ETLA Working Papers

No. 13

12 June 2013

Martin Kenney

COMMERCIALIZATION OR ENGAGEMENT

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Suggested citation: Kenney, Martin (12.6.2013). "Commercialization or Engagement: Which Is of More Significance to the U.S. Economy?". ETLA Working Papers No 13. http://pub.etla.fi/ETLA-Working-Papers-13.pdf

ETLA ELINKEINOELÄMÄN TUTKIMUSLAITOS
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY

ISSN-L 2323–2420
ISSN 2323–2420 (print)
ISSN 2323–2439 (online)

Commercialization or Engagement: Which Is of More Significance to the U.S. Economy?*

June 10, 2013

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JEL codes: I23, O31, O33

* The author thanks Terttu Luukkonen for valuable comments and advice.
This paper was prepared for the Research Institute of the Finnish Economy (ETLA)
Project UNI (Universities, funding systems and the renewal of the industrial knowledge base)
and funded by Tekes (40422/11).

Abstract

Commercialization or Engagement: Which Is of More Significance to the U.S. Economy?

Beginning with the commercialization of genetic engineering (biotechnology) research beginning in the late 1970s and the passage of the Bayh-Dole Act, U.S. university administrators quickly built technology licensing (transfer) offices meant to commercialize inventions made by their researchers. By studying technology transfer in electrical engineering and computer science, statistics and mathematics, scientific instruments, and agriculture, this article demonstrates that biotechnology model does not accurately portray the ways in which most university technology is transferred to society. The application of the biotechnology/technology licensing office model to other university disciplines may stifle the diffusion of technology to society due to undue restrictions in the flow of technology; both from the university to society and, as important, the flow of ideas and resources from society to the university. Finally, it cautions against making wholesale changes in current institutional arrangements on the basis of the current U.S.-centric model based on biotechnology. For European policy-makers, the temptation to follow the U.S biotechnology-derived model may disrupt long-standing and quite successful channels of information transfer, while not bringing the supposed benefits of the U.S. model. This is particularly true because research on European university technology transfer is still at a very early stage.

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 and where all productive activities are increasingly being transformed by new knowledge, it is natural that policy-makers and society 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.[1] Over the last four decades, interest in the monetization of this knowledge has increased among policy makers and university administrators and 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." Moreover, nearly all research agrees that these 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 society.

The literature on the role of universities in society exhibits a number of deep biases: First, it adopts the imagined "U.S. model" described below as the single best global 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 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). Rather than seeing this 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 contributions of the university in the knowledge economy.

This paper begins by briefly introducing the many ways that universities transfer knowledge. We also introduce the term "academic engagement" as a more appropriate way to understand the social role of the university (Perkmann et al., 2012). This is followed by a description of the dominant mental model of technology transfer that emanated from the "biotechnology model" that first came into being in the U.S. during the 1980s. The next sections show that the biotechnology model is only one such model and in other university knowledge fields the mechanisms of technology transfer differ. In fact, it is shown that the biotechnology model does not adequately illustrate the mechanisms of academic engagement. This is followed by showing that not only is the biotechnology model inapplicable to other knowledge realms, but that the model itself is flawed. The penultimate section briefly considers what role of venture capital can play in the funding of university spinoffs. The conclusion suggests that less rigid and legalistic models may be more effective for technology transfer.

The Economic Roles of the Research University

Understanding the economic roles of the research university in capitalist nations is difficult because it is such a multi-purpose institution. However, nearly all observers believe that the two most economically significant roles are educating students and conducting research. In terms of educating, there is

[1] National Science Foundation statistics show that for the last thirty years, private corporations have provided less than 10% of total university research funding in every year. Even at institutions such as MIT, private funding has never exceeded 15%. In other nations, the percentage provided by industry is even less.

the provision of undergraduate and graduate education; both of which operate differently and have different goals. In terms of education 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 in terms of transferring knowledge. After students, studies of the channels of information flow have found that for industry invariably publications, informal interaction, meetings, and consulting are the most important channels of public research transmission (Meyer-Krahmer and Schmoch, 1998; Bonaccorsi and Piccaluga 1994; Link et al., 2007). Interestingly, patents are viewed as very important in "pharmaceuticals" (see, for example, Cohen et al., 1998, 2002: 11; Klevorick et al., 1995). Agrawal (2001: 285), summing up the findings of the academic literature, 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) because of the requirement that a patent sufficiently provide that someone skilled in the art be able to reproduce the patent. However, 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.

The more significant issue is what Agrawal (2001: 294) flags, namely that, "policies that affect 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 we believe current research suggesting that only very little of university knowledge diffusion occurs through TTOs and other such administratively centralized 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

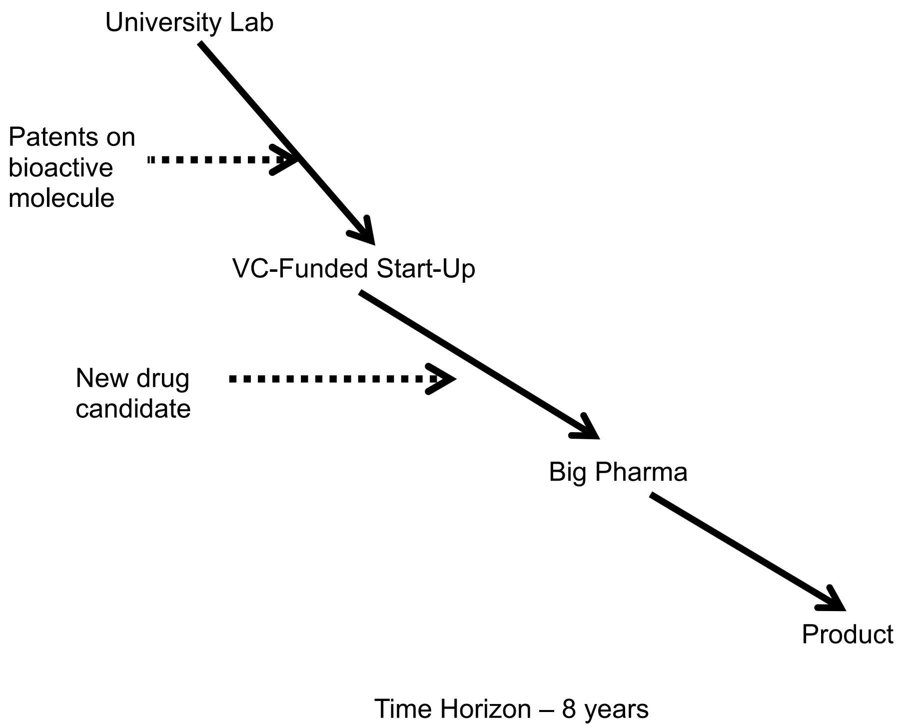
The roots of the biotechnology model are rooted in the recognition in the mid-1970s that some portion of the knowledge being developed in molecular biology had developed sufficiently to be commercializable (Kenney, 1986). In a remarkable period of less than a decade, the techniques of a branch of science became commercialized as a new industrial field termed "biotechnology." The founding knowledge for the firms in this new field 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 researchers 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 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 is largely linear and is really an outgrowth of a notion of technology transfer based on a stylized representation of how it is presumed technology transfer in biotechnology operates (see Figure One). In effect, this model reproduces Vannevar Bush's now deeply questioned linear model whereby inventions generated in basic research flow to applied research and then product development. 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).

In biotechnology, the university's generation of knowledge was funded by the U.S. federal government particularly the National Institutes of Health (NIH) and the National Science Foundation (NSF). A key event that made university patenting of federally funded research possible was the passage in 1980 of the Bayh-Dole Act, which awarded ownership of inventions made with federal funds to the university as an institution (Berman, 2011; Mowery et al., 2001, 2004). The Bayh-Dole Act was advocated by lobbyists for a number of research universities such as Stanford and, in particular, the Wisconsin Alumni Research Foundation, which owns all University of Wisconsin patents. This was motivated by a belief among administrators that the inventions, especially from their biology laboratories, could be an important new source of income. The Bayh-Dole Act recognized that inventors should be motivated to disclose their inventions and therefore mandated that they receive some share of any patent income – a clause that leaves the actual share to be determined by the employer (though it is codified in the researcher's employment contract).

While most of the discussion about biotechnology technology transfer envisions proprietary pharmaceutical applications, which would require 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 for Stanford University and University of California) and Axel Co-transformation patents ($790 million for Columbia University). The remarkable quality of these patents is that there is no credible argument that these technologies would not have been used absent a patent, as they diffused in the research community long before the patent issued (Colaianni and Cook-Deegan, 2009). In these cases, the only contribution by the university technology licensing office was the creation of a licensing contract and the collection of what was effectively a tax on commercial users. In the case of the University of Utah-discovered BRCA breast cancer gene, which was licensed to a small firm, 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 re-

Figure One: Stylization of the Biotechnology Model of Technology Transfer



Source: Author.

ceiving the test (Dalpé et al., 2003; Paradise, 2004). A similar situation has arisen in the use of University of Wisconsin developed embryonic stem cells where 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 (for a glowing analysis, see Jain and George, 2007; for one of many more balanced studies' analyses, see Murray, 2007).

As nearly all research indicates, patents are most valuable in the specialty chemical 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 or euphemistically termed "technology transfer offices") 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 were unable to practice their inventions in terms of producing products. However, they are permitted to receive income from patent licensing provided that it is reinvested in research-related activities. 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. Moreover, within industries there are firm differences. The innovation systems literature suggests that the organization of industries differ and thus could be expected to have differing types and levels of interaction with universities. Drawing upon research such as Cohen et al. (2002), there is little doubt that industry characteristics affect the types of engagements firms have with universities. This section uses illustrations from a variety of industries to demonstrate the diversity of interactions with the goal of showing that no one model best fits the university's engagement with society.

The Wine Industry and the University of California, Davis[2]

In the U.S., the oldest organized technology transfer model can be found in the land grant public universities and the 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 whose charge was to ensure that farmers are aware of the technology being developed at the University. The research results were most obviously embedded in seeds and cultivars that were 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 very influential technology diffusion such as Rogers (1962) and returns to research studies such as Griliches (1958) were based on the study of 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, much of this has been framed in uni-directional terms as universities develop new technologies such as seeds, pesticides, and new farm equipment, which is then

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

transferred to farmers through extension activities or commercialized by farm input industries such as the seed, chemical or farm equipment industries. The wine industry provides another and, perhaps, more interesting insight into the ways in which university research and training can lead to the creation of a high-value agricultural industry. In this section, we concentrate on the relationship between UC Davis and the Napa 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 (McDermott, 2007; 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 vintners in Napa Valley combined with University of California professors came to believe that it should be 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. In 1947, the Napa Valley vintners decided to purchase a twenty acre vineyard site in the heart of the region and donate it to the University so that researchers could experiment close-by. The university was also providing virus-free root stock to the region's growers. Effectively, 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 multi-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. In fact, 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?'"

As the product of a creative industry, wine is, perhaps, unusual as an agricultural industry in the level of interaction between local research and educational institutions and industry (see, for example, Giuliani and Arza, 2009 and McDermott, 2007). Moreover, lately this interaction has become even more complex. Recently, T. J. Rodgers, a wealthy technology entrepreneur and oenophile, contributed nearly $3.5 million on equipping the UC Davis student winery with entirely new 200 liter fermentation tanks that are connected using wireless technology (UC Davis, 2013). The manner by which the relationship began is interesting, as Rodgers was quoted saying:

> *I had a passion for red Burgundy, as well as degrees in chemistry and electrical engineering — but zero knowledge of winemaking — when I decided to plant our first pinot noir vineyard. Professor Boulton at UC Davis took my calls to ask him questions about a paper of his I had read, and UC Davis graduates like John Kelly taught me how to make wine (UC Davis, 2013).*

This case is, of course, serendipitous, but the larger point is that the professor was engaged with the outside community. In this situation, there was a technology transfer from a different industry, electronics, to the university.

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 is suggestive of the rich variety of ways universities and local firms and industries interact. Applying a single model such as the one developed in biotechnology would likely prove disruptive in the economically valuable model that developed in the wine industry – and most important would not further the public good.

Electrical Engineering and Computer Science

In engineering, it is widely recognized that technology transfer is not a linear process, but rather can be seen as a long-term communication that is 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.

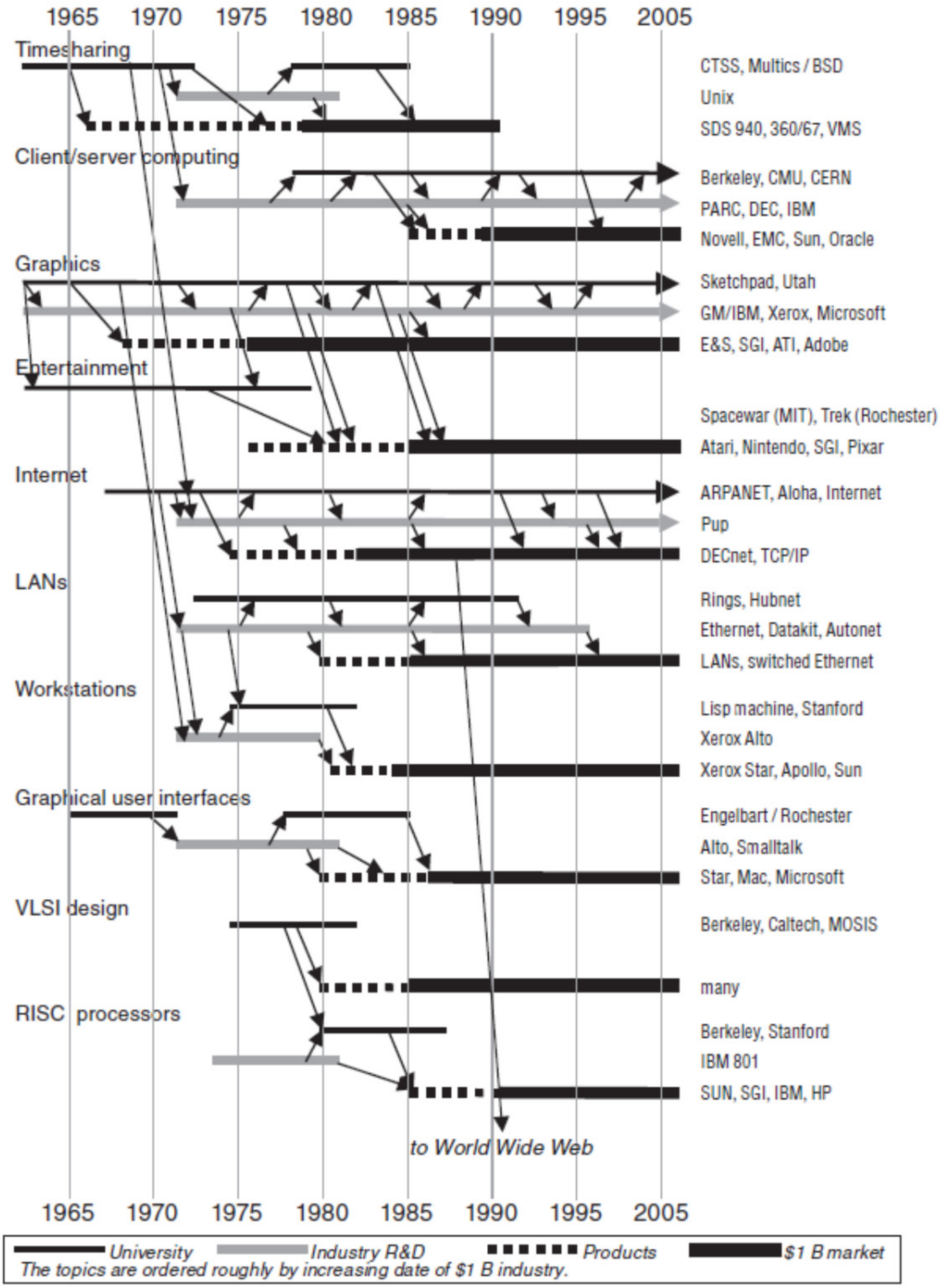
This complicated pattern of interaction is best illustrated in figures drawn from two influential studies by the U.S. National Research Council (1995, 2003, and 2009) that depict the interaction graphically. As Figure Two demonstrates tracing the development of many of the most important information and communications technologies (ICTs) developed during the last seven decades shows the interaction between the university and firms was bi-directional. Moreover, these university-industry interactions are the single most important source of U.S. global dominance in pioneering ICTs in the post-World War Two period. Of course, the scale and scope of federal government investment in university research is unrivalled by any other country or field except for the investment in biomedical technologies.

As Figure Two shows, in most, but not all, cases, universities made the initial developments; industry was an early contributor and, as the vertical arrows indicate, there was significant interaction between the universities and firms. This university interaction with industry can be further divided into interaction with large established firms and smaller startups that were often venture capital financed (National Research Council, 2009). Though Figure Two provides an overview of these interaction patterns, the true complexity and interdependence of the process is far more revealing.

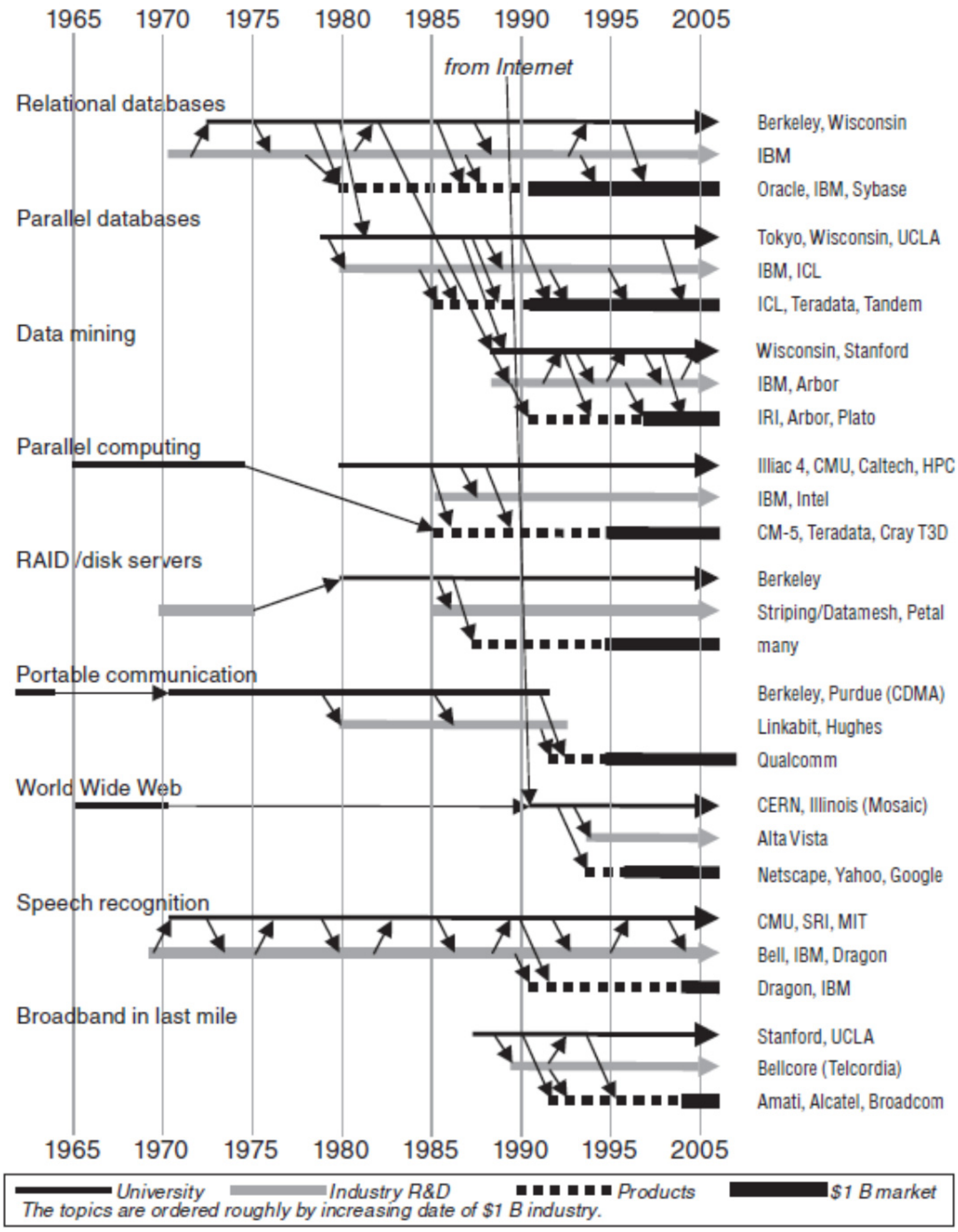
While Figure Two provides a high-level illustration, closer examination shows that the mechanisms for knowledge transfer are myriad and there are many channels for interaction and mutual learning. This is illustrated in Figure Three, though more granular is still a simplification of the process by which UC Berkeley Electrical Engineering and Computer Science faculty interacted with personnel at the Bell Laboratories to develop the improved Unix that was released to the public for free under the moniker "Berkeley Software Development Unix" (BSD Unix). Not only was there an interaction with the Bell Laboratories, but also with entrepreneurial Bay Area firms that utilized the software in commercial products.

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 took out a license

Figure Two: Examples of government-sponsored IT research and development in the creation of commercial products and industries



Source: U.S. National Research Council 2003: 6–7.

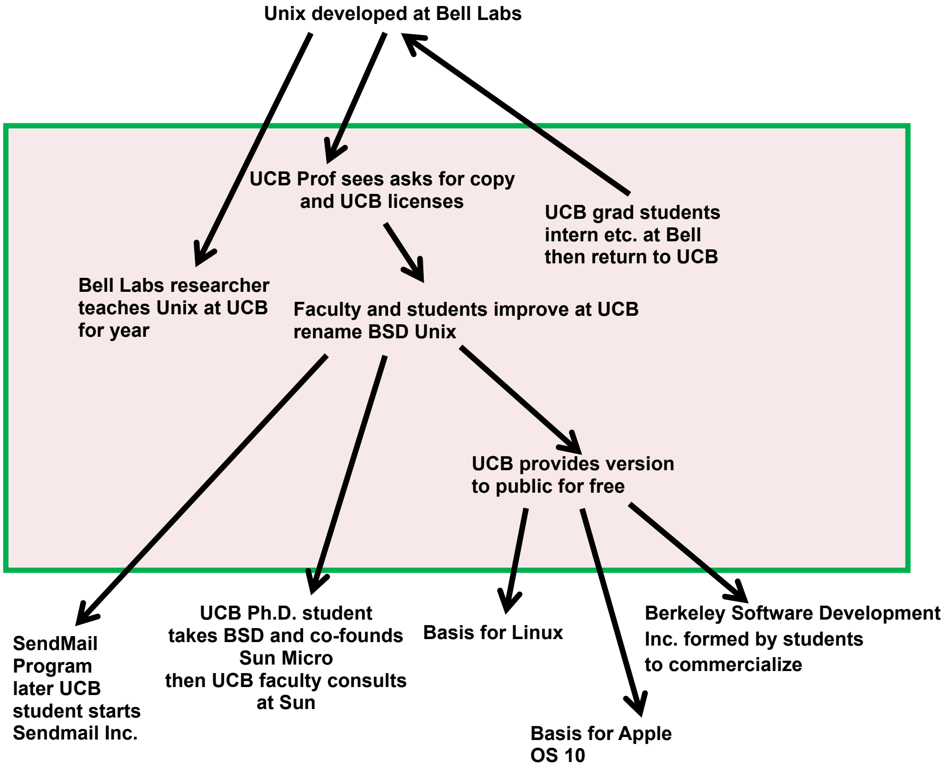


Source: U.S. National Research Council 2003: 6–7.

with 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 other 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. Additionally, 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 anyone requesting a copy. 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. As part of the team developing BSD Unix, Sendmail, the Internet mail server pro-

Figure Three: The Complicated Relationship between Bell Laboratories and UC Berkeley in Developing BSD Unix



Source: Kenney et al. 2013.

gram, was also introduced. Finally, much later the open access BSD Unix was integrated into the Apple operating system and was the inspiration for the Linux operating system used by many firms. 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 that can be managed by a technology transfer office. In fact, inserting an intermediary into engineering relationships might not improve the technology process at all.

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 Varian Associates. For another example, 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 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 of the greatest benefit (Mody, 2013; Lenoir, 1997). Most interesting, because these instrument firms are developing new applications at the cutting edge of physical phenomenon, they can identify scientifically meritorious problems, which university researchers can propose to federal funding agencies. In most respects, these dynamics are not so different from those encountered in engineering, except that the close relationships between scientific instruments might operate to 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 (see Table One). 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. Very few firms are indigenous entrepreneurial ventures that have been 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 (see Table One). SAS was established

Table One: Statistics and Mathematics-based University Spinoffs

Firm	Founder (s)	University	Date	Venture Capital	State	Employment	University Type
SAS	J. Goodnight	North Carolina State Univ.	1976	No	North Carolina	13,000	Public
Quintiles	D. Gillings	University of North Carolina	1982	No	North Carolina	27,000	Public
Wolfram Research	S. Wolfram	University of Illinois	1987	No	Illinois	400	Public
SPSS	N. Nie, C. Hull and D. Bent	Stanford/ Chicago	1975	No	Illinois	NA (acq. by IBM)	Private
WEFA	L. Klein	Wharton	1969	No	Pennsylvania	NA	Private
Ayasdi	G. Karlsson	Stanford	2008	Yes	California	NA	Private
Emcien	G. Marsten	Georgia Tech	2002	No	Georgia	NA	Public

Source: Author's compilation.

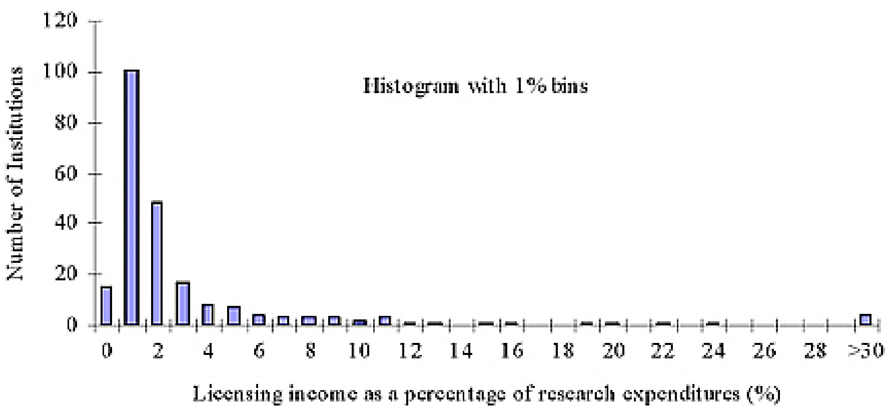
by a North Carolina State University statistics graduate student and professor that developed a statistical program for analyzing agricultural data. The team commercialized the program in a firm that has since grown to over 10,000 employees, the bulk of whom are located in the RTP region (SAS, 2013). Remarkably, the other major regional university-derived entrepreneurial success story, Quintiles, was the result of a similar situation when Dennis Gillings, a statistics professor at the University of North Carolina, began consulting for pharmaceutical customers. Eventually, he and another UNC professor, Gary Koch, established Quintiles. Quintiles never received venture capital and, as was the case with SAS, self-funded its growth.

These are two salient examples, but are a number of other firms that have been founded by professors in these disciplines. 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.

Patenting

For universities, securing a patent and then licensing the technology to a private firm is the most attractive method of monetizing a research invention. However, establishing a technology licensing office can be expensive and it is now generally accepted that in the U.S. only the twenty or so must successful offices are profitable; the remainder are money losers. Moreover, as Figure Four shows the income from technology licensing is trivial when compared to the overall institutional research budget.[3] The efficacy of university ownership, patenting, and technology diffusion can only be evaluated when the social goal is defined.

Figure Four: Histogram of licensing income as a percentage of university research expenditures, based on data from the Association of University Technology Managers (AUTM) U.S. Licensing Activity Survey: Fiscal Year 2007



Source: U.S. National Academy of Sciences, 2010: 23.

[3] This data is reported by AUTM, which is the association representing technology licensing professionals.

With the proliferation of technology licensing offices motivated by the Bayh-Dole Act, new procedures for the commercialization of inventions were inaugurated. With these new procedures came a remarkable desire for income by the university technology transfer offices, as Colaianni and Cook-Deegan (2009) show in the case of Axel patents. When Axel's patent was set to expire in 2000, the Columbia University TLO was able to convince a Columbia graduate, who was a U.S. Senator, to introduce amendments in other legislation that allowed Columbia to extend the patent by 15 months and thereby collect another $70–100 million dollars. In other words, the Columbia TLO was not satisfied with the returns, but actually was lobbying Congress to continue its monopoly rent accrual on inventions that were originally funded by the public. These types of actions by universities have led a Stanford Law Professor, Mark Lemley (2007), to accuse universities of being patent trolls, i.e., suing technology users in an effort to extract a "tax."

The Biotechnology Model of University Technology Transfer Reconsidered

The passage of the 1980 Bayh-Dole Act, which ceded the research results of all federally-funded research to university ownership, combined with the commercialization of molecular biology, led to the creation of technology transfer offices at every major US research university (see Mowery et al., 2004; Berman, 2011). While this has been widely hailed in the popular press, there has been an increasingly vocal critique of the new technology transfer model along two lines: First, conceptually this technology transfer model assumes that the biotechnology model where patenting is central to commercialization is generalizable to other sectors. The evidence for the biotechnology model is not strong. Second, there is an implicit assumption that inserting another actor into the relationship between university knowledge creation and commercial application will improve the process.

The increase in the desire of university's to benefit from professorial inventions has created stress in a variety of ways (Rai et al., 2008; Rooksby, 2011). In electrical engineering and computer science, corporate funders such as IBM, Intel, etc., as a condition of funding, have insisted that universities not patent discoveries made with their funding (Kurman, 2011; Mowery, 2007). There also have been an increasing number of lawsuits between inventors and their universities regarding the ownership and disposition of the intellectual property (Kenney and Patton, 2009). Finally, there has been increasing concern about the use of the intellectual property after it has been licensed to the private sector. For example, Harvard researchers invented, the university patented, and then exclusively licensed to DuPont a mouse that was susceptible to cancer. DuPont then proceeded to price the proprietary mouse very high, even to university researchers. There was an immediate negative reaction as the invention had been made with federal money, but was not available to the researchers (Murray, 2010). On one hand, this and other cases have resulted in U.S. research universities being criticized as become too privatized, and, on the other hand, being criticized for slowing or even stifling the transfer of knowledge to industry.

The Role of Venture Capital

Since the inception of the formal venture capital industry, universities have been a source of profitable investments (Hsu and Kenney 2005). More interesting, is the possibility (there is no research to confirm this suspicion) that universities have been an extraordinarily important source of fundamental firms and a number of these, but not all by any means, were funded by venture capitalists (see Table Two). While Table Two should be interpreted as anecdotal, rather than having any statistical validity. However, it is possible to make a few generalizations from the data. First, all of the biotechnology firms are spinoffs that include faculty and all were funded by venture capitalists. The reasons for this are the following: First, the pioneering biotechnology firms drew almost entirely upon university re-

Table Two: Important Direct University Spinoffs, Founder Affiliation, Field, and Venture Capital Financing

Firms	University	Affiliation	Venture Capital Yes/No	Field
Dell	University of Texas	Undergrad	No	Computers
Microsoft	Harvard	Undergrad	Yes	Software
Facebook	Harvard	Undergrad	Yes	Internet
Linkabyte/ Qualcomm	UCSD	Faculty	No	Communication
Broadcom	UCLA	Faculty/ Grad Student	No	Semiconductor
Genentech	UCSF	Faculty	Yes	Biotech
Chiron	UCSF/UCB	Faculty	Yes	Biotech
Yahoo	Stanford	Grad Student	Yes	Internet
Google	Stanford	Grad Student	Yes	Internet
Cisco	Stanford	Staff	Yes	Communication
Sun Micro	Stanford/UCB	Grad Student	Yes	Computers
Bose	MIT	Grad Student	No	Loudspeakers
Akamai	MIT	Faculty	Yes	Internet
Biogen	Harvard	Faculty	Yes	Biotech
Hybritech	UCSD	Faculty/Staff	Yes	Biotech
DEC	MIT	Staff	Yes	Computers
Amgen	UCLA	Faculty	Yes	Biotech
Quintiles	U. North Carolina	Faculty	No	Statistics
SAS	North Carolina State	Faculty	No	Statistics
Digital Instruments	UC Santa Barbara	Faculty	No	Physics
Beckman Instruments	Caltech	Faculty	No	Chemistry

Source: Author.

search. Key professors were the founders and drew upon the research done in their laboratories. In the information technologies, the pattern was more mixed, as undergraduates, graduate students, faculty, and staff members were important contributors. Also, venture capitalists through active were less prevalent than in biotechnology. In spinoffs from other fields such as statistics and sound equipment, there was far more self-funding from retained earnings. These results suggest that in certain industries, such as biotechnology, venture capital appears to be necessary for successful commercialization. However, in a study of the United States, Kenney and Patton (2005) found that there was a national market for venture financing. This suggests that entrepreneurs with an excellent prospect can find venture funding though it may not be from local venture capitalists.[4]

Venture capital funding does play a role in encouraging the commercialization of some university technologies through entrepreneurship and for biotechnology it appears to be crucial. However, for other technologies venture capital is of little significance as the firm can be self-funded from retained earnings. Having significant numbers of venture capitalists in proximity to universities can be beneficial, but cities such as New York, which have significant concentrations of venture capital and very good universities, have not seen significant numbers of university spinoffs, so many other factors must be in place to encourage successful commercialization of university inventions.

Discussion

In many respects, 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). More recently, Sweden has decided that moving to the Bayh-Dole model might disrupt important channels of knowledge transfer and has 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.

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 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 than (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. For BSD Unix, arguably it was the open access and the lack of commercial intent that made it such a successful program and fueled its diffusion, though eventually it would be surpassed by Linux. In the case of the Napa wine industry, there was a complex and bi-directional

[4] Conversely, the reason there is no local venture capital in peripheral regions is that there may not be sufficient local deals to support them. In the U.S. the venture capitalists that fund biotechnology deals are clustered in the San Francisco Bay Area, New York, and Boston. In Europe, the most important cluster is in London.

flow of knowledge, research questions and individuals. While the public funded the research that contributed to the growth of the Napa wine industry, in later years winery owners proved to be 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 benefit, which is different than measuring the income to the university. Beyond the overhead from the federal grants, the EDA software provided no direct income to UCB (though when the EECS Department decided to expand its building, the industry made significant cash and in-kind contributions). And yet, the social gain was enormous. Arguably, if Berkeley had tried to maximize income from the software by licensing it to a single party, the proliferation of startups in the Bay Area would have been truncated and the software is likely to have developed more slowly thereby reducing the overall social benefit. 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 economic growth has received enormous attention, unfortunately the other social roles of the university as a social critic, home of the arts and humanities, and, foremost, as an educator seem at this time to be neglected. Moreover, much of the discussion of transfer of research results has focused upon private enterprise, but perhaps as 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 society.

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