves UC’s research enterprise susceptible to fluctuations in federal budgetary appropriations.

Of the total research expenditure, about 18 percent of the salaries paid to support research went to ladder-rank and other faculty. Twenty-three percent went to postdoctoral researchers and students, primarily graduate students, providing a critical source of support. Research grants and contracts provided employment for about 27,300 full-time-equivalent personnel. This represents 30 percent of the total UC full-time-equivalent workforce, including student employees.

Figure 11 provides an example of the sources of research funding for the Berkeley campus. During the 2014-15 academic year, Berkeley attracted \$691.1 million in new research funding, often thru multi-year projects. Of that total, the federal government provided 56 percent, followed by California state agencies and other government sources (15 percent), industry



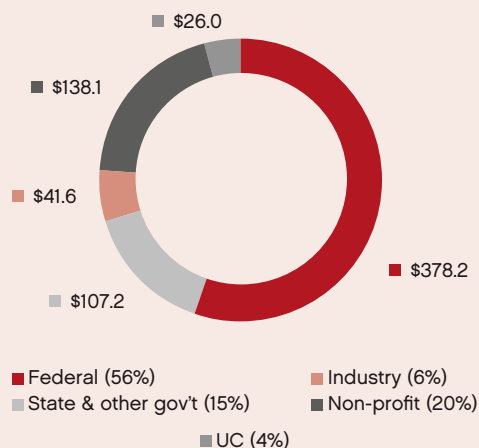
(6 percent), and the non-profit sector (20 percent). Of the research funding provided by the U.S. government, the largest contributors are the National Aeronautics and Space Administration, the National Institutes of Health and the National Science Foundation.

Berkeley does not have a medical school, and so does not attract large amounts of funding from the National Institutes of Health—the single largest funder of academic research in the United States. However, Berkeley has a close relationship with the Lawrence Berkeley National Laboratory, a national research laboratory funded by the federal government, managed by the University of California’s Office of the President, and co-located in the hills above the campus. Berkeley faculty participate and collaborate with researchers in the national laboratory in fields such as energy, biosciences, physics, and the environment.

UC faculty are extremely successful at attracting research support from both government and private sponsors. On average, UC conducts more than \$505,000 in research per tenured and tenure-track faculty member, which surpasses the average of about \$406,000 per faculty member for American Association of Universities (AAU) private institutions, and about \$277,000 for AAU public institutions.

Figure 11 - UC Berkeley Research Funding by Sponsor

2014/2015 Research Funding by Sponsor in millions (USD)



Total Awards = \$691.1 million
Calculated on the basis of project period

3.2. Geographic Presence and Public Service

One of the key features of California’s pioneering public higher education system is a conscious effort to have campuses and services distributed throughout the state, correlated with population centers and regional economic needs. The establishment of the Berkeley campus was soon followed by the development of various agricultural “research stations” and extensions of university programs well beyond the hills of Berkeley. By 1910, this included an agricultural farm in Davis, a citrus research station at Riverside, a research presence in

San Diego (La Jolla) focused on marine science, a growing number of “extension” offices to provide research and support training for agriculture, and tracts in various parts of the state to study and preserve important ecological areas.

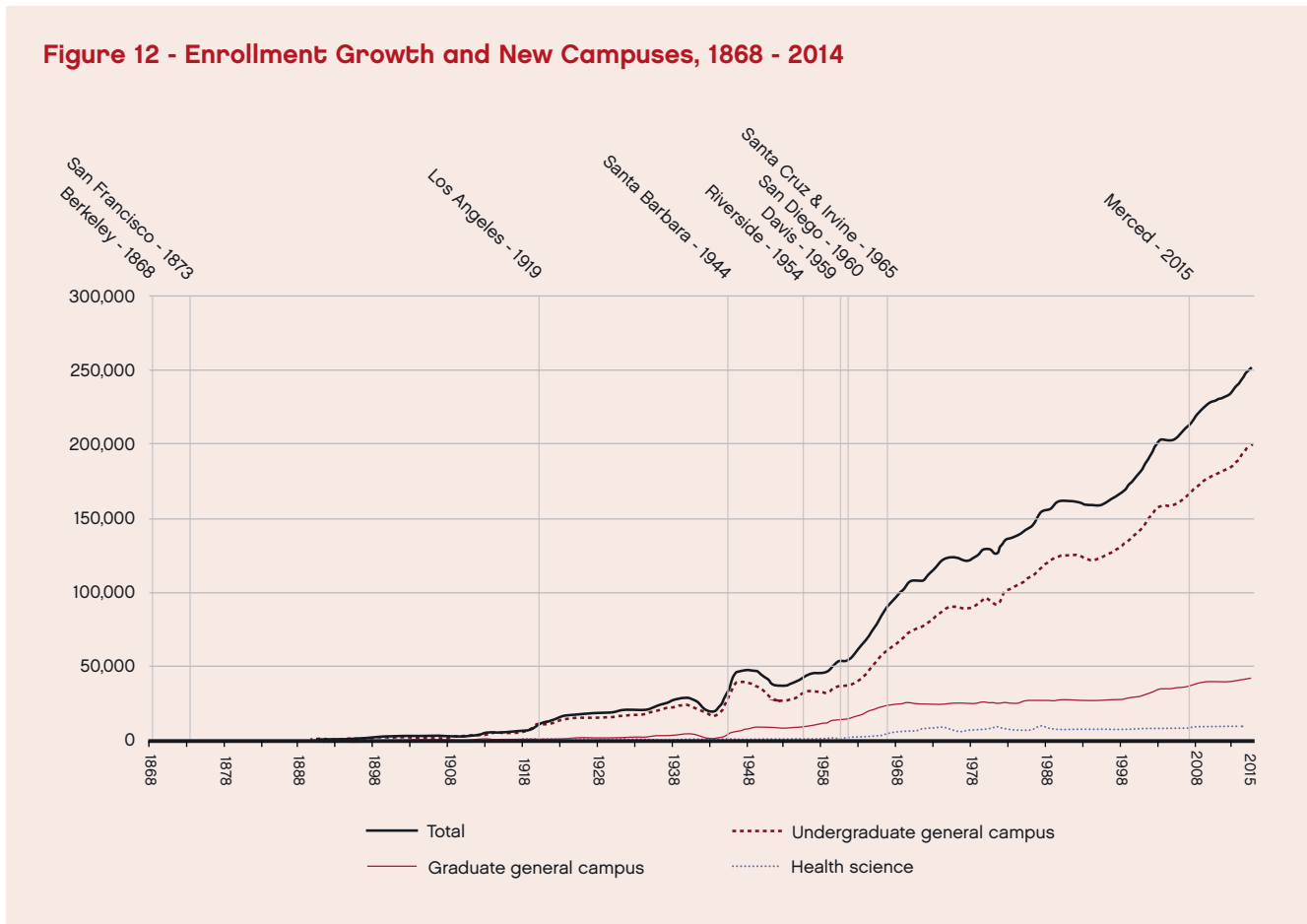
In 1919, UC made an important decision to establish a campus in Los Angeles by absorbing an existing teachers college to help meet a growing thirst for access to the university and for research in Southern California’s booming population. As a result, UC became the nation’s first multi-campus university, and launched a commitment to expanding UC enrollment capacity and regional presence as California grew in population and in its research and labor needs. As discussed later in this report, the growth from a single campus in Berkeley, to general campuses in Los Angeles, Santa Barbara, Davis, Riverside, San Diego, Irvine and Santa Cruz, and lastly Merced, and the San Francisco medical university, was accompanied by shared practices in academic personnel policies, admissions, and governance and management with a strong role of the Academic Senate.

As early as the 1880s, UC was also a key advocate for the development of other segments of California’s education system. In large part because of the influence of university leaders, California became the first state to imagine and establish a network of public community colleges beginning in 1910, offering vocational programs and the two-year Associate of Arts degree as an equivalent to the first two years at Berkeley in a four-year bachelor’s degree program.

UC accredited community colleges and accepted students with the AA degree as “transfer students”, providing an important additional point of entry to UC programs. (By 1930, some 40 percent of undergraduate students at Berkeley and what became UCLA were transfer students.) The development of California’s set of teachers colleges into regional “teaching-intensive” campuses with degrees up to the master level, and with similar matriculation policies with the community colleges, also formed a key component of California’s higher education system. UC’s development, and its impact on economic development, is closely linked to this symbiotic network of public with distinct missions, and to a lesser degree, private institutions.

Geographic availability of higher education, and its various services, remains a key strategic element in the university’s strategy and role in promoting both socioeconomic mobility and economic development. Today, the University of California is a huge enterprise, with ten campuses, some 252,000 students, five medical centers, five law schools, and the state’s only veterinarian school. UC also operates three national Department of Energy laboratories (Livermore, Berkeley, and Los Alamos in New Mexico) as well as thousands of state agricultural and natural resources programs located throughout the state, facilities for extension courses

Figure 12 - Enrollment Growth and New Campuses, 1868 - 2014



and related activities that enroll over 450,000 people, business and economic development programs, food and community health services, outreach programs to schools and teacher preparation projects, and programs to support transfer students from community colleges. Figure 13 displays the widespread geographic presence of the UC system.

3.3. Employment

UC is a major employer in California, with over 190,000 faculty, researchers, staff, and students employed at 10 campuses, five health centers, and other facilities throughout the state. This makes it the third-largest employer in California, behind only the state and federal governments. UC directly employs substantially more people in California than the top private-sector establishments (e.g., Kaiser Permanente, Wal-Mart, Pacific Gas & Electric, or

Wells Fargo). These direct UC jobs are broadly distributed throughout California with about 74 percent associated with the nine general campuses, 23 percent at the five health centers, and 3 percent at other UC entities.

Academic employees (teaching faculty, researchers, librarians, academic administrators, etc.) constitute about 30 percent of UC's workforce; nonacademic employees (staff) constitute the remaining share of the workforce. UC employs 140,000 nonacademic staff (or 103,000 FTE) across a wide range of occupational categories, including doctors, nurses and other health care staff; research administration and laboratory staff; student services staff; food and auxiliary services staff; maintenance and physical plant staff; and management and clerical staff.

UC's five health centers make a disproportionately high contribution to UC's total economic impact in California, especially in terms of state GDP and economic output. Overall, UC Health generates about 117,000 jobs in the state, \$16.7 billion in economic output, and \$12.5 billion in contribution to state GDP. Overall, the multiplier or ripple effects of UC Health tend to be stronger than other UC activities, in part reflecting the higher proportion of economic activity that is captured in the state.

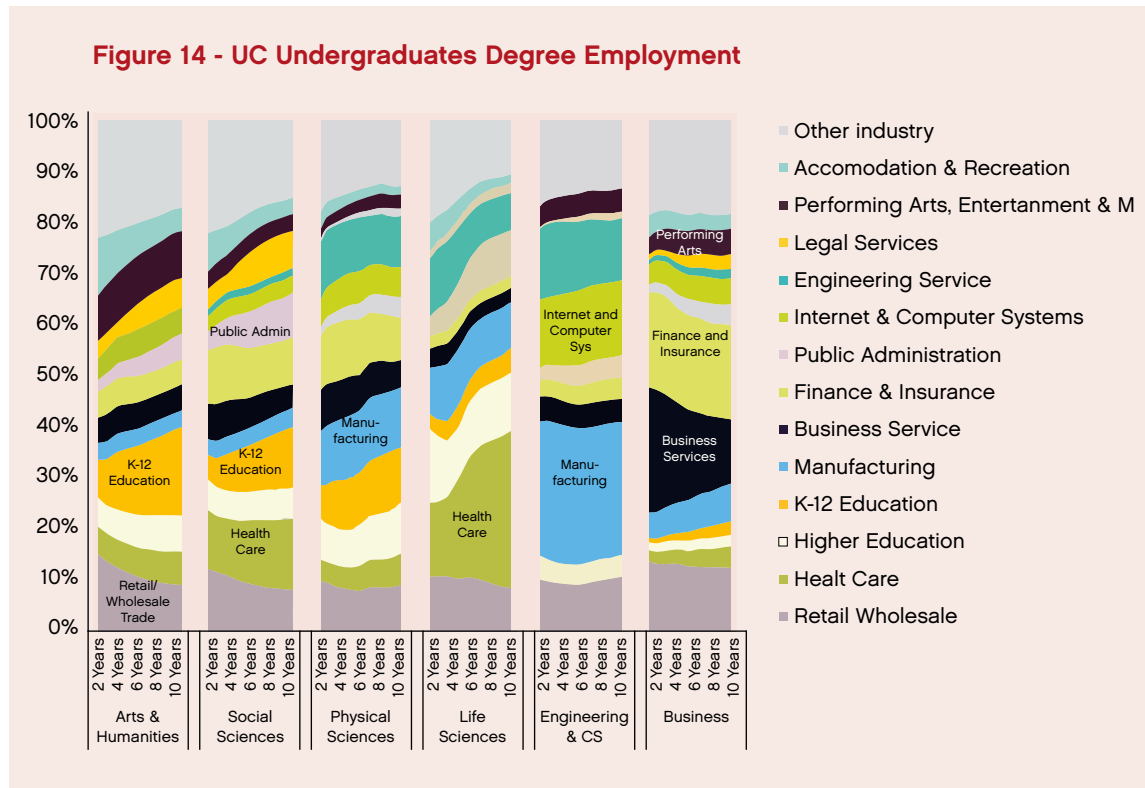
Figure 13 - Examples of UC's Programs and Presence in California: Agriculture and Natural Resources/Extension and Business Development



3.4. Degree Programs and Employment Patterns of Graduates

UC has more than 150 academic disciplines and over 600 graduate degree programs. At the undergraduate level, the university awards nearly one-third of California’s bachelor’s degrees. The demographic composition of the undergraduates is also very diverse: for example, a large proportion of UC students come from low-income families, especially at UC’s newer campuses; roughly 30 percent of UC’s incoming undergraduates are California Community College (CCC) transfers.

Across disciplines, undergraduate degree recipients tend to double their earnings between two and ten years after graduation. Figure 14 provides data on employment of UC bachelor’s degree graduates up to ten years after receiving their degree. Graduates often begin in positions within the retail and wholesale trade sectors but move on to high-skill industries such as education, health care, engineering and manufacturing.



A significant number of UC graduates go on to become educators within California's K–12 and higher education systems. While about 4 percent of UC graduates work in the state's K–12 education system directly after graduation, almost 10 percent go on to do so within ten years of receiving their UC degree. UC graduates also populate the state's health care workforce in large numbers. At ten years after graduation, about 12 percent of them are working in health care (31 percent among life sciences majors). Large numbers of graduates of UC's undergraduate STEM programs enter the state's engineering and high-tech workforce.

Close to 15 percent of UC engineering/computer science graduates employed in the state work in the Internet and computer systems industry, while another 12 percent work in the engineering services industry. The manufacturing sector has been a consistent source of employment for large numbers of UC engineering and physical science graduates.

At the graduate level, UC confers more doctoral degrees per tenured/tenure-track faculty than the average at public American Association of Universities (AAU) peers, and is on par with private AAU peers. More than 25,000 graduates of UC's academic Ph.D. and master's programs (in fields other than engineering/computer science) have entered the California workforce since 2000. Half of them have gone on to participate in the state's higher-education workforce, which includes all of the two-year and four-year colleges and universities, both public and private. This highlights the critical role of UC's graduate academic programs in producing the cadre of faculty who teach California's future college-educated workforce and conduct research that advances the state and national economies (see Figures 15 and 16) .

More than 12 percent of the employed graduates of UC physical sciences and life sciences programs work in the state's manufacturing sector, while another 25 percent work in the engineering industry. UC graduate academic programs in engineering and computer science supply workers to the state's high-skilled and high-tech industries. Since 2000, 14,000 graduates of these programs have entered the California workforce, with 30 percent working in the manufacturing sector and 25 percent working in engineering services. Another 18 percent go on to work in the state's fast-growing Internet and computer services industry. About 16 percent of these graduates go on to teaching and research positions in the state's college and university systems.

Graduates of UC Master of Business Administration (MBA) programs contributed to the state's high-skilled and high-tech industries. The 15,000 UC MBA graduates who have entered the California workforce since 2000 have worked in a wide array of industries, including manufacturing (26 percent), finance and insurance (20 percent), retail and wholesale trade (17 percent), and Internet and computer systems (17 percent).

Figure 15 - UC Doctoral and Masters Degree Employment

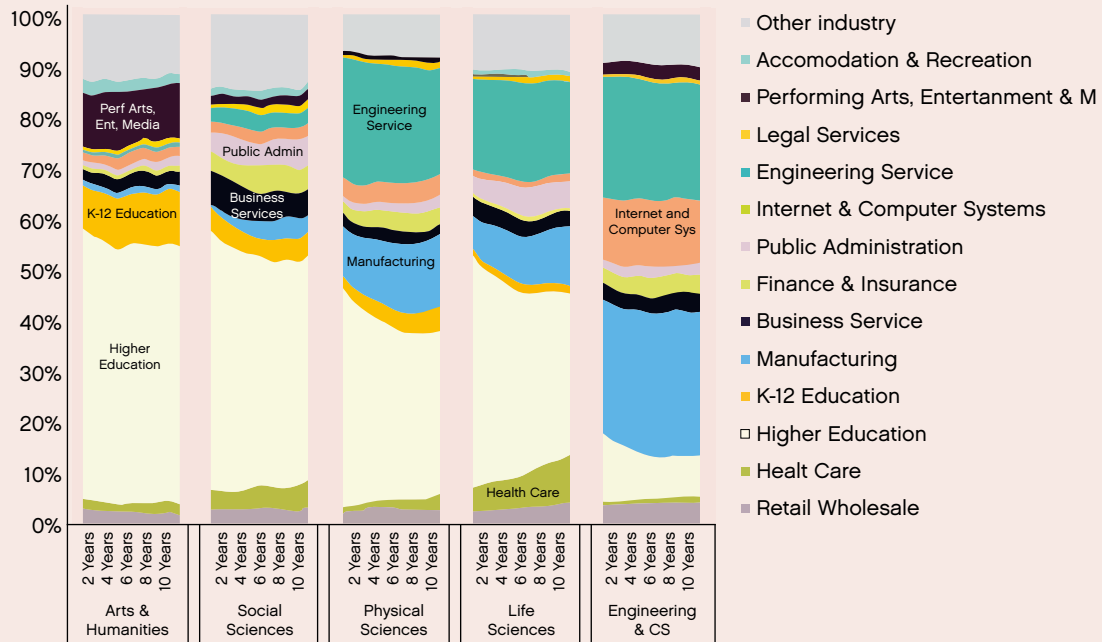
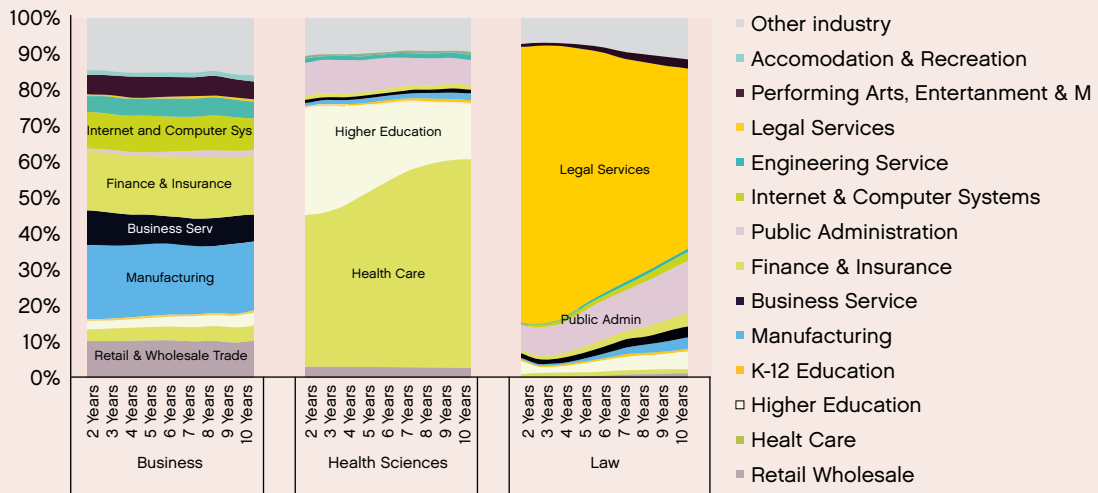


Figure 16 - UC Professional Degree Employment



Nearly 10,000 graduates of UC health science professional practice programs (e.g., M.D., D.D.S., Pharm.D.) have gone on to work in California since 2000. The majority of these graduates (62 percent) go on to work in the state’s health care sector. This highlights UC’s role, per the “Master Plan,” as the state’s sole public provider of many health science professional practice degrees and validates UC’s success in fulfilling that role. UC health science graduates also play key roles in other areas of public service in the state, including 35 percent who go on to work in the state’s higher education system and 12 percent who work in state government.

UC law school graduates go on to work in two main areas—legal services and government. Of the 7,500 UC law school graduates who have worked in California since 2000, more than 80 percent eventually find positions in the legal services industry. Another 15 to 20 percent go on to work in the public sector, including as government prosecutors, as public defenders and in other public agency roles. A large percentage of law school graduates start off in legal services initially after receiving their degree (76 percent), but by ten years after graduation this percentage has fallen to about 49 percent. The percent of UC law school graduates in government rises from 7 percent to 15 percent over the same period.

3.5. Research Impact

The University of California is a major research presence at both the state and national levels, producing about one-twelfth of the nation’s research publications. In all fields, the impact of UC publications exceeded U.S. national averages. UC’s publication impact is particularly high in the fields of arts and humanities, economics, computer science, engineering and medicine. Figure 17 provides an indicator of UC research productivity using citation analysis.

UC researchers reported more than 1,700 new inventions in 2014, and during that same year, UC inventions launched over 70 startup companies in California and generated \$118 million in royalty and fee income. UC has more than 12,500 active U.S. patents from its inventions—more than any other university in the country. UC’s research activities provide clear and substantial benefit for the state of California and beyond. UC researchers have been called upon to share insights on how to adapt water consumption to drought conditions; develop energy alternatives; create greater understanding of the aging process; preserve indigenous languages; improve high school graduation rates; and develop effective therapies and treatments that can enhance global health, among many other areas.

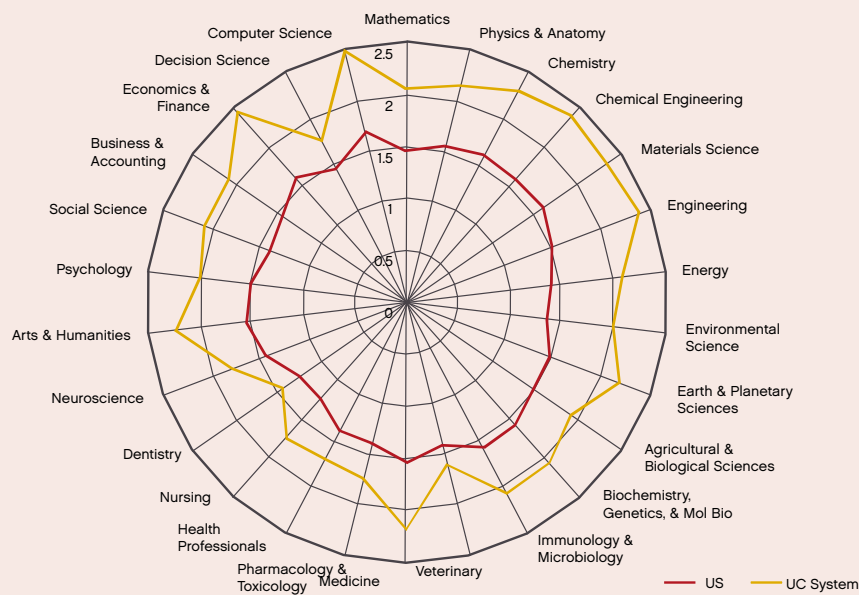
UC research leads directly to new inventions and innovations and bringing those innovations from the lab to the marketplace is a component of UC’s public service mission. Innovations from UC take two paths to the marketplace: they may be licensed to an existing company

or they may become the cornerstone of a new startup company. Both pathways ultimately benefit the economy of the state of California.

University inventions are classified as utility licenses or plant licenses. Utility licenses cover inventions protected by utility patents, such as processes, machines, manufactured items or compositions of matter. Utility licenses are often exclusive to the licensee. Plant licenses cover sexually and asexually reproducing plant varieties, and are often licensed via nonexclusive licenses to nurseries and distribution centers. From the high-tech centers of San Diego and Silicon Valley to the agriculture of the Central Valley, UC technology is licensed throughout California.

UC startups are independently operating companies that formed to commercialize a UC technology. The vast majority (over 85 percent) of these startups were founded in California and have stayed in California. As of 2014, 430 UC startups are actively operating in California.

Figure 17 - UC Research Publication Impact, by Field-Weighted Citation Impact and Discipline: 2009 to 2013



Across all disciplines, the UC FWCI average is 2.15; the U.S. FWCI average is 1.48.

Figure 18 - Active Licenses For UC Technology in California: 2009-10 2013-14

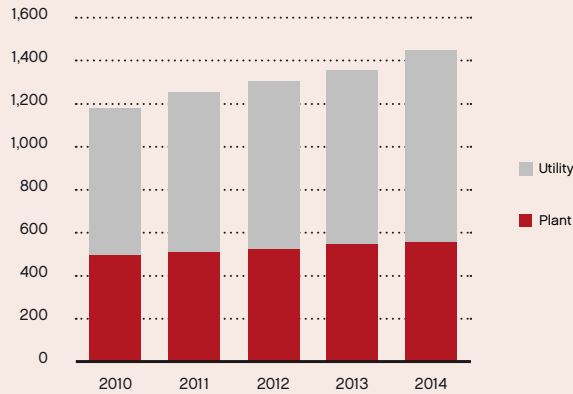
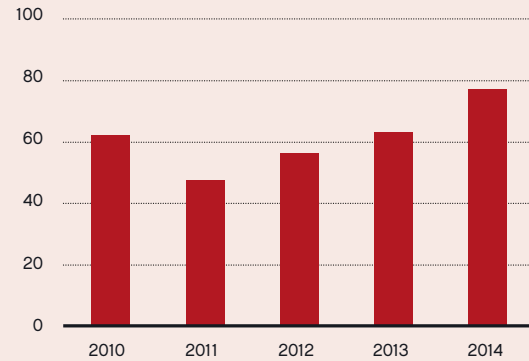


Figure 19 - UC Startups Formed in California, 2009-10 Through 2013-14



These startups employ 5,178 people in California and bring in a combined \$654 million in annual revenues.

UC supports start-up efforts through allowance of up to 39 days per year for consulting and other external activities, by allowing unpaid leaves typically for no more than two years for faculty to engage in outside activities meaningfully related to their university expertise (see Section E.3.1), and by providing incubator facilities and related educational programs for start-up efforts based upon university-owned inventions (see Figures 18 and 19).

The university does sometimes participate in ownership or stock investment in start-up firms. However, the university does this keeping a strictly business-like or “arms-length” relationship with the corporate founders or other owners. The Treasurer’s office or investment firms for which UC is a client select such investments on a business-like basis without interactions with UC faculty that may be involved so as to provide the role of a public university not giving preferential treatment to any private firm or the financial position of any of its employees.

4. California's story – the role of universities in economic progress⁹

America's public universities have a long history of being broadly engaged in regional and national economic development and public service across the disciplines, with participation by faculty, students, and staff, and organizational support by the institution. Most universities, for example, have various activities intended to boost economic development and integrate students and faculty into community based research and service.¹⁰ California's economy, in particular, has benefited from a close relationship between the University of California's multi-campus system, government, and the private sector.

The following provides a series of case studies of UC's economic engagement in two major KBEA in California (Silicon Valley and San Diego), major industries (agriculture and biotechnology), focused research institutes (the University-Industry Collaborative and the four California Institutes for Science and Technology), and industry collaborations (Novartis and BP).

4.1. Specific locales

4.1.1. Silicon Valley^{1*}

The area generally known as Silicon Valley lies in the southwestern portion of the San Francisco Bay region, roughly from Redwood City on the north to San Jose on the south and incorporating San Mateo and Santa Clara counties. It does not have sharp boundaries. The area is well known as the heart of innovation for the electronics and computing industries. The reasons why Silicon Valley blossomed where it did are complex and have been explored by many authors. The complexity of analyzing the origins and working structures is underscored by disagreements among principal authors¹¹.

The Development of Silicon Valley

There is no question but that there was an essential role of Stanford University in the initial development of Silicon Valley, and clearly there are also important roles of the other Bay

* General references for this section are Saxenian, Kenney, Lee et al., Adams, Geiger, and Lenoir

Area universities, UC Berkeley in particular, along with Stanford in sustaining the innovation capabilities and success of Silicon Valley. However, there are a number of other vital ingredients as well.

The area had roots in radio engineering dating back to the early days of that field, one of them being the Federal Telegraph Corporation and Lee DeForest's work on developing vacuum tubes. One of the persons most active in advancing knowledge about radio was Frederick E. Terman, who authored the leading textbook on the subject and carried out research that was both forefront and practical in orientation. Terman was Professor of Electrical Engineering as of 1927, Dean of Engineering from 1945 to 1955, and then Provost (a newly developed post) from 1955 to 1965, all at Stanford University. Academically and with the full support of then-president Wallace Sterling, Terman operationally designed and led the building of Stanford as an academic powerhouse. He is also usually given major credit for enabling and indirectly leading the events that primarily led to Silicon Valley. However, Terman's primary endeavor was to build Stanford, and his contributions to the launch of Silicon Valley are in some ways a side benefit of the ways in which he reached the primary goal.

Terman had spent World War II as Director of the Radio Research Laboratory at Harvard, and in so doing had learned about the finances and academic-building approaches of both those institutions. Vannevar Bush had been the faculty advisor for Terman's doctoral work at MIT during the 1920s and as Director of the Office of Scientific Research and Development was the top technical person in the United States government during World War II. He was the author of the report that is generally credited with having launched the National Science Foundation and brought about the great surge in research funding from the federal government to research universities after World War II.

One great need for Stanford in the aftermath of World War II was to build revenue, since it was in a financial situation that was more precarious (including being less endowed) than other major private U. S. universities such as Harvard, Johns Hopkins, and MIT. From Bush and from his time at Harvard Terman recognized that federal government funding of research would continue and grow after the War. He directed his building of Stanford toward opportunities for coupling excellent, well regarded research with areas of government funding, notably those areas favored by the Office of Naval Research which was the largest government funder of academic research immediately after the war.

Terman also saw a need for close relations with industry in order to further that goal and to keep the research meaningful and informed by opportunities for commercial application. He and others at Stanford also saw the opportunity afforded by creating an industrial park which companies could occupy on land owned by Stanford and adjoining the university.

An industrial park would make use of the prime asset that the university had, land in the total amount of 8200 acres (32.8 km²), a large excess over that which was needed for the campus itself. The industrial park would provide rent as income to the university, industrial consulting opportunities for the faculty, and a way of fostering industry that would build upon the knowledge generated at Stanford¹².

The industrial park was opened in 1951 with Varian Associates as the first tenant and Eastman Kodak as the second. As of 2004 the park, now known as Stanford Research Park consisted of 700 acres (2.8 km²), which is 8% of Stanford's land, with 10 million ft² (930,000 m²) of building space with 23,000 employees of 150 companies distributed among 162 buildings. A map of Stanford Industrial Park, built around Page Mill Road in Palo Alto, is available along with a list of current tenants¹³. The success of the Stanford industrial park touched off the creation of numerous university-affiliated research parks elsewhere in the United States and the world, with none yet having rivaled the success of the Stanford Research Park, with the possible exception of the Hsinchu Science and Industrial Park in Taiwan.

Terman also was a leader in the formation of the Stanford Research Institute (SRI), which was created in 1946 to provide more practical services for industry that did not fit with faculty research programs. SRI was so successful that it became independent of Stanford in 1970 and acquired RCA Laboratories in Princeton NJ in 1988. It is now a nonprofit, independent research center serving government and industry, with 2013 revenues in the amount of \$540 million.

The result of Terman's policies and initiatives, defense contracting, the Stanford Industrial Park, and the Stanford Research Institute was that by the 1950s a vital triangular nexus had formed among Electrical Engineering at Stanford, the Department of Defense, and the nascent electronics industry nearby, riding the wave of the future in a very fast-growing area of technological and economic development.

Terman saw the need for academic engineers to base their work on science and to collaborate with scientists, and he hired faculty accordingly. In building Stanford, Terman adopted an approach that he had learned in his World War II service as Director of the Radio Research Laboratory at Harvard, namely to recruit the best scientists and allow research projects to be formed around topics of their choosing. He coined the phrase "steeple of excellence" as areas of outstanding research that would develop from these recruitments and then be built to the highest stature, rather than striving for such a high level uniformly across the university. He was one of the first to use the technique of splitting academic salaries between the university's own funds and federal grant funds so as to create more faculty positions and thereby grow the fields that were the steeples of excellence.

Terman encouraged Stanford students and researchers to commercialize their inventions; it is he who brought together William Hewlett and David Packard in 1939 to work on Hewlett's audio-oscillator design from his Stanford M. S. thesis, with the result that they launched Hewlett-Packard in a garage in Palo Alto. Further, he personally lent them \$538 for start-up, helped find them work to finance their initial experiments, and helped arrange a loan from a Palo Alto bank to enable them to start commercial development. Hewlett-Packard world headquarters remains in Stanford Research Park. Terman also arranged for the Varian brothers to use the Stanford University physics laboratories without charge to launch what became Varian Associates, the first firm in Stanford's industrial park.

Another chain of events critical to the emergence of Silicon Valley started with the 1954 departure of William Shockley, one of the inventors of the transistor, from Bell Laboratories in New Jersey to form the Shockley Semiconductor Company, which was also located in the Stanford Industrial Park in Palo Alto. He built a team of top-notch engineers, but his management style was off-putting. Eight of these engineers, including Gordon Moore and Robert Noyce, left in 1957 to launch the Fairchild Semiconductor Company, which developed and marketed the monolithic integrated circuit¹⁴. Then, in 1968, Gordon Moore, Robert Noyce, and Andrew Grove left Fairchild and formed Intel Corporation, which succeeded mightily in its goal of producing large amounts of semiconductor memory. Two other companies that also had much to do with the development of Silicon Valley and its culture were Apple Computer and Xerox PARC (Palo Alto Research Center), which is also located in Stanford Research Park.

Although today Silicon Valley is correctly envisioned as the premier location for corporate start-ups in the world, that was not the focus at the start. Instead, there was a much greater representation of firms headquartered elsewhere that opted to create branches in the Silicon Valley area for proximity to other firms or branches located there and to Stanford and, in some cases, Berkeley. Of course, today's support structure (venture capitalists, law firms, services, etc.) for start-ups had not developed in those earlier days.

Characteristics of Silicon Valley

However, an examination of Stanford's early role and a tracing of corporations give a picture of what is involved in Silicon Valley that is only partial at best. Lee, et al.¹⁵, outline the following ten "features of the Valley's habitat" which have been important for its success. These are expanded upon in the various chapters of their cited book.

- » Favorable rules of the game. Rowen¹⁶ outlines the United States system of governing laws, regulations and traditions, with the argument that they are the most favorable in the world for development of new businesses.
- » Knowledge Intensity. The existence of such deep and concentrated knowledge about the various facets of the electronics industry and business start-ups in one small area provides an energy and intense exchange of ideas that build upon one another to facilitate successful new businesses.
- » A High-Quality and Mobile Work Force. Silicon Valley is a magnet for highly capable technical talent, and the workforce is unusually mobile among corporations, bringing knowledge and ideas from one company to another as people move from company to company.
- » Results-oriented Meritocracy. There are no social castes or preferred backgrounds. Immigrants are fully welcome, and success and advancement are rewarded strictly on the basis of the merits of one's accomplishments.
- » A Climate That Rewards Risk-taking and Tolerates Failure. It is well recognized that most business start-ups fail, even in the best environments. Unsuccessful ventures are regarded as learning experiences, and no stigma is attached to failure. Many of the most successful entrepreneurs have also had their shares of failures.
- » Open Business Environment. A characteristic of the electronics industry and certainly of Silicon Valley is that it is, in general, believed to be most effective to share knowledge rather than holding it secret. Shared knowledge can build upon itself more efficiently, and the electronics industry is relatively free of the situation that is confronted by industries such as pharmaceuticals and biotechnology where very large upfront costs and time are needed before bringing a product to market. Therefore exclusive ownership and hence secrecy are less needed in the electronics and computing industries.
- » Universities and Research Institutes that Interact with Industry. This aspect is covered further in the following section. Stanford and the Berkeley campus have been particularly important.
- » Collaborations among Business, Government, and Nonprofit Organizations. There have been important partnerships with governmental and quasi-governmental organizations that have helped the area and the industry as a whole. One such is the Joint Venture: Silicon Valley Network, which provides analysis and action on issues affecting the region's economy and quality of life.

- » High Quality of Life. The Bay Area climate of Northern California, and the cultural, social, and recreational opportunities of the area have been important. Crowding and high costs of living have now become issues and are being addressed in various ways.
- » A Specialized Business Infrastructure. Perhaps the most key element of Silicon Valley is its unique business structure¹⁷ attuned to the needs of the vigorous technological innovation community. These include venture capitalists and “angel” investors, specialized law firms, executive search firms, accounting firms attuned to the specific financial structures of the region, and consultants, both technical and on business and marketing.

University Sustaining Roles

There are vigorous, ongoing relationships between Silicon Valley firms and California universities, most notably Stanford and the Berkeley campus of the University of California. The interactions take a number of different forms including:

- › Consulting by faculty,
- › Licensing by companies of technology stemming from universities,
- › Faculty, student, and/or alumni participation in the formation of new companies,
- › Training university graduates who go to industrial companies and in particular attracting first-class people to the region as graduate students who then go to industry,
- › Recruitment of faculty from industry,
- › Continuing education for professionals,
- › University advisory boards composed of people from industry, and
- › Sponsorship of research at universities by industrial companies or groups of companies.

The term “technology transfer” is used to connote the transfer of university-generated technological innovations and concepts to the world of industry. But the interactions are very much a two-way street, with university researchers learning much from their interactions with companies that is useful to their own formulations of research and building of knowledge.

The differences between public and private universities result in much more information about industrial interactions and technology transfer being available for most public research universities than is the case for private universities. Reasons are that public universities see the use of their technology to be a central part of their public mission and thus want to display what they are doing for the economy as an accountability measure. As well, the laws of the United States require public universities to make information about their operations

available upon request, whereas the private universities are not subject to such laws. Thus a wealth of information on industrial interactions and technology transfer is available for the University of California on both university-wide (<http://www.ucop.edu/innovation-alliances-services/index.html>) and individual-campus web sites. University-wide technology commercialization reports for each of the years 2000 through 2014 are available at <http://www.ucop.edu/innovation-alliances-services/innovation/innovation-impact/technology-commercialization-report.html>.

Economic impact reports for the university as a whole and for most of the individual campuses and national laboratories are at <http://www.ucop.edu/innovation-alliances-services/innovation/innovation-impact/economic-impact.html>. The Berkeley web site (<http://ipira.berkeley.edu/success-stories>) contains information on start-up companies in which Berkeley faculty and alumni have been involved, along with a wide variety of other information. It contains information on individual companies that have been spawned from the Berkeley campus, contains press releases relating to commercialization. Additional information from this report is contained in Section E.3.2. A 2014 commissioned external report by the (San Francisco) Bay Area Economic Council¹⁸ addresses the economic impact of entrepreneurship stemming from UC Berkeley, much of which is in Silicon Valley. The Executive Summary of that report is reproduced as Appendix 2.

Lécuyer¹⁹ explores the quite different ways in which semiconductor innovation and entrepreneurship (again much of it in Silicon Valley) stem from each of three University of California campuses (Berkeley, Los Angeles, and Santa Barbara). He notes that by virtue of its proximity to Silicon Valley, Berkeley focused upon silicon integrated circuits, especially communications circuits and on the software tools required to design complex microchips. Because of its proximity to large defense-industry firms, UCLA brought in technologies from those firms and developed strengths in chips for broadband communications. Santa Barbara, a later and geographically more isolated entrant, concentrated on compound semiconductors, thereby differentiating itself from the other two campuses.

An important mechanism for semiconductor research at the University of California was the MICRO (*Microelectronics Innovation and Computer Research Operation/Opportunities*) Program. MICRO was started in 1981 as a partnership between the State of California, the microelectronics industry and the University of California. The state provided funds, ultimately about \$5 million per year, to be used to match and thereby lever industrial funding for University of California research projects, selected through a peer-review mechanism. The University of California waived overhead requirements on MICRO grants, thereby indirectly contributing its own funds to the research.

The Governor (Jerry Brown at the time) regarded MICRO as an effective defensive measure against loss of the microelectronics industry from California to other countries. In 2001-2002 ninety-six companies invested \$6 million in cash and equipment to fund 98 different MICRO projects. The program was then blended with industry-University Cooperative Research Program of the University of California (see below), adding other areas of research and industry as well and reached state finding of \$17 million per year before being ended in 2009 during a period of state budget stringency.

Kenney, Mowery and Patton²⁰ examine the various modes of engagement over the years between the Department of Electrical Engineering and Computer Science (EECS) at UC Berkeley and Silicon Valley industrial firms. They do this through analysis of six specific major research projects that span a period of fifty years, thereby giving a picture of how interactions between the EECS and what became Silicon Valley evolved over time. They show as well the importance of government funding for research that leads to technological innovation and economic development.

- » California Digital Computer Project (CALDIC), 1948-1954. This project, sponsored by the U. S. Office of Naval Research, constructed a one-only digital computer that was the first at a west coast U. S. university. The most important contribution to the economy was the graduates who had worked with the project, several of whom became leaders of the computing industry. Three joined the new IBM research laboratory in San Jose and were key to the development of IBM's moving-head hard disk drive technology.
- » Project Genie and Commercial Time Sharing, 1964-1968. The U. S. Advanced Defense Projects Research Agency (DARPA) funded research in EECS at Berkeley to develop time-share computing. This led the success of the Scientific Data Systems (SDS) Corporation in Los Angeles and to Tymshare, a successful time-share company in Silicon Valley (Cupertino). Three of the students involved in the creation of the GENIE software developed in connection with this project went to Xerox PARC to become the core of their computer research group which developed the first computer work station.
- » Interactive Graphics and Retrieval System Project (INGRES) and the Relational Database Industry, 1973-1980s. The relational database industry stems from competitive research by the IBM San Jose Laboratory and Berkeley EECS, with the Berkeley work sponsored by the U. S. Department of Defense and the National Science Foundation. The results, which came to fruition during the 1970s, resulted in a tidal wave of entrepreneurial new firms in the San Francisco Bay Area, primarily in Silicon Valley (Oracle, Ingres, Britton Lee, Sybase, PeopleSoft). Previously the database industry had been on the east coast of the United States. With the relational database work and start-ups, the industry moved to the west coast.

- » Reduced Instruction Set Computing (RISC), late 1970s to mid-1980s. IBM pioneered the concept of reduced instruction set computing as a way of accelerating the processing speed of integrated circuits. Competitive DARPA-funded research by David Patterson at Berkeley and John Hennessey at Stanford (where he is now President) greatly improved the technology and resulted in large growth of Sun Microsystems (working with Patterson) and the start of Silicon Graphics (working with Hennessey), as well as a number of other start-ups. The technology ultimately led to the ARM microprocessor that is widely used in cell phones.
- » Berkeley UNIX Software Distribution (BSD), 1973-1995. UNIX is a multi-task, multi-user computer operating system that was initially developed in 1969 at AT&T's Bell Laboratories. Under a 1956 consent agreement (anti-monopoly legal considerations) affecting AT&T, UNIX was placed in the public domain as non-telephone technology. Working closely with Bell Labs, Berkeley EECS greatly improved the UNIX technology to a form known as Berkeley Software Distribution UNIX (BSD UNIX). DARPA made UNIX the standard for the ARPANET computer network that was the forerunner of the Internet. William Joy of Berkeley EECS had worked on BSD UNIX and became a principal founder of Sun Microsystems in Silicon Valley. Sun adopted BSD UNIX as its operating system, thereby helping to lead BSD UNIX to wide adoption and a foundational position for the Internet. BSD UNIX was made publicly available, and UC by choice received no licensing fees or royalties. However, firms such as Sun have made major donations of research equipment and funding to Berkeley EECS.
- » Redundant Arrays of Inexpensive Disks (RAID), 1987. Three Berkeley EECS researchers (Randy Katz, David Patterson, Garth Gibson) developed a methodology for using vast arrays of smaller discs as a superior alternative to very large hard drives for massive data storage. This research was commercialized both by several existing large firms (IBM, DEC, EMC), as well as through at least 45 start-ups, most of which are in the Bay Area.

A seventh case is analyzed by Lécuyer in his aforementioned comparative study of the interactions of the Berkeley, Los Angeles, and Santa Barbara campuses with the semiconductor industry.²¹ Under support from the Army Research Office, the National Science Foundation, and the MICRO program, software for the design of integrated-circuit microchips was developed at Berkeley by Donald Pedersen and associates in the 1970s, leading to a widely-used public-domain simulator known as SPICE (Simulation Program, Integrated Circuit Emphasis). SPICE and evolutions from it and successors to it became the foundation of microchip design, and as well led to numerous start-up companies concentrated in Silicon Valley.

Why Stanford and Palo Alto?

Since faculty from both UC Berkeley and Stanford have been very large intellectual partners with Silicon Valley firms, it is logical to consider the factors which made Silicon Valley arise in the immediate environs of Stanford, rather than Berkeley. Adams²² points out that Terman at Stanford adopted a strategy of business orientation and thereby understood what would build industry-university interactions and the industrial economy of the Stanford region most effectively, whereas the leadership at Berkeley was more oriented toward the politics of Sacramento and preservation of UC's role vis-à-vis other components of the public higher-education sector. Stanford had not yet established a secure financial base, whereas Berkeley and UC had what was, at the time, a comfortable financial base with the State of California. But probably most important of all was the fact that Stanford owned land, and could readily devote a large tract to the development of an industrial park that it saw as an immediate source of revenue, but also turned out to be the magnetic hub of Silicon Valley. The Berkeley campus is essentially land-locked in an urban environment.

4.1.2. San Diego²

San Diego is located in the extreme southwest corner of the United States, sufficiently to the south of greater Los Angeles so that it is a distinct region. The economy historically was tourism, with a large number of military (U. S. Navy and Army) installations coming into being in the first half of the twentieth century as the Panama Canal was completed and on through World War II. An aircraft-manufacturing industry had grown up as well, also closely interacting with the military. With the end of World War II in 1945 many of the military operations wound down or ceased, and the area was left with a problematic economy that was in clear need of diversification and rebuilding.

The University of California, San Diego

The University of California had been present in the San Diego area since 1912 when it took over the Scripps Institution of Oceanography (SIO) in La Jolla about 20 km north of San Diego along the Pacific Coast. SIO was operated as a research laboratory with senior scientists and some graduate students; it had done substantial work with the U. S. Navy during World War II including the development of SONAR and anti-submarine warfare. Roger Revelle, long-time senior scientist with SIO and Director of SIO from 1951 to 1961, and a number of civic leaders of San Diego saw SIO as a base for building toward a new economy that could be based upon

² General references for this section are Walshok & Schragge, Anderson, Walshok & West , and Walshok & Lee.

innovations in science and technology. The keystone would be a public university—a new campus of the University of California. Revelle's initial plan was along the lines of a small, graduate-only public version of Caltech. Over time, as University of California President Clark Kerr and the Regents of UC saw the need for expanded enrollment to meet the needs of a burgeoning population, the plan became for a full-enrollment (27,500 students) University of California campus containing the usual mix of undergraduate and graduate education. Still Revelle and his associates retained several unique features in the plan for the campus.

- » The campus would still emphasize science, but would build towards coverage of a wide range of diverse fields.
- » The campus would be built from the top down, in the sense that outstanding, established research stars would be hired opportunistically as the initial faculty, without following any specific design as to which fields or sub-fields would be built initially. These stars would then attract other faculty and graduate students in their own or allied fields.
- » The campus would be built from the inside out, in the sense that there would be no effort to provide comprehensive coverage among disciplines or even within a discipline.
- » The campus would open first (1960) with only graduate students, which would be possible without a wide array of disciplines and would then admit undergraduates (1964) as sufficient faculty dimensions for undergraduate education had developed.

Revelle hired the initial faculty, starting with Nobel-Prize-winning chemist Harold Urey. He and several others among the initial faculty were hired by taking advantage of mandatory-retirement policies at other institutions, which made these faculty members available as they reached mandatory-retirement age. The University of Chicago and Bell Laboratories were particular targets. As of 1960-61, 57% of tenure-track faculty at UC San Diego were full professors and 67% of those full professors had appointments with salaries above the regular salary scale.

Part of the plan for the San Diego campus was for a Medical School that would be based heavily upon fundamental scientific faculty research. This plan, designed by David Bonner who came from Yale to be one of the founding faculty members, enabled UC San Diego to take a strong role at the forefront of the wave of advances in molecular and structural biology that ultimately became the foundation for the biotechnology industry (see below) and was important to the establishment of San Diego's first biotechnology company, Hybritech.

Anderson describes the development of the UC San Diego campus. The campus achieved very high rankings from the start by virtue of the Revelle plan and the extremely prominent initial faculty. In only twenty-two years the campus went from opening in 1960 to membership in the prestigious American Association of Universities, AAU in 1982, the shortest time from founding that has ever occurred for an AAU member university. As of 2014-15, there have been 16 Nobel Prizes associated with UC San Diego faculty, and as of 2014 there are 85 members of the National Academy of Sciences, 23 members of the National Academy of Engineering, and 38 members of the Institute (now National Academy) of Medicine among its faculty.

The longest-serving chancellor (1980-1995) of UC San Diego was Richard C. Atkinson, who was also the chancellor who was most concerned with university-industry relations and regional economic development.

Research and Hi-Tech Industry in San Diego and La Jolla

Three other non-industrial institutions joined the Scripps Institution of Oceanography and UC San Diego in bringing outstanding scientific research and renown to the La Jolla area. The Scripps Research Institute (formerly known as the Scripps Clinic and Research Foundation and, before that, as the Scripps Metabolic Clinic) was founded in 1924 and moved to Torrey Pines Mesa adjacent to UCSD in La Jolla over the period 1974-1980. It carries out highly regarded research in biomedical sciences and molecular biology.

The Salk Institute for Biological Studies was opened on Torrey Pines Mesa in the 1960s and deals with neuroscience, genetics, cell and plant biology, and related disciplines. Founded and initially led by Jonas Salk, the discoverer of the polio vaccine, it came to La Jolla when the city stepped up to offer the magnificent site when Salk was denied the opportunity to build such an institute at the University of Pittsburgh where he had been located. Nobelist Francis Crick, co-discoverer of the structure of DNA, was drawn to the Salk Institute and spent the last portion of his career there. Subsequently, Sanford-Burnham Medical Research Institute was founded in 1976 by a husband-wife cancer-research team, William and Lillian Fishman. Facing mandatory retirement for William at Tufts University, the Fishmans were drawn to La Jolla by the existence there of UCSD, the Salk Institute, and the Scripps Research Institute. They opened their own institute, also in the Torrey Pines Mesa complex. The annual operating budgets of the Salk Institute, the Scripps Research Institute, and the Sanford-Burnham Institute are now (2015) \$120 million, \$380 million, and \$150 million respectively. Out of this collection of biological and medical expertise came Hybritech, formed in 1978 and described in the section of this report on biotechnology.

In the 1950s and 1960s a series of industrial consolidations and redirections also brought important research activities in the private, commercial sector to San Diego. Notably, in 1952 General Dynamics Corporation was formed as a merger of several companies that had been involved in military production during World War II, including Consolidated-Vultee and the Aviation Corporation (aircraft), Electric Boat (submarines), and Atlas (guided missiles). The CEO of General Dynamics, John Jay Hopkins, was a major force in recreating the San Diego economy and in working with Roger Revelle to bring about the San Diego campus of the University of California.

General Dynamics and Hopkins also spawned General Atomics, to pursue basic research and development relating to atomic energy and other fields such as medical applications, transportation and space flight. It too was located on Torrey Pines Mesa in La Jolla. General Atomics proved to be prolific in producing spin-off companies, more than 60 of them by the early 1980s, including Science Applications International Corporation (SAIC). SAIC, General Atomics, and a number of other companies formed from these roots have been accomplished government contractors and creators of new technology.

Yet another important corporate thread stemmed from the decision that one of the first faculty hires to UCSD should be Henry Booker, a physicist engaged in the electronics of radio, communications, systems, and control. One of Booker's first hires on building the program area was Irwin Jacobs, an Associate Professor at MIT working on digital communications. Jacobs, in turn, formed Linkabit Corporation together with two UCLA faculty members, Andrew Viterbi and Leonard Kleinrock, who later became a developer of ARPANET which then became the Internet. Linkabit served the purpose of pooling the consulting of the three faculty members, moving into satellite encryption devices and television scrambling systems. More than 75 direct or indirect Linkabit spin-off companies have been identified, a rate even greater than that for Fairchild Semiconductor in Silicon Valley.²³ One of these spin-offs, founded by Jacobs, Viterbi and others, was Qualcomm, which has achieved a premier position in cellular telephone technology and is presently (2014) a \$26 billion per year corporation. All told, from 1984 to 2004 more than 200 communications companies were founded in San Diego, making it the largest concentration in the U.S..

It should be pointed out that there is a reciprocal relationship between the success of Linkabit and Qualcomm and the start of Irwin Jacobs at UCSD, in that Jacobs has donated hundreds of millions of dollars to UCSD for various purposes, and the School of Engineering at UCSD is now the Jacobs School of Engineering.

The profusion of expertise and leading-edge technology development in wireless communications in the San Diego area made UCSD a strong contender and a winner in

partnership with the University of California, Irvine, in the competition for the California Institutes on Science and Innovation in the year 2000 (see below).

Facilitating Technology Transfer

Walshok and Lee identify five catalytic factors that they believe were preconditions for the rise of high-tech entrepreneurship in the San Diego area, as follows.

- » **Regional Land-Use Decisions.** The San Diego City Council designated and donated prime ocean-side land on the Torrey Pines Mesa adjoining the existing Scripps Institution for Oceanography for high-tech development. This joined with the acquisition of a decommissioned U. S. Marines rifle range (Camp Matthews) on Torrey Pines Mesa to create the land that was provided to the University of California for its San Diego campus and to the Salk Institute, General Atomics, what became the Scripps Research Institute, and the Sanford-Burnham Institute. This foresighted and focused land-use planning contrasts with the more politically contentious and consequently piecemeal approach that has been taken in many other military base-closure situations in the United States.
- » **Building Globally Competitive Research Institutions from the Ground Up.** The Salk Institute, General Atomics, and the Scripps Research Institute were all de novo start-ups established in the 1950s and 1960s, as was the San Diego campus of UC. The Revelle plan for UCSD brought in academic superstars from the start, and those faculty and their initial hires brought entrepreneurial spirit with them, e. g., Irwin Jacobs and Ivor Royston (Hybritech).
- » **A Local Culture of Collaboration among the Academic, Public, and Private Sectors.** In its efforts to redirect and build the economy after World War II San Diego benefitted greatly from the interest and willingness of civic, corporate, and university leaders to work together synergistically as a team. This helped greatly in the land-use decisions for the Torrey Pines Mesa, in convincing the University of California to undertake elements of the very unusual Revelle plan to give the San Diego campus a running start at the highest level of quality, and in the general appeal of the area for research institutions and corporate start-up ventures.
- » **Continuous Private-Sector Commitment to Engage with UCSD on Supporting High-tech Entrepreneurship.** This was primarily carried out through UCSD CONNECT, described in the following section.
- » **A Powerful Sense of “Place” that Binds All Inhabitants.** Because of San Diego’s location in the extreme southwestern corner of the United States and its geographical separation by

mountain ranges and other features, San Diegans have historically had a sense that they are integrally linked and must work together. This gives rise to the culture of collaboration mentioned above.

UCSD CONNECT. The research institutions had important roles in drawing science-based companies to the San Diego area, although there were no programs or priorities of the university or the research institutions towards fostering industrial development until the 1980s. Instead it was more a matter of what individuals did upon their own initiatives. There was no substantial venture-capital community in San Diego until the 1990s, and until 1995 there was no technology transfer or licensing office on the UC San Diego campus. In part because of this lack, in 1985 UCSD worked with the local community to create UCSD CONNECT. CONNECT is an organization that brings together all participants in the innovation and commercialization process—scientists, corporate pioneers, venture capitalists, law firms, and providers of various other services—with the aims of creating a favorable environment for innovation and formation of new commercial ventures, as well as providing specific advice and help to persons wanting to commercialize technological developments.

In 2005 CONNECT, now with about 20 employees and an annual budget of \$3 million, was spun off from UCSD to achieve independent status. The university retains the same strong degree of involvement with it. Since its founding CONNECT has assisted more than 3000 start-up companies in attracting over \$2 billion of investment capital. CONNECT has achieved a very positive reputation and has been modeled in more than fifty regions world-wide.

As of 2013, the UCSD Technology Transfer Office, was handling 400 disclosures and obtaining about 200 new patents per year, overseeing 403 active licenses of which 215 were in California and 47 were outside the United States, and receiving income from licensing on the order of \$200 million per year.

4.2. Specific industries

4.2.1 Agriculture

California has a larger agricultural industry than any other state of the United States and in 2013 had a 14.7% share of total United States agricultural exports.²⁴ As of 2012, one-third of California's \$37.5 billion agricultural output was exported abroad.²⁵ The industry itself characteristically has very little research in the private sector, with most research being financed by federal and state governments. From the start, the University of California has had the primary agricultural research role in California. Many advances affecting California

agriculture have come from that research. A few relatively recent examples from among many are current varieties of tomatoes and strawberries, a doubling of yields of almonds (a prime export product), pest controls of many sorts, and controllable malolactic fermentation and quantitative sensory evaluation methods for wine production. Five of the 25 top grossing University of California patents are varieties of strawberries or citrus.

As in other areas, in agriculture there is a vast middle ground between the results of research and commercial application. For one hundred years the University of California has had a very extensive Cooperative Extension effort, encompassing nine Research and Extension Centers, 57 local offices throughout the state, 130 campus-based Cooperative Extension Specialists, and 200 locally based Cooperative Extension Advisors and Specialists. These experts work at the interface between researchers, on the one hand, and growers and processors, on the other hand, to help bring advances and knowledge from research into practice and to enable growers and processors to achieve economies and improved products.

As one example of the impact of Cooperative Extension, Taylor, Parker and Zilberman²⁶ examine the economic impact of the Cooperative Extension role in bringing drip irrigation into use in California. Drip techniques were introduced in 1969. By 1988 only 5% of irrigated acreage in California used drip techniques, but as of 2019 almost 40% of irrigated land used them. Improved yields, notably of tomatoes, have also come from drip irrigation. Taylor, et al., conclude that \$78 to \$283 million per year are now saved through the introduction of drip irrigation. Given the predicted effects of global warming in accentuating drought conditions in California, research into efficient use of agricultural water will become even more vital.

These efforts in agriculture bring benefits to the university as well. The agricultural community in California is extremely supportive of the university and has often been helpful to the university in connection with the annual state budget processes or other needs associated with state legislation.

4.2.2. Biotechnology³

The biotechnology industry stems heavily from California and has a uniquely close involvement with universities. The San Francisco and San Diego campuses of the University of California have both had major roles in the birth and continued development of the industry in their respective regions of the state. Stanford University, the Berkeley campus of the University of California, and the University of Southern California have had significant

³ General references for this section are Bourne and Casper.

albeit substantially lesser roles, and there were contributions as well from Caltech and other University of California campuses. The three largest clusters of the biotechnology industry in the United States, in order, are (1) the San Francisco Bay area in California, (2) the Boston area in Massachusetts, and (3) the San Diego area in California. That fact is strongly related to the nature of the universities located in those areas and activities within those universities.

In many ways the current biotechnology industry was launched through the technology for recombinant DNA that came from the collaborative research of Herbert Boyer at UCSF and Stanley Cohen at Stanford. That technology was protected jointly by Stanford and the University of California through a patent for which the application was filed in 1974 and which was issued in 1980, and which is now among the most licensed of all time^{27, 28}. By agreement of the two owning institutions, Stanford took the prime role in the patenting and licensing process. Patenting of such a fundamental biological technique was a novelty at the time and was controversial in several respects. Neils Reimers, who led the Stanford Office of Technology Licensing and had the prime role, describes the situation, the controversy, and the decisions in an on-line oral history²⁹.

The two largest actors, the University of California, San Francisco (UCSF) and the University of California, San Diego (UCSD), have had their influences in strikingly different ways.

UC San Francisco

In the mid-1960s UCSF was in a position of having little research, but a strong desire of its new leadership to build forefront research that would markedly increase the stature of the campus and integrate with clinical practice. A prime leader of the research rise of UCSF was William Rutter, who was hired in 1968 as Chair of a newly integrated Department of Biochemistry and Biophysics. Rutter had the ability to build the research faculty essentially *de novo* and was given the faculty positions to do it. Recognizing and building upon the remarkable growth that had begun in the capabilities of molecular and structural biology, he saw the promise of utilizing multi-disciplinary research and the rapidly growing techniques of molecular biology to address more complex organisms than had been the usual subject of such research to date. Working in that arena would also enable researchers to use the clinical operations of UCSF and the research interests of clinical faculty synergistically. He therefore emphasized three things in his selection of faculty and intellectual leadership—researchers who would willingly work together with other researchers with training in other disciplines or sub-disciplines, research directed toward human-scale organisms, and close integration with clinical research at UCSF.

Rutter's approach met the needs of the time and through the 1970s enabled UCSF to attain research eminence through discoveries such as recombinant DNA, oncogenes, and prions, the former accomplishment leading toward much of the new biotechnology industry and the latter two leading to Nobel Prizes. By building his research faculty in this manner Rutter leapt over the issues that other universities faced in needing to promote trans-disciplinary research, expand interests to more complex organisms, and/or integrate with clinical research.

Jong³⁰ analyzes the differences between UCSF, Berkeley and Stanford in biochemistry and molecular biology at the time of the recombinant-DNA revolution. He contrasts Rutter's approach at UCSF with (1) those at Stanford, where the disciplines remained separate in research and the interests of the principal figure, Arthur Kornberg, remained on simpler organisms, and (2) those at Berkeley which was hampered by organizational and geographic separation of researchers. Berkeley ultimately in the early 1980s had to reorganize 20 departments that were based on species and applications into three departments based upon scale so as to gain a structure that enabled forefront research and sufficient interactions and access to key instrumentation.

Commercial biotechnology in the San Francisco Bay Area started with the decision by Boyer and Robert Swanson, a young itinerant venture capitalist, to form Genentech Corporation, which in 1976 became the first substantial biotechnology company³¹. The founders of Genentech worked on an "open-science" model in which research and scientific information were shared freely, through open publication and through close interactions with researchers in universities and elsewhere. This was a natural outgrowth of the atmosphere that Rutter and co-workers had established at UCSF, and which had worked so well for advancing science there. In fact, co-founder Boyer maintained his UCSF professorship and research rather than transferring to Genentech.

Open science was the natural way of working in the universities from which the Genentech scientists had come, and it had the added advantage of keeping everyone at the forefront of knowledge without restrictions of secrecy. It leads to a constant flow of ideas and people back and forth between universities and companies. This non-secret mode of operation was acceptable and even appealing to the San Francisco Bay Area venture capitalists involved in financing the start of the industry since it was also the working mode of the Silicon Valley electronics industry, with which they were heavily involved and which was already flourishing. From a business standpoint, the idea was to gain fame and start-up investments by exhibiting scientific capabilities and promise. Thus one of the first undertakings of Genentech was to enter and win in 1978 an open competition held by the Eli Lilly pharmaceutical company for the development of human insulin, the technology for which would then be licensed to Lilly.

Universities now have policies on relations with industry, on what will and will not be done under contracts or grants from industry, and on the uses of space and resources within the university. In the early years of Genentech, experiments for company purposes including the human-insulin work for the Eli Lilly competition were performed in Boyer's UCSF laboratories. Research supporting faculty entrepreneurial ventures was performed in other UCSF laboratories too, leading to controversies within the university, introspection, and eventually policies which forbid use of space and resources for non-university purposes and which govern conflicts of interest (see below).

The success of Genentech, the research atmosphere at UCSF, and the fact that both Berkeley and Stanford biological sciences were evolving in the research direction of UCSF, resulted in a flood of other new biotechnology companies. At least 79 companies licensing UCSF technology were founded between 1976 and 2003, and UCSF faculty were directly involved in the founding of 41 of these.³² One of them, Chiron, was successfully founded by Rutter himself, along with Pablo Valenzuela of UCSF and Edward Penhoet of UC Berkeley. The open-science approach was followed by most of these other Bay Area biotech start-up companies. One reason is that many of the founders were faculty members. Also venture capitalists would often seek managers and scientists from firms already in their portfolio to staff new start-up companies. Genentech itself was a particular source. Genentech was sold in 2009 to Roche for \$46.8 billion, and Chiron was acquired by Novartis in 2006 for \$5.4 billion.

The sales of Genentech and Chiron to large, multi-national corporations (Roche and Novartis) are indicative of a common path, whereby technological innovation enters the economy through start-up industries, these start-ups succeed or fail, and the most successful start-ups are then sold to larger, existing corporations. This path is by no means universal, since there are also many companies, such as Google and Apple, that originate as start-ups around a technological concept and then grow quite large while still maintaining their independent corporate status.

UC San Diego

UCSD was also able to get a running start towards the sort of molecular and structural biology research that would launch the biotechnology industry, through the timing and nature of the founding of the campus. The plan created by Roger Revelle for the San Diego campus encompassed hiring star-quality targets of opportunity as founding faculty and then counting on them to draw other outstanding faculty and graduate students (see above). In this way, as already noted, David Bonner, an outstanding molecular biologist from Yale was hired and arrived in 1960. His vision was to build in much the same way that Rutter did at UCSF, with emphases on bringing the relevant disciplines and sub-disciplines together and

on integrating modern biology research into what would be the new research-based School of Medicine. UC San Diego actually had ten faculty positions in the School of Medicine that were controlled by the campus Biology Department. As for UCSF, modern biology at UCSD became the catalyst for launching a biotechnology hub within the region.

However, the way in which the industry came about in the La Jolla/San Diego area was substantially different from what happened in the San Francisco Bay area. The industry developed much more on a proprietary model without open science or free flow of information. That ownership approach fits the fact that most products of biotechnology require extensive up-front investment before there can be sales and revenue, mainly because of the extensive needs for clinical trials preceding governmental approval of the product by the U. S. Food and Drug Administration. In fact, this need has caused the open-science model in San Francisco Bay Area biotechnology to drift over towards the proprietary and ownership model over the years.

The creation of the biotechnology industry in the San Diego area started with the 1978 formation of Hybritech by Ivor Royston, who had that same year joined the UC San Diego School of Medicine as Assistant Professor. The subject area for Hybritech was molecular medical diagnostics, using target-specific monoclonal antibodies. This technique had also come from the university world—1975 work at Cambridge University in England by Cesar Milstein and Georges Köhler that was recognized by the Nobel Prize for Medicine in 1984. Cambridge has chosen to dedicate that invention to the public domain. Equipped with that knowledge, with cell lines from his postdoctoral work at Stanford, and with the services of his Stanford associate Howard Birndorf, Royster worked with Brook Byers of the venture-capital firm Kleiner Perkins to form Hybritech and commercialize the technology. Howard (Ted) Greene of Baxter International was hired as CEO and brought with him several other persons from Baxter. The Baxter background was useful because of Baxter's policy of moving employees among positions so as to give them diverse and comprehensive experience; thus they were versatile.

Hybritech was a large success, so much so that it was bought by Eli Lilly in 1986 for about \$413 million. That acquisition was not a happy one, since it generated strong tensions between the conservative, mid-western management of Lilly and the more free-wheeling approach of the Hybritech people in San Diego, leading to the comment of one senior Hybritech scientist that "it was like 'Animal House' meets 'The Waltons'". That result was unhappy for Lilly and for the future of Hybritech, but it greatly stimulated the biotechnology industry of the San Diego area as former Hybritech managers spread out to form other biotechnology companies, often in concert with scientists from UC San Diego or one of the other strong biotech research

institutes in La Jolla (see above) A 2002 study found over 40 biotechnology companies in San Diego with a senior manager or board advisor linked to Hybritech.

Long-Term Research Linkages

Another approach of the early days of biotechnology was for major corporations to undertake formal, long-term linkages with major universities in order to stay close to developments in molecular and structural biology. These activities were primarily with institutions in the eastern and mid-western portions of the United States, and in particular Harvard and M. I. T., although there was also a \$30 million research agreement in 1980 between Johnson & Johnson and the Scripps Clinic and Research Foundation (now Scripps Research Institute) in La Jolla directed towards synthetic vaccines. These linkages, along with the Whitehead Institute, a privately funded adjunct of MIT, are described and compared by Kenney³³. Although some relationships of this sort continue to exist (see Novartis and BP examples with UC Berkeley below), in general they have not paid off as well as the entrepreneurial efforts undertaken in the San Francisco Bay and San Diego areas in California, and large companies have now gotten into the biotechnology business more by purchase of successful start-up firms.

4.3. UC Collaborative Research Programs and Institutes

4.3.1. Industry-University Cooperative Research Program

The Industry-University Cooperative Research Program (IUCRP) of the University of California was set up at the initiative of then-new-President Richard Atkinson in 1996. It bore similarities to, and held the same name as, a program that had been established at the U. S. National Science Foundation in the 1970s during Atkinson's tenure as Deputy Director and then Director of NSF. The program received state funding through a series of budgetary initiatives put forward to the state for consideration as part of the Regents' annual state budget proposals.

IUCRP served to fund research projects for which industrial support would be paired with state support, thereby leveraging the industrial funds. Projects were selected from annual rounds of proposals through a peer-review process. Four areas were initially identified for the program—biotechnology, telecommunications, digital media, and information technology for life sciences. Over time, the program subsumed the MICRO program (described above) and grew further to add energy, health and wellness, and nanotechnology as eligible fields. At its height, IUCRP drew about \$20 million in industrial funds per year, matched with \$17 million from the State of California, which in turn were matched by \$3 million taken from

within the university's general budget. Following university policy, all intellectual property from IUCRP projects was owned by the University of California, but could be licensed to firms under standard terms. The MICRO program continued its policy of waiving UC overhead costs, but in the other areas full indirect costs were recovered.³⁵

The program was discontinued in 2008 as a budget cut during a time when state funding available to the University of California considerably declined. However, by any measure the program was a considerable success.

4.3.2. Institutes of Science and Innovation

Four major research institutes were launched by the state of California in the year 2000, as a gubernatorial initiative to support the role of innovation in spurring the California economy. The idea originated with Richard Lerner, President of the Scripps Research Institute, and John Moores, a successful San Diego entrepreneur and a new Regent of the University of California. Both were close associates of then-Governor Gray Davis. With the approval of UC President Richard Atkinson they approached the Governor, who was enthusiastic. Gray Davis had been a Regent for four years through his position as Lieutenant Governor of the state and was still a Regent as Governor; hence he knew the university well and had high regard for its research activities in support of industry. The basic concept was to create a set of research institutes that would be directed toward the future economic needs of California, and to base these institutes within the arm of the state that is designated for research—the University of California.

As originally defined, the initiative provided \$100 million for each of three institutes, spread over four years, with a requirement that the institutes raise even greater funds as a 2:1 match. Because of the nature of the state budgetary situation, the state funding was almost totally for capital expenditures, i. e., buildings. (The state capital budget is separate from the state operating budget, and at the time funds were more readily available from the capital budget.) Since the funds were from the capital budget there was a restriction that no more than 5% of the funding could be used for purposes other than design and construction. The matching funds could be from any source outside the university and could be either operating or capital funds.

The institutes were to be on University of California campuses and would carry out research in fields believed to be promising for the economic growth of the state. They were envisioned as catalytic partnerships between the university and private industry that would “increase the state's capacity for creating the new knowledge and highly skilled people that will drive

entrepreneurial business growth and expand the California economy into new industries and markets—and bring the benefits of innovation more quickly into the lives of people everywhere.”³⁶ The four institutes were subsequently renamed the Governor Gray Davis Institutes for Science and Innovation in recognition of Davis’s key role as initiator.

Through the Office of the President and in consultation with the campuses and Academic Senate, the university designed and administered an internal competition, encouraging multi-disciplinary approaches and synergistic involvement of multiple campuses. Topics for the institutes were not specified; instead, selection among proposed topics was a part of the competition. Two rounds of judging were used, based upon peer review, with the first round reducing the field to a smaller number of finalists. Final proposals were subjected to extensive peer review and were judged by a multi-dimensional, highly distinguished panel, external to the university. The use of competition was essential for honing the quality of the proposals, since the proposers put great effort into making the proposals convincing and attractive in the competition. Because of the strength of the ultimate proposals, a fourth institute was also funded by the state.

The four institutes and the web sites for each are:

- » California Institute for Telecommunications and Information Technology [Cal-(IT)²] – San Diego and Irvine campuses (<http://www.calit2.net/>)
- » California Institute for Quantitative Biomedical Research [QB3] – San Francisco, Berkeley and Santa Cruz campuses (<http://qb3.org/>)
- » California Nanosystems Institute [CNSI] – Los Angeles and Santa Barbara Campuses (<http://www1.cnsi.ucla.edu/>)
- » Center for Information Technology Research in the Interest of Society [CITRIS] – Berkeley, Davis, Merced and Santa Cruz campuses (<http://citriss-uc.org/>)

A PowerPoint presentation³⁷ and two independent case studies^{38, 39} describe the California Institute for Telecommunications and Information Technology in more detail.

The needed match (\$800 million) was a very large sum, yet it was raised and exceeded with the total match being more than \$1 billion. The acquisition of these matching funds was facilitated by having the competition, since it was clear for donors that the match would be required to bring the particular institute into existence. The fact that the subject matters of the institutes were not specified before the competition provided yet another incentive for

corporations to provide funding, since the institute in question would have to be selected in order for there to be an institute matching the particular interests of a corporation. The matching funds were raised primarily from industry for three of the institutes and primarily as federal government project funds for the fourth (CNSI), reflecting the fact that there was at the time no cohesive substantial nanoscale systems industry, while there were existing industries for the other three areas.

The state funding was almost totally for capital expenditures and thus has gone primarily into building the campus facilities that bring the researchers of an institute together, while the researchers must still propose and obtain extramural funding for projects themselves. Obtaining core operating funds for administering the institutes was a problem. Portions of the allowable 5% of the state capital funds were a start, but now another \$20 million of operating funds annually are part of the state operating budget for the University of California.

Now in their fourteenth year of existence, the four institutes have become an important part of the University of California's research and technology transfer portfolio. All of them generate substantial extramural grant funding. QB3, for example, reports that it generated 57 patents and 44 new partnerships, and raised some 20.5 million for research, the vast majority from the private sector, in 2013 alone. QB3 also states that it has generated a total of 45 bioscience start-ups. It also operates Mission Bay Capital, an \$11.5M seed-stage venture capital fund designed to support UC startups. CITRIS reports spawning 51 start-up companies since the institute was established, and with an annual investment for operating funds of \$4-5M from the University of California it leverages \$80-\$95M in outside research funding each year. The various institutes are also creating collaborations with HT business and university researchers internationally. A recent UC internal review found that all four institutes leverage external resources and have a significant impact on California's economy. But the review did have concerns that the goal of engaging faculty throughout the UC system was not as robust as first planned.

CITRIS produced an economic impact report in 2014-15, available at http://citris-uc.org/wp-content/uploads/2014/10/2014-2015_CITRISImpactReport.pdf. Incubators have been key parts of QB3 at both the San Francisco and Berkeley campuses, with an impressive list

of start-ups resident or previously resident at several different incubator sites of different natures and scales (<http://qb3.org/startups/incubators>).

4.4. Large relationships with particular companies

4.4.1. Novartis Agreement with UC Berkeley

In 1998, a controversial research agreement was made between the Berkeley campus of the University of California and Novartis, a large Swiss pharmaceutical and biotechnology company. As was noted above, this arrangement is one of many made between large biotechnology/pharmaceutical companies and major universities over the years, reflecting the very close relationship between academic research and commercial innovation within that field. However, it was unique in its design and in that it made such a sizeable arrangement between a commercial firm and a public university. The arrangement was controversial, has been thoroughly analyzed by various parties, is relatively well documented in public media, and is therefore worthy of consideration as a learning experience. A useful and insightful analysis of the drivers for the arrangement and the benefits and concerns has been made by University of California, Berkeley, Political Science Professor Todd LaPorte⁴⁰.

The agreement followed a formal, two-year process in which the College of Natural Resources of the Berkeley campus solicited proposals from six major corporations, with four responding. By the terms of the agreement, Novartis contributed \$5 million per year for five years, or \$25 million total, for support of research in the Department of Plant and Microbial Biology. This was about 30% of the total extramurally funded research budget of the department. The portion of the funds devoted to overhead was 33%, covering renovations, support of the general graduate program, and general campus overhead.

Another very important component was access by Berkeley researchers on a confidential basis to the Novartis agricultural genomic database, coupled with \$3 million for a Novartis facility near the campus with workstations through which that database could be accessed and advisory Novartis employees could help with access. The value of this aspect of the arrangement lay in the fact that substantial genomic data are confidential to large companies, thereby placing the academic sector in a situation where they carry out research without full access to the available knowledge base.

In return, Novartis received first rights to license a percentage of inventions from research in the department, whether or not supported with actual Novartis funds. That percentage was the ratio of the Novartis funding to the total departmental extramural research support,

cited as a method of calculation recommended by National Institutes of Health guidelines for arrangements involving both NIH and private support. Novartis also received the conventional thirty-day opportunity to review potential publications for patentable items, and an additional sixty days if the decision was made to patent. As noted in the section of this report on Policies, such a component of industry-university agreements is not unusual.

The project was overseen by a six-member Advisory Committee with three members from the campus Vice Chancellor for Research, Dean of the College of Natural Resources and a non-involved faculty member), and three members from Novartis. There was also a five-member Research Committee, three of whom were from the campus, to award actual grants.

There were a number of concerns expressed at the time and throughout the term of the agreement. These are summarized by LaPorte⁴¹. Many of the concerns dealt with academic freedom—the right of faculty to choose and pursue research as they see fit. Those concerns eventually formed the lead item for a highly critical story in the *Atlantic Monthly*.⁴² As the controversy continued, there was an internal review commissioned by the Berkeley campus, followed by an external review undertaken at the behest of the Academic Senate with the concurrence of the administration. That review⁴³, subsequently published as a book⁴⁴, concluded that academic freedom and the academic conduct of the department had not been seriously compromised. The reviewers also made a number of recommendations, one of which was that the university should avoid industry agreements that involve complete academic units or comparable large groups of researchers.

During the five-year period of the agreement, there was a major restructuring of Novartis that eliminated the unit that had made the agreement. Hence renewal of the agreement became moot.

In addition to the academic-freedom issue, which was probably well enough addressed with regard to the specifics of research, the essential issue surrounding this venture was the extent to which a public institution, and an entire department within that institution, can pair themselves with a private corporation. Can academic objectivity be maintained amid such a presence? And is it appropriate for a public institution that derives substantial taxpayer support, including corporation taxes, to match itself so visibly with one corporation? Conversely, it can be argued that a large amount of the total revenue of public universities (on order of 77% for the University of California) comes from sources other than the state budget and student fees, and that corporations within the state do receive benefits for their taxes, even when such arrangements are made with a single corporation. A final substantive issue

is how confidential data can be used in publishable research while fulfilling simultaneously the requirements of the openness of science and the ability for others to reproduce results.

4.4.2. BP: Energy Biosciences Institute

In 2006, the multi-national energy firm BP announced an intention to create an Energy Biosciences Institute (EBI) in conjunction with a major university. After preliminary explorations, BP invited five universities to form teams to submit proposals to join with BP in an Energy Biosciences Institute, which would be funded by \$500 million spread over ten years. This institute would bring BP researchers together with university researchers and would emphasize innovative means of creating and producing fuels from biological sources. In early 2007, the competition was won by a team headed by the University of California, Berkeley (UCB) that included the Lawrence Berkeley National Laboratory (LBNL) and the University of Illinois at Urbana-Champaign (UIUC). BP spokespersons indicated that important factors in the selection of the Berkeley-led team were the large and diverse array of distinguished researchers, the tradition of technological innovation and entrepreneurship in the San Francisco Bay Area, and the history of successful, large, interdisciplinary science at LBNL.

The existence of QB3, one of the Governor Gray Davis Institutes, was important to the ability of the team to win the competition, since the team was already established and the final proposal had to be written in what was a short time interval of 60 days. The attention given at the time to the UC Berkeley Artemisinin Project and Amyris Biotechnologies⁴⁵, for which the CEO was a former BP employee, may have been helpful as well. It is worth noting that LBNL is a laboratory of the U. S. Department of Energy, managed under contract by the University of California system. The inclusion of LBNL thereby brings the federal government into the arrangement.

The full agreement between BP and the Regents of the University of California is posted online.⁴⁶ Elements of the arrangement and governance include the following.

- » A new building would be built on the Berkeley campus land to house the Energy Biosciences Institute. Construction of the building was funded largely by state funds along with some private gifts. The building belongs to UC and during the EBI project is a form of state and university cost-matching to the project. There is a similar space provision for the portion of the project at the University of Illinois.

- » The building space is divided into open and proprietary research portions, with up to fifty BP researchers who do BP proprietary research accommodated in the building along with UC and LBNL scientists.
- » Up to 30% of the total funding from BP is spent on the BP scientists.
- » \$100 million of the total funding is used at UIUC to fund research on crops for ethanol and other biofuels.
- » The Director is both a UCB faculty member and a Faculty Senior Scientist at LBNL. An Associate Director is a BP employee, and a Deputy Director is a UIUC faculty member.
- » A Governing Board is composed of eight senior persons from the various participating organizations (two from BP, one each from UCB, LBNL and UIUC, and the Director, Associate Director and Deputy Director of the Institute).
- » There are twenty-five themed research teams, seven of which are located at UIUC.
- » Full institutional overhead is paid to UCB and UIUC on all open research funded by BP, with 75% of these indirect costs returned by those institutions to the Energy Biosciences Institute for administrative purposes.
- » Intellectual property is owned by the participating institution that generates it, with BP having the right to license, royalty-free and non-exclusively, inventions made by researchers supported with BP money. Joint inventions have joint ownership.
- » BP as well has the right to take royalty-bearing exclusive licenses in a time-limited fashion.

An apparent motive for BP in setting up such an institute was close access to leading-edge research in an area that was seen as vital to the future of the corporation, with a high premium placed on intimate day-to-day interactions of BP researchers with those from the other institutions.

There were a number of concerns to be dealt with in the relationship. One was how to handle proprietary research that is being carried out in close proximity with academic and national-laboratory researchers. The presence of proprietary corporate research on a university campus is not unprecedented, however. A second concern, familiar from the Novartis agreement described above, is the preferential position given by a public university to a single private corporation with regard to the research of a large number of distinguished

faculty members. A third concern is the need to ensure academic freedom in the choice and conduct of research. Recognizing such concerns, the Berkeley campus developed both the proposal and the ultimate agreement in close consultation with the leadership of the faculty Academic Senate. Both the administration and the Academic Senate were usefully informed by the experience gained in the earlier Novartis project, which had been useful as a learning experience.

As is also noted in the section below on Policies, The Academic Senate chartered a special committee to develop a guidance document⁴⁷ on university-industry relationships, which was of considerable use to the administration in the negotiations with BP and also provides guidelines for future relationships.

The interests, structure and management staffing of corporations change over time, as does the business environment. Just as the Novartis-Berkeley relationship was not renewed, there is also the possibility or even probability that the arrangement with BP for the Energy Biosciences Institute will not be continued beyond the initial ten-year term. Already, BP has exercised an option in the agreement to reduce the funding level for the final three years of the agreement. This is most probably associated with the world-wide drop in the price of petroleum due to the onset of “fracking” and other factors, which reduces the immediate incentive toward biofuels, and also relates to a change in the financial situation for BP resulting from the Gulf of Mexico oil spill. It is important that universities recognize that industrial needs can change rapidly and that large-scale industrial partnerships should be viewed as a one-term package when they are established, with renewal or extension being risky.

5. University of California Policies and Administrative Structures – Incentives and Rules of Engagement

The University of California, a multi-campus, one-university system with ten campuses, provides an example of an effective management organization that includes a governing board (The Board of Regents), a university-wide President, executive leaders on each campus (Chancellors) and a strong tradition of shared governance. UC's particular legal status as a semi-autonomous from state and federal government control has allowed the institution to develop strategies and processes for engaging with the private sector, and for allowing faculty and university research staff to create and become engaged enterprises.

5.1. University Governance, Management and a Tradition of Shared Governance

The Board of Regents

The Board of Regents is, in effect, the corporation that administers the public trust known as the University of California. The California State Constitution grants to The Regents full powers of organization and government, subject only to such legislative control as may be necessary to ensure compliance with the terms of the University's endowments and the security of its funds. The Regents are vested with broad powers, including the power to delegate authority or functions to its own committees or to the faculty or administration of the University. The Regents have adopted Bylaws and Standing Orders which establish the basic policies of the corporation and the University.

Among the important functions of the Board of Regents is the review and approval of Presidential recommendations on such matters as University and campus academic plans, proposals to establish or disestablish schools, colleges, and Organized Research Units, the University's operating and capital improvements budgets and related enrollment plans, and establishment of certain student fees and tuition (only for non-resident students).

The Board of Regents consists of twenty-six members. Seven of them are ex officio members (the Governor and Lieutenant Governor of the State, the Speaker of the State Assembly, the State Superintendent of Public Instruction, the President and Vice President of the Alumni Association of the University, and the President of the University). The Governor, with the

approval of the State Senate, appoints eighteen other Regents who serve twelve-year terms. The Board appoints a Student Regent who serves for one year. The Academic Senate has chosen to be represented on the Board by the Chair and Vice Chair of the Academic Council who sit with the Board and participate in its discussions but do not vote.

UCwide President and Campus Chancellors

Appointed by and directly responsible to The Regents, the President is the University's chief executive. All other officers of the University, except the Principal Officers of The Regents, are responsible to the President directly or through designated channels. The President has full authority and responsibility over the administration of all affairs and operations of the University, excluding those which are the responsibility of the Principal Officers of The Regents. The President may delegate Presidential duties except for services as an ex officio Regent.

Among the President's most notable functions are consultations with the Chancellors and Academic Senate regarding the University's educational and research policies, recommendations to The Regents concerning the academic plans of the University and the campuses, annual presentation to The Regents of a single operating budget and a capital budget for the entire University, and administration of the Office of the President.

Chancellors, to whom broad powers are delegated, are the executive heads of all campus activities and are responsible for the organization and operation of their respective campuses, including academic, student, staff, and business affairs; and for discipline within them. Decisions made by Chancellors within the provisions of budget allocations for their campuses and the provisions of policies established by The Regents or the President are final. Each Chancellor is assisted by various administrative officers -- Vice Chancellors, Deans and Provosts, Department Chairs, and Directors of Organized Research Units.

The Academic Senate

A tradition of shared governance and development of specific policies on the respective role of the Board of Regents, the university's academic administrators and the faculty is one reason for UC status as one of the great university systems in the world. It includes delegated authority by the university's Board of Regents to its Academic Senate—the representative body of the faculty—in six areas of university management:

- » The authorities to determine the conditions for admission, to establish conditions for degrees, and to supervise courses and curricula.

- » Responsibility to monitor the quality of the educational programs that students must complete to earn their degrees and to maintain the quality of the components of those programs.
- » The authority to determine the membership of the faculty and the process for their advancement, as well as the organization of the Academic Senate.
- » The right to review continually the quality of the faculty who teach courses, develop the educational program, and conduct research at the University of California. Faculty are evaluated under a uniform set of criteria that are intended to maintain a level of excellence on each UC campus. In order to ensure the quality of the faculty, the Senate also monitors faculty welfare issues that affect recruitment and retention of high-quality faculty.
- » Authority to advise on the budget of the campuses. The University empowers the Senate to advocate, but not decide on, budget allocations that channel resources into activities that enhance the academic programs of the university.
- » The authority to conduct hearings in disciplinary charges against faculty that enforce the Faculty Code of Conduct and other policies of the university related to faculty performance in carrying out the university responsibilities.

Yet, it is also important to note that statements on the relative authority for faculty and administrators are not sufficient unto themselves for effective shared governance. The best universities have an academic community with a strong sense of their shared burden in maintaining and improving the effectiveness and quality of their institutions, and mutual respect among administrators and faculty.

5.2. Promotion and Advancement of Faculty

Faculty members at the University of California are not in government civil-service positions. They fall under a special set of academic personnel provisions for the university and, through the constitutional autonomy of the university, come under the exclusive purview of the Regents of the university. By an agreement between the Regents and the Academic Senate of the university dating back to 1920 the Senate has the primary role in review and evaluation of faculty and in recommending promotions and advancement for them, although the actual decisions are made by the campus administration, typically the Provost and/or Chancellor. All salary increases beyond simple cost-of-living increases come about through the process of review and evaluation that is described here.

The university has a unique system for continual evaluation of faculty and determination of promotions and advancements in salary. There is a published salary scale⁴⁸, consisting of the three traditional ranks (Assistant Professor, Associate Professor, and Professor) and steps within those ranks. For initial appointment, promotion from rank to rank, and even for increases from step to step within rank a faculty member is reviewed by peers through an elaborate process in which no one person or no few people have controlling roles. Thus the process is designed to be as knowledgeable, objective, and fair as possible. The various aspects of faculty personnel policy, as well as the review process and criteria themselves, are included in the Academic Personnel Manual⁴⁹, which is available on-line.

As is shown by the referenced salary scale, there are “normal” periods at step for the various ranks—two years for Assistant Professors and three years for higher ranks. Depending upon performance advancements may occur at either faster or slower rates than normal, however. Above Professor, Step IV there is no normal period, meaning that the intervals will normally be longer and that some faculty members will not rise above that step. There are ten steps of Professor and also the possibility of a faculty member eventually going above scale. Special, more intensive reviews are made for promotions, for advancement from Step V to Step VI Professor, and for advancement to Professor above scale.

The criteria for review fall under the categories of (1) teaching, (2) research and other creative work, (3) professional activity, and (4) University and public service. The rankings among these factors are not stated and can vary within reason, but all four elements are sought, with the third applying only to faculty within the professions. Approximate weights are 40% for #1, 40% for #2, and 20% for the combination of #3 and #4. What is sought is described in some detail in Section 210.1-d of the University of California Academic Personnel Manual,⁵⁰ which is reproduced as Appendix 3. Notice that successful entrepreneurship, consulting or technology transfer enters only through the creativity and recognition of research, creative work, and professional activity.

A review begins with the faculty member assembling material listing his or her teaching, publications, and service, as well as describing the design of his or her research and providing other supporting information, such course syllabi. For the special advancements referenced above, the department Chair also obtains letters of evaluation from experts in the candidate’s field, half of whom are chosen from a list supplied by the candidate and half based upon the Chair’s own knowledge. For promotions, a meeting is held of faculty members of equivalent rank or higher to discuss the case with a resultant numerical yes-no vote of the faculty involved. The Department Chair reviews the material, includes teaching evaluations that are regularly obtained by the department from the students in courses, and provides a narrative evaluation and recommendation. The file is then forwarded to the Dean, who also reviews

the material and provides a recommendation with supporting rationale. The Dean forwards the file to the Provost or an Associate Provost for Academic Affairs, who immediately refers the file to the Committee on Academic Personnel⁵¹ of the Academic Senate. That committee is composed typically of nine members, chosen by the Committee on Committees of the divisional Academic Senate for that campus, reflecting a variety of disciplines. For promotions in rank the Committee on Academic Personnel recommends faculty members for an *ad-hoc* committee, the members of which are selected by the Provost from among the names provided and to whom the case is referred for another in-depth review, resulting in a confidential report.

Equipped with all this information, the Committee on Academic Personnel carries out its own evaluation and makes a recommendation to the Provost with supporting rationale. The Provost receives this evaluation, makes an independent assessment, and determines whether to accept the advice of the Committee on Academic Personnel. In some cases the Provost may return the file to the Committee on Academic Personnel with questions or with the suggestion that the facts support a different recommendation. In such cases the Committee on Academic Personnel reassesses the case and makes what may be a revised recommendation, but is usually the same recommendation. If the Provost still contemplates a different action, he or she meets with the Committee on Academic Personnel, and the Committee then responds again as to whether they change their recommendation. Ultimately in only perhaps two or three cases per year the Provost and Chancellor go against the recommendation of the Committee on Academic Personnel.

This system, although complex and time-consuming, is usually credited with being the main single reason for the academic quality and prestige of the University of California campuses. In a world where there is much concern about the lack of post-tenure review of faculty members in universities, this system stands in stark contrast, since a faculty member is seriously reviewed about every three years throughout his or her academic career. Even the receipt of a Nobel Prize does not remove a faculty member from this requirement.

There is also a requirement that a faculty member must be reviewed at least every five years even if the faculty member does not request the review. These mandatory reviews can feed into an established procedure for considering the termination of tenured faculty members for lack of satisfactory performance. This procedure is described in Section APM-075⁵² of the Academic Personnel Manual.

This system for faculty review and advancement has been in place now for almost 100 years. The one departure in recent years from the previous norm has been frequent use of off-scale salaries (higher than the salary specified for a given step). These have been necessitated by

market competition for faculty members and have not been addressed by simply elevating the salaries on the scale because both availability of budget and personnel policy have made it undesirable to provide across-the-board increases. These off-scale salaries are awarded through the same review and evaluation process.

5.3. Institutional Oversight: Organization and Mechanisms

As noted previously, the 1980 Bayh-Dole Act established that ownership of intellectual property stemming from government-sponsored research lies with the institution performing the research. This legislation was passed in recognition of the fact that protective ownership was necessary in most cases for actual commercial development of inventions. Before 1980, unless the university had an Institutional Patent Agreement with the specific federal agency, intellectual property from government-sponsored research had been placed in the public domain, meaning that anyone could use the invention without payment of licensing fees.

By similar logic, the university asserts ownership of intellectual property stemming from industrially sponsored research, usually with understandings that a corporate sponsor funding the full cost of research will have first right of refusal to license intellectual property stemming from that research on an exclusive basis under standard commercial licensing terms. Occasionally the university has instead given a royalty-free, non-exclusive license as an exception to policy.

The University of California historically had separate operations and mechanisms for technology transfer (patents, licensing, etc.) on the one hand and oversight of research liaisons with industry on the other hand. The Berkeley campus and some other campuses of the University of California have now moved to structures that integrate these two operations. The reason for this is to combine the positive aspects of facilitating relationships with what are often the negative perceptual aspects of negotiating over licensing arrangements.

Also historically, the university initially handled licensing of technology centrally at the university-wide level so as to assure consistency of approach and policy interpretation. Starting in the early 1990s, the university moved to decentralize licensing operations to the individual campuses, so as to put that function closer to the faculty inventors. Legal interpretation and approval is still handled at the university-wide level so as to assure consistency. The need to consult with the university-wide lawyers can cause some undesirable time lags in negotiations with companies.

5.3.1. Institutional Policies

Many policies are determined for the entire ten-campus university, while other implementing policies are campus-specific. There are two different categories of policies—those for the relationship of the University of California as an institution with industry, and those governing relationships with companies by faculty and other researchers, individually or as groups.

Policies for Institutional Interactions

For years institutional interactions with specific companies were evaluated on an *ad-hoc* basis, following what seemed at the time to make good academic sense. An example was the aforementioned relationship between the Berkeley Department of Plant and Microbial Biology and Novartis Corporation. As described above, when the consortium headed by the Berkeley campus became the winner of a world-wide competition for the establishment of a large, BP-funded Energy Biosciences Institute in 2004 and before the actual contractual negotiation with BP began, the campus administration worked with the Academic Senate to codify policy ground rules for large-scale campus interactions with industry. The report resulting from that process (http://academic-senate.berkeley.edu/sites/default/files/page/tf_uip_final_report.pdf) was highly useful in setting boundaries for the contract negotiations with BP and in established a relationship that would work well for both parties. That document now exists as guidance for the future large-scale interactions with industrial companies as well.as well.

Incentives for Faculty Interactions with Industry and Entrepreneurial Efforts

No salary or released-time incentives are provided to encourage faculty interactions with industry. However, faculty are provided up to 39 days per academic year for outside activities, compensated or not, unpaid leaves upon request and approval for activities relating to their university expertise, incubator facilities for trying out commercialization ideas based upon UC-owned research, and advisory services and programs relating to entrepreneurship. See below for further information on all of these. The President of UC has recently created a position of Special Advisor to the President on Innovation and Entrepreneurship.

Policies for Faculty Interactions with Industry

The most common form of faculty interaction with industry is private consulting. The Berkeley campus statement of policy for faculty consulting⁵³ is extensive and includes limits on consulting time (39 days per nine-month academic year), intellectual property aspects including the opportunity for the university to review invention disclosures to ascertain

ownership, the requirement of annual reporting, review for conflicts of interest, and counsel for faculty on what should and should not be in consulting agreements. Consulting is further restricted for certain health-sciences (medical, etc.) faculty whose clinical activities are included in a comprehensive compensation plan that includes practice (http://ucop.edu/academic-personnel-programs/_files/apm/apm-670.pdf) and for those faculty members in agricultural areas whose appointments involve advisory work through Cooperative Extension (see <http://www.ucop.edu/academic-personnel-programs/programs-and-initiatives/faculty-resources-advancement/faculty-handbook-sections/cooperative-extension.html> and http://ucop.edu/academic-personnel-programs/_files/apm/apm-334.pdf)

Several general concepts have driven the generation of University of California policies for interaction with industry.

- » In line with the nature of a public university and to avoid suspicion, the university emphasizes transparency and strong rules on full disclosure. Potential conflicts of interest must be revealed and analyzed. Judgement of potential conflicts are typically reviewed by committees of faculty peers from a variety of disciplines.
- » Economic and societal benefits are major outgrowths of a strong public research university. Hence public service is encouraged as is consulting, within appropriate limits. Leaves by faculty for business start-ups are also encouraged, but all these activities are subject to limits. In the case of leaves without pay, it is expected that well justified leaves for up to two years will be approved, but that leaves longer than two years will not be approved
- » Time paid for by the university should be used for purposes that serve the university and a faculty member's roles within it. Leaves without pay can be considered when faculty are engaged in non-university matters, but should be limited in duration as described in the preceding bullet.
- » The university is open and, in general, does not engage in secret or confidential research. Both the University of California and its Lawrence Berkeley National Laboratory have no classified (i. e., military secret) research.
- » There should be clear rules about graduate student involvement, which ensure that students can interact freely with faculty and peers, without information being withheld from them.

A list of both university-wide (“UCOP”) and campus policies governing university-industry relations for faculty members on the Berkeley campus is given at <http://vcresearch.berkeley.edu/universityindustry-relations/uc-policies-governing-universityindustry-relations>. Brief descriptions of the most pertinent specific policies follow.

Disclosures and Patents.

All employees are required to sign and adhere to the UC patent policy, which is given at <http://policy.ucop.edu/doc/2500493/PatentPolicy>. It acknowledges that inventions made under university employment belong to the university, and indicates that the employee will assist fully with the university's decision to pursue patent protection. The decision as to whether or not to patent is made by the university. In some cases the university will release patenting rights to the inventor upon request following a decision by the university that it does not choose to pursue patent coverage.

Copyright.

Following the tradition that scholars own their own writings or other output subject to copyright, the University of California copyright policy gives ownership to an academic employee producing a book, paper, work of art, etc. For externally sponsored work the university may take title, but only for reports or other work stemming directly from the sponsored project and still not for resultant books or journal articles. The university may give its ownership to a sponsoring firm in an agreement. (<http://policy.ucop.edu/doc/2100003/CopyrightOwnership>).

Conflict of Interest.

Conflict of interest falls under an array of policies (<http://researchcoi.berkeley.edu/sitemap.html>) reflecting university-wide and campus policies, as well as California state law. Any application for approval of a research proposal to an entity in which a Principal Investigator has a financial interest requires submitting a California state form (<http://www.fppc.ca.gov/forms/700-14-15/Form700-14-15.pdf>) to be reviewed by a campus faculty Conflict of Interest Committee. The determination of a conflict of interest does not doom a research project, since there are mechanisms for managing conflicts of interest, see, e. g., <http://researchcoi.berkeley.edu/faq.html#4>.

Conflict of Commitment.

Policies covering conflict of commitment and faculty leaves are given in Section 025 of the UC Academic Personnel Manual (http://ucop.edu/academic-personnel-programs/_files/apm/apm-025-07-01.pdf). Faculty members are limited to 39 days of outside activities during the academic year (an average of one day per week), and are required to request leave without pay when exceeding this limit or when the faculty member will be away from his or her UC campus for more than seven consecutive days. There are no considerations or limits in this policy concerning the amount of compensation that faculty members can receive from external activities. Faculty members cannot, in general, hold an executive or managerial activity for a private firm. Leaves of absence without pay may be obtained for purposes such as start-up of a company, and are usually granted for the first and even a second year, but

are normally not approved beyond the second year. The faculty member would then have to make a basic career decision—company or university.

Students and the Conduct of Research.

The Administration and the Academic Senate are responsible for assuring that an open environment exists throughout the University. It is the responsibility of the campus administration, departmental faculty, and the Academic Senate to establish appropriate norms and to assure the existence of an open environment. The following passage is in the University of California Guidelines on University-Industry Relations (<http://www.ucop.edu/ott/genresources/unindrel.html>).

All University research, including research sponsored by industry, is governed by the tradition of the free exchange of ideas and timely dissemination of research results. The University is committed to an open teaching and research environment in which ideas can be exchanged freely among faculty and students in the classroom, in the laboratory, at informal meetings, and elsewhere in the University. Such an environment contributes to the progress of teaching and research in all disciplines.

Reasonable steps should be taken to insure that commercial pressures do not impede faculty communication with their colleagues or their students about the progress of their research or their findings. Indicators of possible problems include the disruption of the informal exchange of research findings and products, the lessening of collegiality, and the rise of competitive and adversarial relations among faculty.

Use of University Resources

University laboratories, equipment, personnel, and resources cannot be used for outside purposes unless there is an agreement with the university (http://www.ucop.edu/academic-personnel/_files/apm/apm-020.pdf). Faculty members can, in general use university offices, computers and telephones for consulting work.

Publication

It is expected that research results will be published in full without limitations. A sponsor cannot specify that any methodology or results cannot be published, except for the restrictions regarding confidential items described in the next paragraph. A publication delay of up to 60 days is acceptable so that a sponsor may review publications and offer comments or suggestions and/or determine that proprietary data are not inadvertently disclosed. In either case, the final decision on content must rest with the author. A delay of up to 90 days can be allowed so that the University and/or the sponsor may screen proposed publications for possibly patentable ideas. If both 90- and 60-day delays are applicable, the total period of

delay should not exceed 90 days. (<http://vcresearch.berkeley.edu/research-policies/policy-guidelines-governing-openness-and-freedom-to-publish>).

Confidential Materials and Information.

Access to and/or use of a sponsor's proprietary data or materials are accepted only if regulations regarding access, use, and protection of such data or materials do not restrict the full dissemination of scholarly findings made under the grant or contract or put the University in a position of assuming financial liability. (<http://vcresearch.berkeley.edu/research-policies/policy-guidelines-governing-openness-and-freedom-to-publish>).

Licensing

University of California licensing guidelines for intellectual property are given at http://www.ucop.edu/research-policy-analysis-coordination/_files/licensing_guidelines_2012.pdf. These conform to generally accepted practice and are intended to keep all licensing and all campus on the same basis of guidelines. In some cases, and again subject to limits, the University of California will take equity in a firm, particularly a start-up firm, instead of a licensing fee. The policy governing such situations is given at <http://www.ucop.edu/ott/genresources/equi-pol.html> and is designed to avoid issues of favoritism towards financial gain of a faculty member and any influence of a faculty inventor on the university's decision and to reduce the amount of risk assumed by the university.

Oversight of Industrial Partnerships

The University of California develops policies through highly consultative and interactive processes involving the Academic Senate and groups of persons with like administrative functions on the different campuses, coordinated through the administrative chain of leadership. University-wide policies are incorporated into the Academic Personnel Manual (<http://ucop.edu/academic-personnel-programs/academic-personnel-policy/index.html>) or other readily available compendia, as appropriate.

Enforcement is achieved through mandatory disclosure policies, including the use of an annual "supplement to the bio-bibliography", which is a comprehensive report on activities that each faculty member must make each year (<http://apo.chance.berkeley.edu/forms/biobib.doc>) and disclosures of any potential conflicts of interest (<http://researchcoi.berkeley.edu/>; <http://researchcoi.berkeley.edu/700U.pdf>) at the time grant proposals are submitted for university approval before being sent to the potential sponsor. Judgements on potential conflict situations thereby disclosed are made by specially constituted faculty committees, deans and department chairs, as appropriate to the situation. These committees can be either standing or *ad-hoc*.

Tech Transfer Support

Berkeley has a number of units to assist in the review and negotiation process with the private sector, non-profits and governmental entities, and to maintain and monitor partnerships, including the following.

- » The Office of Intellectual Property and Industry Research Alliances (IPIRA) provides leadership for the Berkeley campus for the full range of research and technology relationships with industry. IPIRA's mission is to:
 - › Recognize, establish, nurture and maintain multifaceted relationships with companies and foundations,
 - › Enhance the Berkeley campus research enterprise through Intellectual Property (IP) management,
 - › Facilitate and strengthen new types of agreements to reflect changing relationships with foundations and industry, and
 - › Support economic development through technology and knowledge transfer including entrepreneurship.

- » Within IPIRA, the Office of Technology Licensing (OTL) works with campus inventors to facilitate transfers of technologies created at UC Berkeley to the commercial sector for public use and benefit. The scope of OTL activities includes: evaluating the commercial potential of new technologies, determining patentability, prosecuting patents, registering copyrights, marketing and licensing patents, tangible material, and software, negotiating license agreements, and receiving and distributing royalties and other income to the inventors, the UC Berkeley campus and its departments.

- » Also within IPIRA, the Industry Alliances Office (IAO) works with UC Berkeley employees and companies to enable innovative research relationships with offices across campus to streamline research agreement management and negotiation. The IAO is responsible for negotiating all research contracts dealing with private industry, including: sponsored research agreements, membership agreements, material transfer agreements, data/software transfer agreements, and collaboration agreements.

5.3.2. Mechanisms for Assisting Commercialization of Research and Corporate Start-ups

As a public research university the University of California encourages utilization of its research by industries, both in California and worldwide. Licensing and technology transfer policies are designed to maximize commercial and societal uses of research results, rather than maximizing royalty income *per se*. However, University of California licensing income is substantial. For all ten campuses, ordinary royalty and licensing fee income averaged about \$100 million for fiscal years 2009 through 2013.

The Berkeley campus has a number of programs that are designed to assist faculty members and students in bringing their accomplishments and ideas along to commercial ventures. Among these are the following.

- » SkyDeck (<http://skydeck.berkeley.edu/management/>) SkyDeck is an accelerator program, designed to help faculty and student entrepreneurs move ideas into commercialization effectively and efficiently. A team of consultants is available to advise and help. Elements of the accelerator program include the Product Story, Market Traction, Business Model, Team Development, and a Funding Plan.
- » Coleman Fung Institute for Engineering Leadership (<http://funginstitute.berkeley.edu/>) The Fung Institute is an arm of the College of Engineering that provides full- and part-time Masters programs and continuing education in engineering as linked to entrepreneurship and the business world. The aim is to transform engineers and scientists into leaders who can take risks and develop technical, social, and economic innovations.
 - » Lester Center (<http://entrepreneurship.berkeley.edu/>) The Lester Center serves as a hub for education and research relating to entrepreneurship in the business world. It is a component of the Haas School of Business. This very month the activities of the Lester Center have been expanded into a Berkeley-Hass Entrepreneurship Program for enriching the overall student experience at the Berkeley Hass School of Business (<http://entrepreneurship.berkeley.edu/>).
- » Product Development Program (<http://chemistry.berkeley.edu/grad/cbe/pdp>) The Product Development Program is a Masters degree program provided by the Department of Chemical and Biomolecular Engineering within the College of Chemistry. Students gain knowledge and field experience in the complex process of transforming technical innovations into commercially successful products.
- » Bakar Fellows Program (<http://vcresearch.berkeley.edu/bakarfellows/about>) Bakar Fellows are selected early-career faculty members whose work shows commercial promise in the fields of Engineering, Computer Science, Chemistry, Biological Sciences, Physical Sciences, and in multidisciplinary work in these areas. The Fellows receive discretionary

research support of \$75,000 per year for up to five years and participate in the network of other activities on campus relating to entrepreneurship.

- » The Foundry@CITRIS (<http://foundry.citris-uc.org/>) The Foundry@CITRIS is a technology incubator based at the Center for Information Technology Research in the Interest of Society (one of the Governor Gray Davis Institutes) to help entrepreneurs build companies at the intersection of hardware, software, and services. The Foundry provides access to design, manufacturing, and business tools within a community of mentors that transforms startup teams into founders.
- » QB3 Garage@Berkeley (<http://qb3.org/startups/incubators/berkeley>) The QB3 Garage is a similar incubator supporting start-up and commercialization exploration activities in the area of biotechnology, affiliated with the California Institute for Quantitative Biosciences (QB3), another of the Governor Gray Davis Institutes. It has 80 square meters of wet laboratory space and access to the numerous specialized facilities of QB3. There is also a QB3 Garage at the Mission Bay campus of UC San Francisco, as well as a yet larger QB3@953 incubator facility (<http://qb3.org/startups/incubators/953>).
- » Big Ideas@Berkeley (<http://bigideas.berkeley.edu/about/>) The Big Ideas program is an annual contest designed to provide funding, support, and encouragement to interdisciplinary teams of students who have “big ideas” that could lead to important innovations. The program was founded in 2006 and has a number of sponsors inside and outside the university.

Similar activities are on a number of other UC campuses.

Over 170 startup companies have been founded to commercialize IP rights under license from the Berkeley campus of the University of California. Between 2007 and 2012 these companies raised over \$1.3 billion, and 65 of them raised an average of \$13.8 M each in private funding. A total of 45% are in the life science sector, 26% are in information technology, 15% are in electronics and hardware, and 12% are in clean technology and energy. As of 2012, startups licensed from Berkeley had received about \$67 million under the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs of the United States government.

These figures do not count faculty research done through the Lawrence Berkeley National Laboratory, and for that reason Berkeley tends to appear lower than it should in comparative rankings with other universities on research support, output, commercial activity, etc. (There is substantial engagement of Berkeley faculty with the Lawrence Berkeley National Laboratory, and many faculty members have most of their research through LBNL.) An

independent report is also available analyzing the contributions of the Berkeley campus to the economy through entrepreneurs⁵⁴.

These data for Berkeley reflect only one of the ten campuses of the University of California. Summary information for the entire University of California is given in the annual Technology Commercialization report⁵⁵. Reports for individual campuses are available and listed at <http://ucop.edu/innovation-alliances-services/innovation/innovation-impact/economic-impact.html>.

6. Universities and innovation – Conclusions and a Reflection on California and Catalonia

Universities play an essential role in innovation systems, or what we previously describe as Knowledge Based Economic Areas (KBEA's). This includes a Political and Legal Environment that supports innovation, Quality of Life factors key for attracting and retaining talent, a conducive Business Environment including sources of venture capital, access to and nurturing of a Quality Workforce, robust sources of R&D Funding for both academic and applied research, and finally, but not least, productive Universities who value economic engagement and that actively seek interaction with the private sector. The ability of businesses to innovate is increasingly tied to acquiring knowledge from outside sources, including universities. Businesses generally prefer engagement with local or regional universities who have knowledge of the socioeconomic, cultural, and legal environment in which they operate.⁵⁶

All of these components of a robust regional innovation system exist in various forms within California. In a highly interactive and iterative process of shaping and being shaped by these KBEA variables, the University of California has long helming a central place within California's growing and diverse economy. In a globalizing world where businesses investment and activity are increasingly competitive, universities can also play an essential role as a KBEA anchor -- a physical space that generates new knowledge and talent not transportable to another region, another nation. The University of California plays this anchor role in California's innovation system, along with other major research universities, including Stanford, Caltech and the University of Southern California.

What are the main lessons from California's experience, specifically focused on UC's role in California's innovation economy? The following outlines six major observations that may be of value to Catalonia.

› University Autonomy and Management Capacity

Early in its development as the Flagship University for the state of California, UC gained a high level of institutional autonomy, granted to its Board of Regents and including a prominent role for faculty in institutional management. This allowed the university to manage financial and capital (buildings and land) resources, and, most importantly, to shape its academic programs, admissions standards, faculty advancement policies, and the role of university administrators, all relatively free of government interference and influence.

With such autonomy has come a responsibility to insure that the university is responsive to the political, cultural, social, and economic needs of the people and the state that gives the institution life and purpose. Higher levels of institutional autonomy, along with role of the Board of Regents, provide a balanced governance structure that allows the university to be accountable to the public, yet also free from being buffered from political vacillations and the constant and growing and sometime contradictory demands of stakeholders.

In turn, UC's autonomy has been a precondition for building a significant level of management capacity, essentially empowering a university to make strategic choices in a deliberate manner, and fostering a desire for institutional self-improvement, and evidence based management.

At the same time, it is important to note that UC is a coherent network of ten university campuses under a single governing board with substantial management capacity under its "One University" model. It is also part of a larger pioneering system of higher education that is highly mission-differentiated and that serves the other higher education needs of the state. In contrast, Catalonia's public universities are independent entities. As outside observers, we think that members of the ACUP may wish to more fully explore how to better coordinate key policies and activities of their universities in a number of areas, including economic engagement, public service, and degree programs.

› Internal Academic Culture that Values Economic Engagement

A sufficient level of autonomy and management capacity provides the environment for UC to build a performance-based academic culture that focuses on faculty productivity. This includes regular campus peer review of faculty and clear policies regarding the criteria they are evaluated on that reflects the larger mission and goals of an institution, and placing sufficient value on economic engagement and public service as a vehicle through which a faculty member may demonstrate intellectual creativity and achievement. As noted, this does not mean that all faculty should be economically engaged. But to foster this activity, universities need to include policies that provide time and resources to engage with businesses, local and regional governments and public agencies and nonprofits. They also need to hire and retain faculty who will keep them at the forefront of research that may eventually influence or result in technological innovation relevant to their regional economy. For example, both the San Francisco and San Diego campuses undertook structural-biology research on complex and human-scale organisms at a critical point in time when that field was rapidly blossoming due to new research capabilities and fundamental biological knowledge. The UC San Francisco approach of stressing teamwork among outstanding researchers from different disciplinary backgrounds was particularly effective.

› Robust Sources of External and Competitively Funded R&D

The University of California, and specifically its faculty and researchers, have long operated successfully in a competitive environment for securing extramural research grants, and with relatively robust sources of external research funding. Most of this funding has come from the federal government that understands its crucial role in promoting both basic and applied research, and its fundamental role in shaping innovation and economic growth.

Another important aspect of California's innovation system, and that of the United States, is that most research funding is not directed to a specific industrial, medical, energy or other outcome. There are also few institutional block grants. Through the process of competitive peer review and funding for general areas of research, researchers themselves shape the research agenda. Universities play the key role in fundamental (or blue-sky) research in which the value and future use is not always clear. Further, a balanced investment portfolio insures research in all the disciplines and encourages research that falls between disciplines and/or brings several needed disciplines together.

It is also important to see research income, from public and private sources, as one part of a larger funding model for research universities. UC has benefited from overhead rates that recognize the larger costs of its research activities, including administrative staff support and capital costs. Universities need to cover the real costs of grant-generated research, integrate these activities where appropriate into its teaching and public service roles, and generate resources for future investment in promising research and economic engagement initiatives. UC has worked out a financial structure with the State of California whereby about half of the recovered overhead that is made available by the federal government in recognition of expenses already made by the state in support of research is passed on to the university and has become an essential and flexible source for major unanticipated expenses such as financial-support packages for faculty recruitment and retention.

› Universities and Technology Transfer

Universities need to develop policies and mechanisms to encourage interaction and collaborations with businesses and public agencies and to move inventions stemming from faculty research into commercial use. This includes establishing the "rules of engagement" with business in which the university outlines conflict-of-interest and conflict-of-commitment policies and appropriate expectations between the academic community and the private sector.

Over time and with substantial experience, the University of California has developed its own “rules of engagement,” along with administrative support offices and policies to link faculty expertise and knowledge generation with regional businesses and local governments, and participated in formal and informal interactions with stakeholders—including business-university forums and industry specific university centers or institute that encourage the exchange of ideas, knowledge, and people. As the technology transfer operations of the university increased and as experience was gained over the years, the university moved toward more active marketing of technology and decentralization that placed technology-transfer operations closer to the faculty inventors.

› A Supportive Political and Business Environment

An essential component of California’s innovation system, and that of any KBEA, is the interest and support of lawmakers, business interests, and more generally the public on the multiple roles universities play in socioeconomic mobility and economic growth. The development of the San Diego/La Jolla area into science-based industry and independent research organizations surrounding the UC San Diego campus is a strong example of how important these factors are.

There is significant complexity to promoting a positive environment for universities to interact and support local and regional, and national economies. Political support is in part based on the performance, real and perceived, of universities in meeting a larger set of institutional responsibilities: from socioeconomic mobility, to generating talent for local labor markets, generating societal leaders, and producing research that both furthers knowledge and provides possible utility, including start-ups. The business environment is part of the political environment and, as we have discussed in this report, includes a broad range of variables: including a society supportive of risk taking, perception regarding the interest and flexibility of a university to engage with the private sector, to tax and land-usage policies that encourage private sector investment in university research, and the availability of venture capital.

› University Accountability

Developing and sustaining a vibrant KBEA, and a positive and strategic relationship with local communities and the private sector, takes time and effort. The University of California has a long history of significantly shaping California’s economy. But there is always the question of what UC has done for the state, and the nation, lately. Universities need to actively research and report on their overall economic and social impact, on their collaborations and influence on specific business sectors, and seek avenues to disseminate and help explain their role in society.

Much of the data on the University of California's economic impact provided in this report is from annual UC generated "accountability reports"⁵⁷ and "economic impact reports" generated by third parties. These activities provide formal and transparent sources of information on the wide variety of UC's activities and comparative performance.

Internationally, most accountability standards have been developed by ministries and are sometimes used for resource allocation. But universities need to creatively seek their own internally generated processes for setting performance standards, including their economic impact and the strength of their relationship with the private sector, and evaluating their strengths and weaknesses in these activities.

From our brief review of the current role and economic impact of universities in Catalonia, these six policy areas have the most relevancy. There are many contextual differences between California and Catalonia, as briefly discussed in this report's introduction. They include macro issues, such as the size of the population and their educational attainment level; the mix of existing businesses, including the balance between Small Business Enterprises and large corporations; along with the autonomy and finances for higher education, and legal standing of Catalonia within Spain that has become more complicated after the vote for independence..

The growing role of the European Research Council and the evolving Horizon 2020 program, and in turn the competition for EU R&D funding that is increasingly based on peer review, add another important evolving context for Catalonia—although with some similarities with the competition for research funding in the U.S. Brexit and political changes in the EU may influence the competition, and perhaps funding, available via the ERC.

On the micro or institutional level, differences include the still strong adherence to a civil service mentality of faculty in Catalonia, rather than advancement through systematic performance evaluation that values economic engagement and public service along with research and teaching; sufficient salaries to attract and retain talented faculty members (and the paths for citizenship important for attracting international talent); the level of institutional autonomy and current management capacity of public universities; and the experience and policies for encouraging interaction with the local economy.

Previous studies on Spain and Catalonia's innovation systems by the OECD and the European Commission provide data and information, but only limited guidance on the internal culture and practices required for promoting economic engagement. The examples of California and the University of California offered in this report may generate ideas and examples for both macro (state) and micro (institutional) policies and practices useful in the Catalonia

context. It is our sense that the unique culture of Catalonia, its present economic role in Spain, its existing private sector strength and the entrepreneurial drive of its businesses and universities, provide a significant opportunity to increase the economic and social impact of its public universities. Self-reflection, the search for best practices and new ideas, and a willingness to adopt and change are essential elements for seeking productive innovation systems.

Yet, in the aftermath of the independence vote, Catalonia's universities also face a confusing political and economic environment. The Spanish government has taken over responsibility for higher education and research in Catalonia. The assumption of greater management authority by Madrid may present significant obstacles for university autonomy and their ability to further build their research and public service portfolio. Universities need political stability, sufficient levels of autonomy, and an understanding of their current and potential role in society to remain productive and innovative, and to enable them to attract and retain talent.

At the same time, there may be significant opportunities for Catalonia's universities to increase their research funding support from the EU and the Horizon 2020 program following a hard- or soft-Brexit.

Project principals brief bios

John Aubrey Douglass

Dr. John Aubrey Douglass is Senior Research Fellow - Public Policy and Higher Education at the Center for Studies in Higher Education (CSHE) at the University of California - Berkeley. He is the author of numerous journal articles and papers on globalization and higher education, the role of universities in economic development, and the history and development of California's pioneering higher education system. He is the author of *Envisioning the Asian New Flagship University* (Berkeley Public Policy Press 2017), *The New Flagship University: Changing the Paradigm from Global Ranking to National Relevancy* (Palgrave Macmillan, 2016), *The Conditions for Admissions* (Stanford Press 2007), *The California Idea and American Higher Education* (Stanford University Press, 2000; published in Chinese in 2008 and in Japanese by fall 2015), and with Jud King and Irwin Feller (ed) *Globalization's Muse: Universities and Higher Education Systems in a Changing World* (Public Policy Press, 2009). He recently was a Visiting Researcher at the Wissenschaftszentrum Berlin für Sozialforschung (WZB) in the fall of 2015 working on the forthcoming book on *The Nexus of Science and Economic Policy*. Among the research projects he founded and leads is the Student Experience in the Research University (SERU) Consortium—a group of major research universities in the U.S., China, Japan, Russia, Brazil, the UK, Europe and South Africa that includes a survey of students and a policy and scholarly research agenda. He is also the editor of the Center's Research and Occasional Paper Series (ROPS), sits on the editorial board of a number of international higher education journals in Europe, China and Russia, and is on the international advisory board of a number of higher education institutes. For more information on his research, publications, and professional activities see: <http://cshe.berkeley.edu/people/jdouglass.htm>

C. Judson King

C. Judson King is Provost and Senior Vice President, Emeritus of the University of California, having served in that position 1995-2004. He is Professor Emeritus of Chemical and Biomolecular Engineering on the Berkeley campus, where he has also been Chair of Chemical Engineering (1972-81), Dean of the College of Chemistry (1981-1987), Provost—Professional Schools and Colleges (1987-94), and Director, Center for Studies in Higher Education (2004-2014). He is a member of the National Academy of Engineering (elected, 1981) and has received a number of major awards from the American Institute of Chemical Engineers, the American Chemical Society, and the Council for Chemical Research, the American Society for

Engineering Education, and the Yale Science and Engineering Association. He is past member (1994-2004) and Chair (2002-2004) of the California Council for Science and Technology, and past Vice Chair (2000-2003) and Chair (2003-2006) of the California Association for Research in Astronomy, which operates the Keck telescopes atop Mauna Kea in Hawaii, and was both a founder (1978-1981) and Chair (1989) of the Council for Chemical Research. He has been a board member of the American University of Armenia Corporation (1995 to date) and for 15 of those years Chair of that Board. Within chemical engineering his research pertained to separation processes and methods of drying of foods and pharmaceuticals, particularly spray drying and freeze drying. He is the author of two books—Separation Processes (1971, 1980) and Freeze-Drying of Foods (1972). He was consultant for 20 years with the Procter and Gamble Company on these subjects. Within studies of higher education his interests have been university structure and governance, technological innovation and the roles of universities in economic development, and the structure of engineering education. He is presently writing a book on the subject of the University of California and the factors contributing to its success. For more information on his research, publications, and professional activities see: <http://www.cshe.berkeley.edu/c-judson-king>

Appendices

Appendix 1

General Principles for a University Governing Board Association of Governing Boards (AGB)

- » The ultimate responsibility for governance of the institution rests in its governing board. Boards are accountable for the mission and heritage of their institutions and the transcendent values that guide and shape higher education; they are equally accountable to the public and to their institutions' legitimate constituents. The governing board should retain ultimate responsibility and full authority to determine the mission of the institution within the constraints of state policies and with regard for the state's higher education needs in the case of public institutions or multi-campus systems, in consultation with and on the advice of the president, who should consult with the faculty and other constituents.
- » The board should establish effective ways to govern while respecting the culture of decision making in the academy. By virtue of their special mission and purpose in a pluralistic society, universities have a tradition of both academic freedom and constituent participation—commonly called “shared governance”—that is strikingly different from that of business and more akin to that of other peer-review professions, such as law and medicine. Faculty are accorded significant responsibility for and control of curriculum and pedagogy. This delegation of authority results in continuous innovation. Board members are responsible for being well informed about and for monitoring the quality of educational programs and pedagogy. Defining the respective roles of boards, administrators, and faculty in regard to academic programs and preserving and protecting academic freedom are essential board responsibilities.
- » The board should approve a budget and establish guidelines for resource allocation using a process that reflects strategic priorities. Budgets are usually developed by the administration, with input from and communication with interested constituents. The board should not, however, delegate the final determination of the overall resources available for strategic investment directed to achieving mission, sustaining core operations, and assuring attainment of priorities. Once the board makes these overarching decisions, it should delegate resource-allocation decisions to the president who may, in turn, delegate them to others.
- » The governing board should manifest a commitment to accountability and transparency and should exemplify the behavior it expects of other participants in the governance process. From time to time, boards should examine their membership, structure, policies, and performance. Boards and their individual members should engage in periodic evaluations

of their effectiveness and commitment to the institution or public system that they serve. In the spirit of transparency and accountability, the board should be prepared to set forth the reasons for its decisions.

- » Governing boards have the ultimate responsibility to appoint and assess the performance of the president. Indeed, the selection, assessment, and support of the president are the most important exercises of strategic responsibility by the board. The process for selecting a new president should provide for participation of constituents, particularly faculty; however, the decision on appointment should be made by the board. Boards should assess the president's performance on an annual basis for progress toward attainment of goals and objectives, and more comprehensively every several years in consultation with other constituent groups. In assessing the president's performance, boards should bear in mind that board and presidential effectiveness are interdependent.
- » Boards of both public and independent colleges and universities should play an important role in relating their institutions to the communities they serve. The preceding principles primarily address the internal governance of institutions or multi-campus systems. Governance should also be informed by and relate to external stakeholders. Governing boards can facilitate appropriate and reciprocal influence between the institution and external parties in many ways.

Source: Statement on Board Responsibility for Institutional Governance, AGB, 2010

Appendix 2. Executive Summary from Bay Area Economic Council, “UC Berkeley Stimulating Entrepreneurship in the Bay Area and Nationwide: An Exploration of the Economic Contributions of

UC Berkeley through Company Formations by Alumni, Faculty, and Affiliates”⁵⁹

The University of California, Berkeley, widely considered the top public university and one of the leading research universities in the world, is located in the heart of the San Francisco Bay Area. The region leads the world in its ability to generate high-value businesses, venture investment, and transformative technologies. The region is also a leading center for entrepreneurial activity, generating home-grown start-ups, and attracting talented technologists and entrepreneurs from around the world.

UC Berkeley’s entrepreneurial ecosystem consists of formal and informal elements that help drive innovation and entrepreneurship.

These include talented students and faculty, the commercial licensing of technologies developed on campus, specialized programs for developing entrepreneurial skills, and university-sponsored incubators and accelerators designed to support incipient entrepreneurs and help them to launch companies.

This analysis estimates a minimum economic impact of entrepreneurial activity associated with UC Berkeley. The direct and ripple economic impact reported here likely underestimates the true impact.

Who are UC Berkeley’s entrepreneurs?

- » Baby Boomers have been a driving force behind the growth of new businesses by identified Berkeley founders. Graduates from the 1970s represent the most prolific cohort with a total of 809 founders. More recent cohorts have also generated substantial entrepreneurial activity.
- » More women graduates are founding companies. Women represent 21 percent of all identified Berkeley founders. Women graduating in the 2000s, however, accounted for 31 percent of founders in that cohort.
- » Identified Berkeley founders have diverse academic backgrounds, drawing on 15 different colleges. Nearly 70 percent of founders have earned graduate or professional degrees from UC Berkeley. Nearly a quarter of founders have more than one degree from Berkeley.

The firms founded by UC Berkeley alumni, faculty, and other affiliates identified through this analysis generate significant jobs and revenues, span a diverse set of industries, and are located around the world.

- » With significant variations by industry, the 2,610 firms identified in this study account for 542,433 total jobs and on average employ 208 workers each.
- » Total global revenues of these identified firms are estimated at \$317 billion.
- » Fifty-two percent of all firms established by Berkeley founders are in the fields of Professional, Scientific & Technical Services.
- » Manufacturing and Computer Systems Design top the list for Berkeley founders in the generation of jobs and revenues.
 - › Manufacturing reports the highest levels of both employment and revenue. With average employment of 1,592 workers, the aggregate \$273 billion annual revenue of these companies leads all other sectors.
 - › Computer Systems Design firms report average employment of 518 workers and aggregate annual revenues of \$19 billion.
- » While Berkeley founders have started businesses around the world, their activities, and the employment they generate, are concentrated in the Bay Area.
 - › Fifty-five percent of companies established by Berkeley founders are located in the Bay Area. These companies account for 91 percent of total employment attributed to Berkeley founders globally.
 - › Berkeley founders have particularly deep roots in Silicon Valley. Computer & Electronic Manufacturing firms in Santa Clara County make up 86 percent of total revenue in the Bay Area and 51 percent of total employment in the region associated with Berkeley founders.
 - › Firms located across the rest of the U.S. account for 19 percent of total companies founded and 6 percent of total jobs. Foreign-based firms represent less than 2 percent of total firms established by Berkeley founders and less than 1 percent of jobs.

This is only part of the story.

- » The direct impact of identified UC Berkeley company founders in terms of employment and revenue generation provides only part of the picture. The ripple effects of these successful ventures translate into broader new value creation across industries and across the United States. Looking at the broader ripple effects across the U.S. economy, firms started by Berkeley founders are responsible for 1,247,490 jobs and

- » \$238 billion in total U.S. economic output (i.e., the value of goods and services produced).
- » Similarly, the business activities of Berkeley founders generate direct business revenues but also indirect and induced revenues in other businesses through business transactions. As a result, total business revenues account for \$85.9 billion of the total value of goods and services produced in the U.S., and of this, \$24.4 billion is personal (payroll) income.
- » Federal, state, and local tax revenues associated with firms started by Berkeley founders and the broader ripple effect through the economy totaled \$27.3 billion in 2012. This includes employee compensation tax, direct corporate tax, and taxation revenues resulting from increases in household spending.

Appendix 3. UC Academic Personnel Manual, Section 210-2(d), “Criteria for Appointment, Promotion and Appraisal”

The review committee shall judge the candidate with respect to the proposed rank and duties, considering the record of the candidate’s performance in (1) teaching, (2) research and other creative work, (3) professional activity, and (4) University and public service. In evaluating the candidate’s qualifications within these areas, the review committee shall exercise reasonable flexibility, balancing when the case requires, heavier commitments and responsibilities in one area against lighter commitments and responsibilities in another. The review committee must judge whether the candidate is engaging in a program of work that is both sound and productive. As the University enters new fields of endeavor and refocuses its ongoing activities, cases will arise in which the proper work of faculty members departs markedly from established academic patterns. In such cases, the review committees must take exceptional care to apply the criteria with sufficient flexibility. However, flexibility does not entail a relaxation of high standards. *Superior intellectual attainment, as evidenced both in teaching and in research or other creative achievement, is an indispensable qualification for appointment or promotion to tenure positions.* Insistence upon this standard for holders of the professorship is necessary for maintenance of the quality of the University as an institution dedicated to the discovery and transmission of knowledge. Consideration should be given to changes in emphasis and interest that may occur in an academic career. The candidate may submit for the review file a presentation of his or her activity in all four areas.

The University of California is committed to excellence and equity in every facet of its mission. Contributions in all areas of faculty achievement that promote equal opportunity and diversity should be given due recognition in the academic personnel process, and they should be evaluated and credited in the same way as other faculty achievements. These contributions to diversity and equal opportunity can take a variety of forms including efforts to advance equitable access to education, public service that addresses the needs of California’s diverse population, or research in a scholar’s area of expertise that highlights inequalities. Mentoring and advising of students and faculty members, particularly from underrepresented and underserved populations, should be given due recognition in the teaching or service categories of the academic personnel process.

The criteria set forth below are intended to serve as guides for minimum standards in judging the candidate, not to set boundaries to exclude other elements of performance that may be considered.

(1) **Teaching** - Clearly demonstrated evidence of high quality in teaching is an essential criterion for appointment, advancement, or promotion. Under no circumstances will a

tenure commitment be made unless there is clear documentation of ability and diligence in the teaching role. In judging the effectiveness of a candidate's teaching, the committee should consider such points as the following: the candidate's command of the subject; continuous growth in the subject field; ability to organize material and to present it with force and logic; capacity to awaken in students an awareness of the relationship of the subject to other fields of knowledge; fostering of student independence and capability to reason; spirit and enthusiasm which vitalize the candidate's learning and teaching; ability to arouse curiosity in beginning students, to encourage high standards, and to stimulate advanced students to creative work; personal attributes as they affect teaching and students; extent and skill of the candidate's participation in the general guidance, mentoring, and advising of students; effectiveness in creating an academic environment that is open and encouraging to all students, including development of particularly effective strategies for the educational advancement of students in various underrepresented groups. The committee should pay due attention to the variety of demands placed on instructors by the types of teaching called for in various disciplines and at various levels, and should judge the total performance of the candidate with proper reference to assigned teaching responsibilities. The committee should clearly indicate the sources of evidence on which its appraisal of teaching competence has been based. In those exceptional cases when no such evidence is available, the candidate's potentialities as a teacher may be indicated in closely analogous activities. In preparing its recommendation, the review committee should keep in mind that a redacted copy of its report may be an important means of informing the candidate of the evaluation of his or her teaching and of the basis for that evaluation.

It is the responsibility of the department chair to submit meaningful statements, accompanied by evidence, of the candidate's teaching effectiveness at lower-division, upper-division, and graduate levels of instruction. More than one kind of evidence shall accompany each review file. Among significant types of evidence of teaching effectiveness are the following: (a) opinions of other faculty members knowledgeable in the candidate's field, particularly if based on class visitations, on attendance at public lectures or lectures before professional societies given by the candidate, or on the performance of students in courses taught by the candidate that are prerequisite to those of the informant; (b) opinions of students; (c) opinions of graduates who have achieved notable professional success since leaving the University; (d) number and caliber of students guided in research by the candidate and of those attracted to the campus by the candidate's repute as a teacher; and (e) development of new and effective techniques of instruction, including techniques that meet the needs of students from groups that are underrepresented in the field of instruction.

All cases for advancement and promotion normally will include: (a) evaluations and comments solicited from students for most, if not all, courses taught since the candidate's

last review; (b) a quarter-by-quarter or semester-by-semester enumeration of the number and types of courses and tutorials taught since the candidate's last review; (c) their level; (d) their enrollments; (e) the percentage of students represented by student course evaluations for each course; (f) brief explanations for abnormal course loads; (g) identification of any new courses taught or of old courses when there was substantial reorganization of approach or content; (h) notice of any awards or formal mentions for distinguished teaching; (i) when the faculty member under review wishes, a self-evaluation of his or her teaching; and (j) evaluation by other faculty members of teaching effectiveness. When any of the information specified in this paragraph is not provided, the department chair will include an explanation for that omission in the candidate's dossier. If such information is not included with the letter of recommendation and its absence is not adequately accounted for, it is the review committee chair's responsibility to request it through the Chancellor.

(2) Research and Creative Work—Evidence of a productive and creative mind should be sought in the candidate's published research or recognized artistic production in original architectural or engineering designs, or the like. Publications in research and other creative accomplishment should be evaluated, not merely enumerated. There should be evidence that the candidate is continuously and effectively engaged in creative activity of high quality and significance. Work in progress should be assessed whenever possible. When published work in joint authorship (or other product of joint effort) is presented as evidence, it is the responsibility of the department chair to establish as clearly as possible the role of the candidate in the joint effort. It should be recognized that special cases of collaboration occur in the performing arts and that the contribution of a particular collaborator may not be readily discernible by those viewing the finished work. When the candidate is such a collaborator, it is the responsibility of the department chair to make a separate evaluation of the candidate's contribution and to provide outside opinions based on observation of the work while in progress. Account should be taken of the type and quality of creative activity normally expected in the candidate's field. Appraisals of publications or other works in the scholarly and critical literature provide important testimony. Due consideration should be given to variations among fields and specialties and to new genres and fields of inquiry.

Textbooks, reports, circulars, and similar publications normally are considered evidence of teaching ability or public service. However, contributions by faculty members to the professional literature or to the advancement of professional practice or professional education, including contributions to the advancement of equitable access and diversity in education, should be judged creative work when they present new ideas or original scholarly research. In certain fields such as art, architecture, dance, music, literature, and drama, distinguished creation should receive consideration equivalent to that accorded to distinction attained in research. In evaluating artistic creativity, an attempt should be made to define

the candidate's merit in the light of such criteria as originality, scope, richness, and depth of creative expression. It should be recognized that in music, drama, and dance, distinguished performance, including conducting and directing, is evidence of a candidate's creativity.

(3) Professional Competence and Activity—In certain positions in the professional schools and colleges, such as architecture, business administration, dentistry, engineering, law, medicine, etc., a demonstrated distinction in the special competencies appropriate to the field and its characteristic activities should be recognized as a criterion for appointment or promotion. The candidate's professional activities should be scrutinized for evidence of achievement and leadership in the field and of demonstrated progressiveness in the development or utilization of new approaches and techniques for the solution of professional problems, including those that specifically address the professional advancement of individuals in underrepresented groups in the candidate's field. It is responsibility of the department chair to provide evidence that the position in question is of the type described above and that the candidate is qualified to fill it.

(4) University and Public Service—The faculty plays an important role in the administration of the University and in the formulation of its policies. Recognition should therefore be given to scholars who prove themselves to be able administrators and who participate effectively and imaginatively in faculty government and the formulation of departmental, college, and University policies. Services by members of the faculty to the community, State, and nation, both in their special capacities as scholars and in areas beyond those special capacities when the work done is at a sufficiently high level and of sufficiently high quality, should likewise be recognized as evidence for promotion. Faculty service activities related to the improvement of elementary and secondary education represent one example of this kind of service. Similarly, contributions to student welfare through service on student-faculty committees and as advisers to student organizations should be recognized as evidence, as should contributions furthering diversity and equal opportunity within the University through participation in such activities as recruitment, retention, and mentoring of scholars and students.

The Standing Orders of The Regents provide: "No political test shall ever be considered in the appointment and promotion of any faculty member or employee." This provision is pertinent to every stage in the process of considering appointments and promotions of the faculty.

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