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Chapter title	Commercialization or Engagement: Which Is of More Significance for Regional Economies?
Chapter abstract *3–5 sentences, or around 120 words and no more than 150 words*	The literature on the university’s role in regional economic development has almost entirely focused on commercialization as managed through technology licensing offices. Drawing upon case studies from a forthcoming book, it is shown that technology transfer through regional engagement by University of California campuses is far more complex and bi-directional than the current academic literature indicates. The chapter suggests better understanding of the true nature of technology transfer would allow both policy makers and university administrators to develop more effective policies.
Chapter keywords *Around 5 keywords. No fewer than 3 and no more than 10.*	Commercialization, regional engagement, universities, disciplinary differences, University of California

Commercialization or Engagement: Which Is of More Significance for Regional Economies?

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Martin Kenney
Professor
Department of Human and Community Development
University of California, Davis
1 Shields Avenue
(530) 752-0328
mfkenney@ucdavis.edu

and

Senior Project Director
Berkeley Roundtable on the International Economy
University of California, Berkeley
Berkeley, CA

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In a global society within which the creative use of information transformed into knowledge is increasingly accepted as the major source of new value creation, it is natural that regional and national policy-makers would ponder the role of the university, an institution dedicated to the creation and diffusion of information and knowledge. In every nation including the United States, the university's role in knowledge creation has been overwhelmingly funded by public and non-profit entities. Over the last four decades, interest in the monetization of this knowledge has resulted in the proliferation of offices dedicated to patenting, firm incubators, and even university-funded venture capital firms (Clarysse et al., 2005; Siegel et al., 2003). While this paper does critique these new institutional mechanisms, it does not adopt the position of those that critique what they term, "academic capitalism" (Slaughter and Leslie, 1997). In contrast, this paper suggests that the emphasis on direct monetization devalues the traditional channels of university knowledge transmission to the economy, or what Perkmann et al. (2012) describe as "academic engagement," that have been very powerful regional development forces. Moreover, nearly all research agrees that these earlier channels continue to be of far greater importance than the newer, formalized channels (Perkmann et al., 2012). Further, in suggestive terms, it is argued that an emphasis on these formal channels could disrupt the other traditional channels, thereby decreasing the contributions of university knowledge to the region and society as a whole.

The literature on the role of universities exhibits a number of deep biases: First, it adopts the imagined "U.S. model" described below as the single best model. Second, when considering the U.S. the literature appears to privilege MIT and Stanford (Shane, 2002; Agrawal and Henderson, 2002), despite the fact that more than 68% of U.S. research is undertaken at public universities. In fact, the University of California is the largest supplier of research. Third, the now accepted U.S. model for technology transfer emerged from the commercialization of basic molecular biology research through university-patented molecules commercialized by venture capital-backed startups (see, Kenney, 1986 for one of the earliest statements on this process) and is probably more applicable to this field and not necessarily other fields of university research. Rather than seeing the biotechnology pattern as industry-specific, it has become the dominant conceptual model (hereafter referred to as the biotechnology model). When combined with other biases, the biotechnology model profoundly misrepresents the regionally important economic contributions of the university in the knowledge economy.

The Economic Roles of the Research University

Because the research university is a multi-purpose institution, understanding its economic roles is difficult. However, nearly all observers agree that the two most economically significant roles are educating students and conducting research. In addition to imparting skills, the university certifies a certain level of capability among its graduates. Students are important not only in terms of skills, but also transfer knowledge. Studies of the channels of information flow have found that after students, the most important channels of public research transmission are informal interaction, meetings, consulting, and for industry in particular, invariably publications (Meyer-Krahmer and Schmoch, 1998; Bonaccorsi and Piccaluga, 1994; Link et al., 2007). Patents are viewed as very important only in "pharmaceuticals" (see, for example, Cohen et al., 1998, 2002: 11; Klevorick et al., 1995). Summing up the findings of the academic literature, Agrawal (2001: 285) concludes that for, "knowledge transferred through the formal university technology transfer channel, patenting . . . represents only a small fraction of the total economically valuable transfer from universities."

Normally, when considering a market for knowledge in the form of patents (Arora et al., 2004), the tacit dimension is forgotten (Agrawal, 2001). And yet, there is ample evidence that very often even after a firm licenses a patent from a university, it is important for the licensee to interact with the inventor (Jensen and Thursby, 2001), because many university inventions are quite early stage and thus require significant further investment in bringing them to practice. This need for interaction makes localness of startups an important factor in easing the transfer of tacit knowledge.

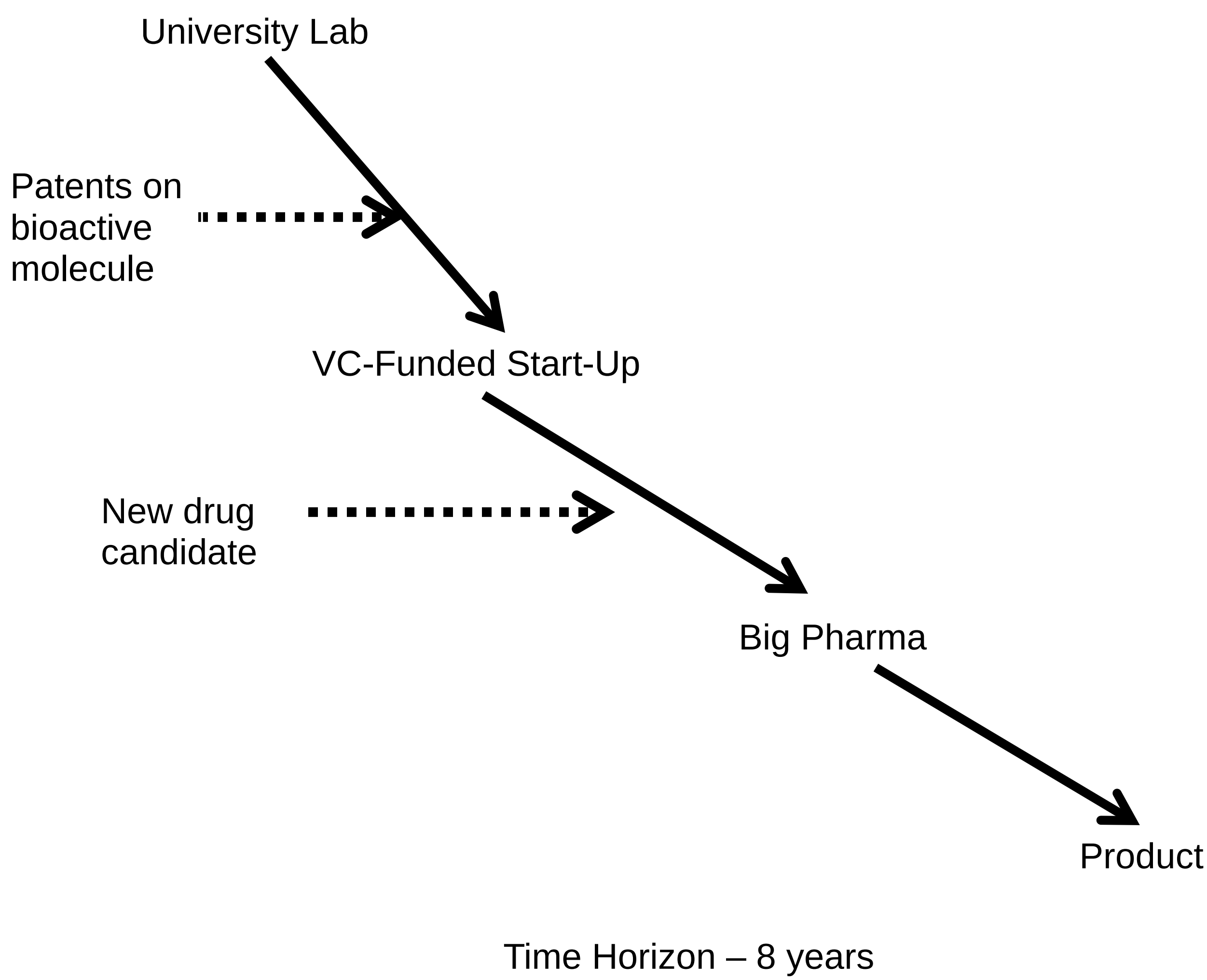
A significant issue that Agrawal (2001: 294) flags is that "the vibrant trade in scientific knowledge for commercial application that is not patented and does not flow through the university technology transfer office have been largely overlooked." This is extremely important if research is correct in finding that only a small proportion of university knowledge diffusion occurs through TTOs and other such administrative offices. If administrative centralization disrupts the existing and traditional informal channels of knowledge diffusion, then there will be a, likely unobservable, social loss.

The Biotechnology Model Described

The biotechnology model took root in the recognition of the mid-1970s that some portion of the knowledge developed in molecular biology had matured sufficiently to be commercializable (Kenney, 1986). In a remarkable period of less than a decade, the techniques of this branch of science became commercialized as a new industrial field termed “biotechnology.” The founding knowledge came directly from university research. What ensued was a “gold rush” within which both large pharmaceutical firms and small venture capital-financed firms rushed to university biology departments and medical schools to secure access to faculty members undertaking research on potentially valuable, patentable therapeutic compounds. There was initially a great deal of experimentation with different knowledge-commercialization models, however two became dominant: 1) The university knowledge was patented and then licensed to a large existing pharmaceutical firm. 2) The university knowledge was patented and then licensed to a small, almost always local, venture capital-financed firm, often founded by the university researcher and possibly one or more post-doctoral students. In each of these models, the university monetized the research through patenting.

The biotechnology model most closely resembles Vannevar Bush’s now deeply questioned linear model, whereby inventions generated in basic research flow to applied research and then product development (see Figure One). In the biopharmaceutical model, patents are considered vital for commercialization, which agrees with the common belief propagated by organizations such as the Association of University Technology Managers (AUTM).

Figure One: Stylization of the Biotechnology Model of Technology Transfer



Source: Author

While most of the discussion about biotechnology technology transfer envisions proprietary pharmaceutical applications requiring extensive and expensive testing, a number of the largest biopharmaceutical income earners have been university-developed techniques such as the Cohen-Boyer recombinant DNA patent ($250 million) and Axel Co-transformation patents ($790 million). And yet, for these patents there is no credible argument that they would not have been used absent a patent, as they diffused in the research community long before the patents issued (Colaianni and Cook-Deegan, 2009). The only contribution by the university technology licensing office was the creation of a licensing contract and the collection of effectively what was a tax on commercial users. In the case of the University of Utah-discovered BRCA breast cancer gene, which was licensed to a local startup, there can be little doubt that the technology would have been used and that the expensive screening tests are precluding at-risk women without appropriate health insurance coverage from receiving the test (Dalpé et al., 2003; Paradise, 2004). Effectively, women with this predisposition to cancer are being taxed to discover this. The use of University of Wisconsin-developed embryonic stem cells is similar. There is no doubt that the technology would have transferred, but the patents of the publicly funded research preclude their widespread use as the university and the private firm that secured the license operate to maximize their profits (Jain and George, 2007; Murray, 2007).

In general, patents are most valuable in the specialty chemical industry and especially the pharmaceutical industry where a firm can protect its molecules (Mansfield, 1986). With the biotechnology revolution and the passage of Bayh-Dole, in the space of less than a decade, universities around the U.S. established technology licensing offices (TLOs) and proceeded to patent increasing swathes of research results. With this development, what Rhoten and Powell (2007) term the "patent-grant" university model was born. The ability to own the patent was central for research universities, because, as non-profit institutions, they are unable to practice their inventions. However, they are permitted to receive income from patent licensing. For this reason, through their technology licensing offices, universities have been on the forefront of pressing for stronger patent protection. While the patent-grant university may be the icon of the 21st century university, it is not a very accurate description of the many ways in which universities contribute information, knowledge and technology to society.

Other University Technology Transfer Models

Industries differ dramatically in their dynamics, structure, and sources of competitiveness and knowledge. Research such as that by Cohen et al. (2002) demonstrates that industry characteristics affect the types of engagements firms have with universities. This section uses illustrations from a variety of knowledge fields to demonstrate the diversity of interactions with the goal of showing that no one model best describes the ways in which universities engage with society.

The Wine Industry and the University of California, Davis[1]

In the U.S., the oldest organized technology transfer model is the land grant public universities and their Colleges of Agriculture. In U.S. agriculture there is an entire technology production and transfer system consisting of university researchers and publicly funded extension personnel who charged with ensuring that a particular state's farmers are aware of the technology being developed at the University. In the past, the research results were most obviously embedded in seeds and cultivars known in the vernacular as "college-bred" and provided to all interested parties for free (see, for example, Kloppenburg, 1988). Despite the fact that there was no proprietary technology embedded in these seeds, they were widely diffused and adopted. In fact, some of the early and influential technology diffusion literature such as Rogers (1962) and returns-to-research studies such as Griliches (1958) were based on agriculture where commercially valuable research results were placed in the public domain.

The history of the interaction between universities (and research institutes) and agriculture is well-known (Evenson et al., 1979). However, it has been framed in uni-directional terms as universities develop new technologies such as seeds, pesticides, and new farm equipment, which are then transferred to farmers through extension activities or commercialized by farm input industries. The wine industry provides another perspective into the ways in which university research and training contributed to the creation of a high-value agricultural industry. In this section, we concentrate on the relationship between UC Davis and the Napa

[1] This section draws heavily upon Lapsley (2013).

Valley, but draw upon the much larger literature on the role of research in the development of fine wine industries in a number of nations.

The relationship between scientific research and the wine industry goes back at least as far as Louis Pasteur's research on wine fermentation (Debré, 2000). More recently, others have documented the role of public institutions in providing skilled personnel and actionable knowledge to the wine industry (Giuliani and Arza, 2009). After the repeal of Prohibition, the California wine industry, including the Napa Valley, produced low quality sweet wines. However, in the 1950s a group of Napa Valley vintners in discussion with University of California professors came to believe that it was possible to produce fine wines in the Napa Valley (Lapsley, 1996; Lapsley, 2013). In the immediate post World War Two period, Napa winemakers were dependent upon and eager to receive information from the university on how to upgrade regional production. To cement this commitment, in 1947, the Napa Valley vintners purchased a twenty acre vineyard site in the heart of the region and donated it to the University so that researchers could experiment close-by. The university also provided virus-free root stock to the region's growers. During this early period, the Napa wine industry was technically unsophisticated and depended heavily upon university research and assistance. At that time, vintners and growers in the Napa Valley were mainly identifying problems for the university researchers to solve. As the wine industry matured, however, the information flow became bi-directional.

As Americans began to consume more and better wines in the 1960s, the market for Napa wines also grew. Moreover, the emphasis on quality increased creating greater demand for technically trained winemakers. As enrollment in the Department of Enology and Viticulture grew, it partnered with the self-supporting UC Davis University Extension to offer professional courses for those in the wine industry. Through students and extension courses, university knowledge diffused into the industry. Likely because they were so far behind the French wine industry, California and particularly Napa vintners were eager to adopt new technology to improve their production. As Lapsley (2013) points out, quality became their overwhelming goal. As the Napa wine industry matured, UC Davis research continued to be important, but it was the training in scientific winemaking that became paramount. Lapsley (2013) quoted a prominent Napa winemaker as saying “somewhat rhetorically, ‘Can you think of a great winemaking region that doesn’t have a university associated with it?’”

Wine is, perhaps, unusual in agriculture in terms of the level of interaction between local research and educational institutions and industry (see, for example, Giuliani and Arza, 2009). Lately this interaction has become even more complex. Features of the wine industry in California, particularly the industry’s belief in the importance of university research and training, make generalization even to other agricultural fields hazardous, but it is suggestive of the rich variety of ways universities and local firms and industries interact. Applying the biotechnology model would prove disruptive to the successful wine industry model .

Electrical Engineering and Computer Science[2]

In engineering, it is widely recognized that technology transfer is not a linear process, but rather can be seen as a long-term dialogue better modeled as a complicated set of interactions. Remarkably, the pattern of interaction in engineering has received far less attention than the biotechnology model, perhaps because of its complexity and the relative lack of importance of patents, which are so easily researchable and can generate revenue for the university through licensing income. This lack of attention is unfortunate because engineering provides an entirely different perspective on the patterns of interaction between industry and the university. This is emphasized by Agrawal and Henderson (2002) in a study of the interactions by 225 MIT engineering professors that found “a focus on patent citations or on licensing behavior may offer only partial insights as to the ways in which MIT interacts with the private sector.” Nearly half of their respondents had patented an invention and a subsample believed that patenting accounted for only 7% of all of the technology transferred from their laboratories.

The mechanisms for knowledge transfer are myriad and there are many channels for interaction and mutual learning. This is illustrated in the ways in which UC Berkeley Electrical Engineering and Computer Science faculty interacted with personnel at the Bell Laboratories to develop an improved UNIX that was

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[2] See Kenney et al. 2013 detailed discussion.

released to the public for free under the moniker “Berkeley Software Development Unix” (BSD Unix). The development of BSD Unix followed a complicated interactive path. It began with a UCB professor becoming aware of Unix at a conference where he heard the Bell Laboratory inventors describe the program. One of the Bell Laboratory inventors was a former UCB Ph.D. student. The UCB professor requested a copy of the program and its documentation. The University of California then negotiated a license from AT&T, the owner of the Bell Laboratories at the time. The original Bell Unix developer with his Ph.D. from UCB returned and spent a one year sabbatical at UCB teaching graduate seminars about UNIX, thereby training UCB students about UNIX. Still other UCB graduate students did internships at Bell Laboratories with Unix developers. These human relationships deepened the interaction and ensured a two-way transfer of technology. The research at the University of California was sponsored by the U.S. Department of Defense Advanced Research Projects Agency, which was committed to UNIX diffusion.

The Berkeley Unix software team freely distributed their versions to the public. The UCB graduates that were employed by firms were important carriers of the software into the economy. Of particular importance was Sun Microsystems, which built its industry-changing work stations on a BSD Unix variant. Another output of the team developing BSD Unix was Sendmail, the Internet mail server program. Much later BSD Unix was integrated into the Apple operating system and also was the inspiration for the Linux operating system. This case study illustrates a number of points. First, openly published and freely provided university knowledge can make enormous contributions to the public good and local (and global) economic growth. Second, though only a single case, there is significant evidence that interactions between universities and firms is multifaceted and cannot be reduced to a process to be managed by a technology transfer office. In fact, inserting an intermediary into engineering relationships might weaken the technology transfer process.

Scientific Instruments

Modern science depends upon new instruments for measuring and understanding physical phenomenon. There is a long history of interaction between industry and academe that finds economic uses for machinery developed for research (Lenoir, 1997; Mody, 2006). There are many historical examples, such as Arnold

Beckman's establishment of Beckman Instruments to market a PH meter he developed when he was an assistant professor of chemistry at Caltech. Beckman Instruments would evolve into a large instruments firm later on (Simoni et al., 2003). In the case of nuclear magnetic resonance (NMR), which was actualized in scientific instruments, Felix Bloch, a physicist at Stanford, was a scientific pioneer in the area and would go on to work very closely with the local firm, Varian Associates (Lenoir 1997). In the field of probe microscopy, university research led Vergil Elings, professor in the department of physics at UC Santa Barbara, to leave the university and establish a Santa Barbara firm to commercialize the technology (Mody, 2013).

In all of these cases, the entrepreneurial commercialization of the equipment first invented at the university does not end the interaction; rather it creates a new dynamic of interaction. As the firm experiments with and advances the university-derived technology, the relationship often becomes bi-directional and, if sufficiently powerful, can help improve the scientific status of the university laboratories where it was borne. Some think of this process in terms of securing research funding for the university laboratory, but this may be a less important issue – as the most important source of funding for the majority of these laboratories is federal research funds. In fact, all of the extant research suggests that it is the collaboration and information sharing that is vital. For example, the ability of grad students to visit the firm, use new sophisticated equipment, secure spare parts, and interact with the corporate scientists seems to be a particularly large benefit (Mody, 2013; Lenoir, 1997). Because these instrument firms develop new applications at the cutting edge of physical phenomenon, they can identify scientifically challenging problems, which university researchers can use in proposals to secure federal research funding. In most respects, these dynamics are not so different from those encountered in engineering, except the degree to which these close relationships might accelerate technology development and scientific research.

Mathematics and Statistics

For many, mathematics and statistics appear to be among the most "academic" of all departments and quite detached from the economic world. Naturally, there is good reason to accept this commonsense understanding. And yet, there is a long history of commercial ventures spinning-off from mathematics and especially statistics departments. To illustrate, North Carolina's Research Triangle Park (RTP) has been hailed as an economic success, despite the fact that most of the largest biomedical operations in the region are branch operations for larger firms headquartered in other areas. Far fewer firms are indigenous entrepreneurial ventures established to commercialize university science, and of the local ventures few have become significant firms. The exception is firms specializing in data analysis. The two most important indigenous North Carolina technology firms are SAS and Quintiles; both of which are statistics department spinoffs. SAS was established by a North Carolina State University statistics graduate student and professor that developed a statistical program for analyzing agricultural data. The team created a firm to commercialize the program and has since grown to over 10,000 employees, the bulk of whom are located in the RTP region (SAS, 2013). Remarkably, the other major regional university-derived entrepreneurial success story, Quintiles, was the result of Dennis Gillings, a statistics professor at the University of North Carolina, who began by consulting for pharmaceutical customers. Encouraged by his success, he joined with another UNC professor, Gary Koch, to establish Quintiles, which has become a pharmaceutical research consulting giant employing 27,000 persons globally. Quintiles never received venture capital and, as was the case with SAS, self-funded its growth.

These are two salient examples, but there are a number of other firms founded by professors in mathematics and statistics. These firms are the outgrowth of successful consulting practices that were part of a professor's normal activities. Without a doubt these firms have been important for RTP's economic development, not only in terms of employment, but also in creating many further consulting opportunities for professionals in the region. More recently, with the rise of cloud computing and "big data," mathematics and statistics are becoming more economically valuable, as startups are being formed to exploit the increasing amount of data available. The point of this section is not to argue that mathematics and statistics should be commercialized but rather to suggest that serendipitous economic benefits can emerge from an extremely wide variety of departments.

Discussion

It is remarkable that on the basis of so little evidence European and other nations abandoned their previous models by which the university and industry engaged to adopt the U.S. patent-based biotechnology model (Baldini et al., 2006; Grimaldi et al., 2011; Lissoni et al., 2008; Mowery et al., 2001). As more research is undertaken on the European model, there is increasing evidence of technology transfer that was concentrated in improving existing local firms. This transfer was not so visible because few new firms resulted. More recently, Sweden has decided that moving to the Bayh-Dole model might disrupt important channels of knowledge transfer and decided to retain the "professor privilege" model (Jacobsson et al., 2013). In Europe and other nations, the adoption of the biotechnology model has slowed due to recognition that a better goal than university commercialization may be university engagement, especially with smaller regional firms.

Recently, some technology transfer professionals and academics have advocated directly considering professorial patenting and/or entrepreneurship in tenure and promotion decisions (Stevens et al., 2011; see, also Siegel et al., 2003), though in academic bioscience this does not yet seem to have occurred (Stuart and Ding, 2006). Thus far, the movement toward including this in tenure has occurred among weaker U.S. research universities (e.g., Texas A&M and Boston University). At this point, a university researcher's decisions about commercialization are largely individual and, though there are financial and often personal rewards for success, it remains optional and not directly rewarded in the academic personnel system. In the U.S., university inventors normally receive between 30-50% of the invention's net income (divided among all the inventors). A successfully licensed invention thus can provide a significant income. There has been some movement toward more directly considering commercialization activities in the academic personnel system, and yet, in first rank research universities it has been halting at best with many believing that the financial rewards for commercialization are sufficient to motivate those so inclined to undertake commercialization. In many cases, the Technology Licensing Office meant to encourage technology transfer may be creating barriers to transfer. If this is the case, then removing university technology licensing offices from the path could encourage greater levels of commercialization (Kenney and Patton, 2009, 2011).

In terms of technology transfer of economically valuable research, this essay argues that patents, in certain industries such as pharmaceuticals, may be of importance, but in many others, they are of less or even minimal importance. Moreover, in a patent-based transfer system in which patents are auctioned off to the highest bidder, smaller local firms are likely to lose out to large multinational firms that are almost certain to develop the invention extra-locally and as a result contribute little to local capability development. In the case of BSD Unix, which was open access, arguably the greatest beneficiaries were local Silicon Valley firms, both in terms of the technology but also the students that graduated. In the case of the Napa wine industry, there was a complex and bi-directional flow of knowledge, research questions, and individuals. Initially, the public funded research contributed enormously to the growth of the Napa wine industry, in later years it was the students, and, most recently, winery owners that have become generous contributors to the Davis campus.

Assessing the value of the proliferation of technology transfer institutions on university campuses is difficult particularly because it is difficult to measure the social and regional benefit, which is different than measuring the income to the university. This observation is specific to this case and leads to the larger question of whether university efforts to increase patenting is rendering private ever greater amounts of what were previously freely available research results, thereby decreasing the knowledge commons.

Technology transfer and the role of the university in regional economic growth has been the topic of this article, but the university contributes far more to local and global society. The university has a vital role as a social critic and home to the arts and humanities. While much of the discussion of the transfer of research results has focused upon private enterprise, as important or even more important is the transfer of research findings to society on issues such as poverty and global warming. These cannot be given a monetary value, and yet, their social value is undeniable. Absent a university that values all forms of knowledge, vital outputs such as these might be lost. A university focused only upon economic outcomes is likely to result in an impoverished region and society.

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