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Commercializing University Innovations: Alternative Approaches

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Executive Summary

For much of the past century, universities and university-based researchers have played a critical role in driving technological progress, from the fortification of milk with vitamin D in the 1920s to the creation of Google in the 1990s. In the process, universities have been a strong catalyst for U.S. economic growth. But a perennial challenge related to university-driven innovation has been ensuring that university structures help—not hinder—innovation and the commercialization of innovations. Multiple pathways for university transfer exist and can be codified to provide broader access to innovation, allow a greater volume of deal flow, support standardization, and decrease the redundancy of innovation and the cycle time for commercialization. The proposed changes focus on creating incentives that will maximize social benefit from the existing investments being made in research and development (R&D) and commercialization on university campuses.

I. Introduction

Today we take for granted the rapid pace of technological progress that has carried many national economies forward for the past 200 years. Continued innovation that has diffused through the marketplace has made this progress possible. In turn, entrepreneurs have been instrumental in commercializing innovations, especially the radical or breakthrough innovations—such as the automobile, airplane, air conditioner, and personal computer, among others—that have transformed economies and societies in fundamental ways that the more typical incremental innovations associated with large corporate enterprises have not (Baumol 2002).

As technologies have grown more sophisticated and emerging industries have become more high-tech, universities have become more important players in the processes of invention, innovation, and commercialization. We have written this paper largely because we anticipate universities playing an even more important role in the innovation process in the future.

To be sure, bringing innovations to market has not been the main historical role of university-based researchers. Instead, university researchers quite appropriately concentrate on basic science. But the ultimate aim of scientific research, after all, is to improve the human condition, and so aiding the transfer and commercialization of discoveries serves the interests of the inventor and society. "Since the Industrial Revolution, the growth of economies around the world has been driven largely by the pursuit of scientific understanding, the application of engineering solutions, and continual technological innovation" (National Academy of Sciences and National Academy of Engineering 2006, 41). Ideally, university structures should support all aspects of this process, from invention to innovation, as well as commercialization.

In theory, the Bayh-Dole Act of 1980 was supposed to make commercialization easier by clearing the way for universities to claim legal rights to innovations developed by their faculty using federal funding. This clearly was a constructive step forward. But with new rights have come new layers of administration and often bureaucracies. Rather than implementing broad innovation/commercialization strategies that recognize different and appropriate pathways of commercialization, as well as multiple programs and initiatives to support each path, many have channeled their innovation dissemination activities through a centralized technology transfer office (TTO).

We have spent the last several years discussing the role of TTOs with multiple university leaders and researcher-innovators. While we have found that some universities have enabled their TTOs to disseminate innovations effectively, in too many other cases, university leaders have backed policies that encourage TTOs to become bottlenecks rather than facilitators of innovation dissemination. Where this has happened, it is because TTOs have been charged with concentrating too heavily on maximizing *revenues* from the licensing of university-developed intellectual property, rather than maximizing the *volume* of innovations brought to the marketplace.

What can be done to better achieve this essential objective? What should be done? Our central purpose here is to answer these questions. We begin with a brief background of university research, move on to discuss the emergence of technology transfer as a university goal, and then describe how technology transfer exists on most campuses today.

We believe the current process is suboptimal, however, and thus offer universities several alternative pathways to enhance and accelerate commercialization and spillover activities. These alternatives all are predicated on the view that society is likely to benefit more if universities seek to maximize the volume and speed of their commercialization activities rather than pursue the conventional objective of maximizing licensing revenue. Four approaches are offered as examples. These approaches range from the more conservative expansion of technology transfer matching services via the Web to the more radical free agency model, which would have universities relinquishing intellectual property rights to faculty. No single approach is right for all universities given the incredible diversity of types of research and local/regional contexts in which universities exist. We offer potential approaches that are meant to encourage further local discussion among university leaders, technology transfer professionals, and faculty.

II. Financing of University Research: A Brief Background

For several decades after World War II, most R&D in the United States was financed by the federal government, specifically through the National Science Foundation, the National Institutes of Health, and the Department of Defense (figure 2.1). By 1979, industry R&D expenditures passed government spending, growing more than threefold after controlling for inflation between 1975 and 2000. By comparison, while government funded R&D rose quickly after the war, since 1975 it has inched up about 75 percent (National Science Foundation 2006). Government funded R&D has focused, appropriately, more on basic than applied research, while the priorities of private R&D spending have been reversed.

As figure 2.2 shows, industry performance of government funded R&D rose quickly from 1955 to the early 1960s, but has since fluctuated significantly. Conversely, universities and colleges have shown a steady acceleration in their R&D performance, particularly with basic research. Today, more than half of basic research is conducted in universities (figure 2.3). And while much less is spent on basic science than on applied science, the absolute dollars of funding going into basic science are a misleading indicator of its importance as basic science stands at the base of our economic "pyramid." These breakthroughs in basic science, after all, have created new industries.

U.S. institutions of higher learning and their research output appear

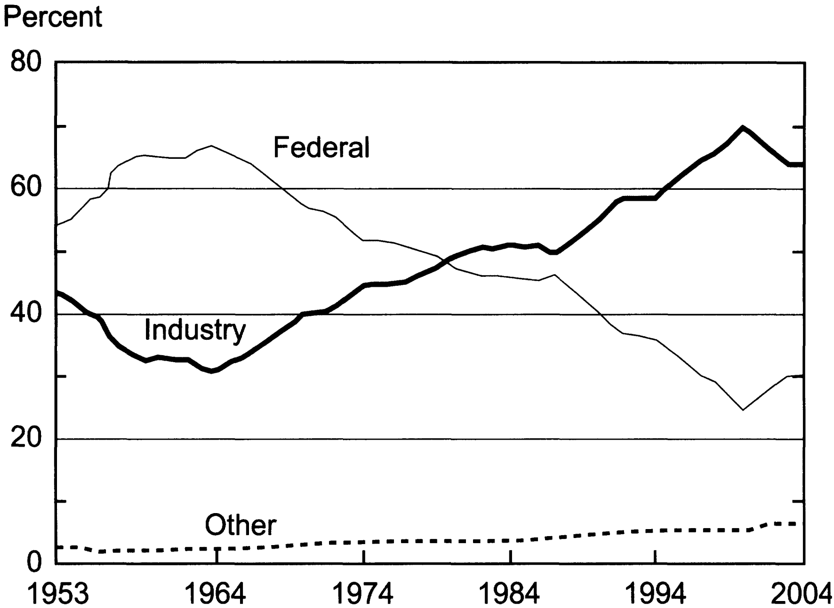

Figure 2.1
Research and development funding, 1953–2004.
Source: National Science Foundation (2006).

to be in good shape, remaining atop the standard global rankings. But there are several disturbing signs beneath the surface:

- The United States has experienced stagnant to declining levels of industrial R&D investments, decreasing industry-university coauthorships, and decreasing citations of U.S. science and engineering articles by industry (Rapoport 2006).
- There is some indication that foreign-sourced R&D is being driven in part by access to foreign universities and that the type of science is driven primarily by access to and the quality of university faculty (table 2.1) (Thursby and Thursby 2006).
- Industry investments in U.S. university-based R&D have stagnated.

For forty years, funding from industry to universities steadily rose, and now for four consecutive years, universities have seen stagnation in industry support at the aggregate and micro level. It is too early to know whether this is a long-term trend, let alone the reasons for it, but there is reason for concern (see figure 2.4 and 2.5).

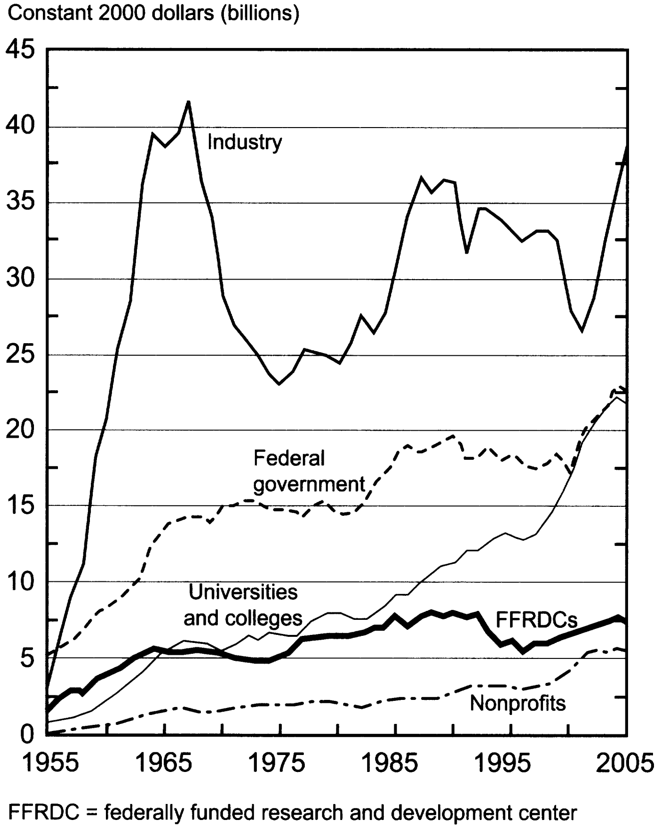

Figure 2.2
Research and development performance, 1953–2004.
Source: National Science Foundation (2006).

Anecdotally, it appears that, relative to some foreign universities, U.S. universities are becoming less friendly to collaborations and commercialization. In particular, U.S. universities historically have benefited significantly from an inflow of R&D capital from U.S. affiliates of foreign companies (particularly European companies). These benefits are threatened, however, by a growth in bureaucracy and an increasing (and shortsighted) emphasis on the part of U.S. universities, acting through their TTOs, on securing intellectual property rights to inventions by their faculty (Lemley 2007). If these two trends continue, the flow of R&D funding from these U.S. affiliates is likely to slow, if not reverse (figure 2.6).

In short, if the U.S. economy is to continue its rapid pace of economic growth, it will be necessary not only to adopt innovations from other

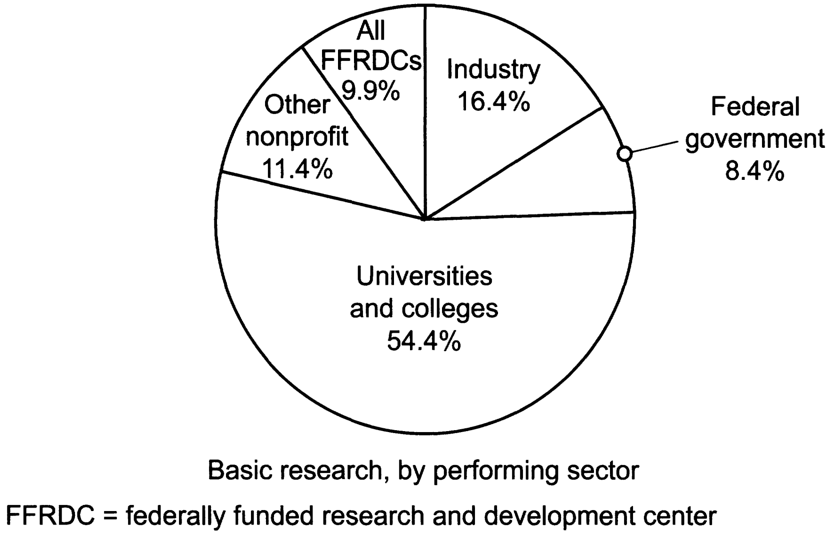

Figure 2.3
Basic research, performance, 2004.
Source: National Science Foundation (2006).

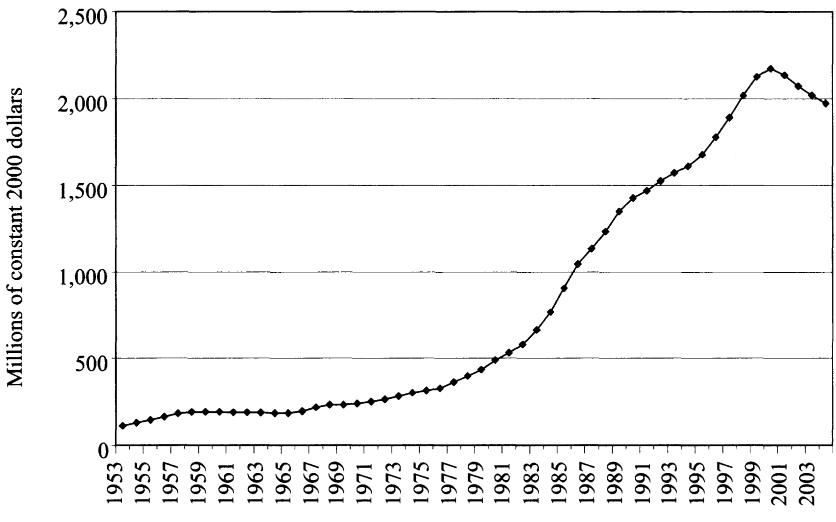

Figure 2.4
Industry funding of university research, 1953–2004.
Source: National Science Foundation (2006).

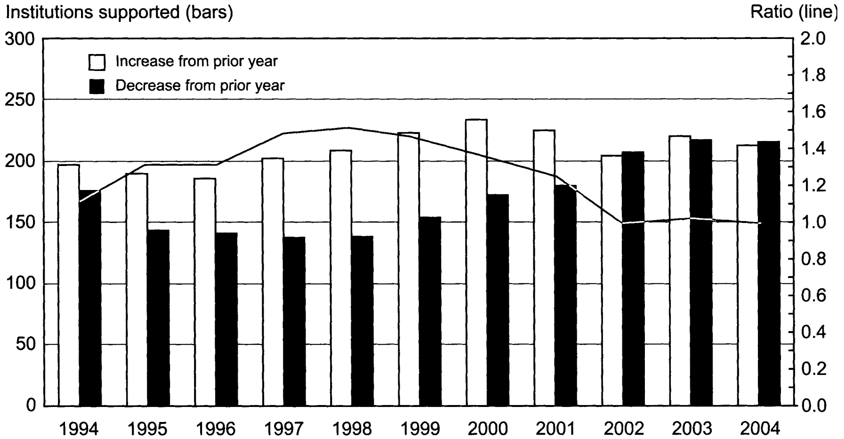

Figure 2.5
Trends in industrial R&D and support.
Notes: Ratio is the number of institutions reported increasing industrial R&D expenditures from prior year divided by number of institutions reporting decreased industrial R&D expenditures from prior year. Institutions with imputed or estimated values are excluded from the analysis.
Source: Rapoport (2006).

parts of the world but also to make investments in basic research in a setting that supports commercialization, spillovers, and general interactions between academic researchers and industry. In the discussion that follows, we will briefly discuss the ways in which universities and industry currently interact, paying particular attention to TTOs that are now found on many campuses. Outside the TTO setting, universities and industry also engage with each other in a host of ways that can be better understood and nurtured for the health of both parties. We will discuss the important role that culture appears to play on university campuses at the departmental level and how universities must consider more than just their policies toward TTOs if they want to encourage and support invention and entrepreneurship.

III. The Rise of University Technology Transfer

When Harry Steenbock demonstrated a means of fortifying vitamin D in food and drugs through a process called irradiation, he became concerned with how the technology would be implemented. Specifically, Steenbock recognized that unqualified individuals or organizations

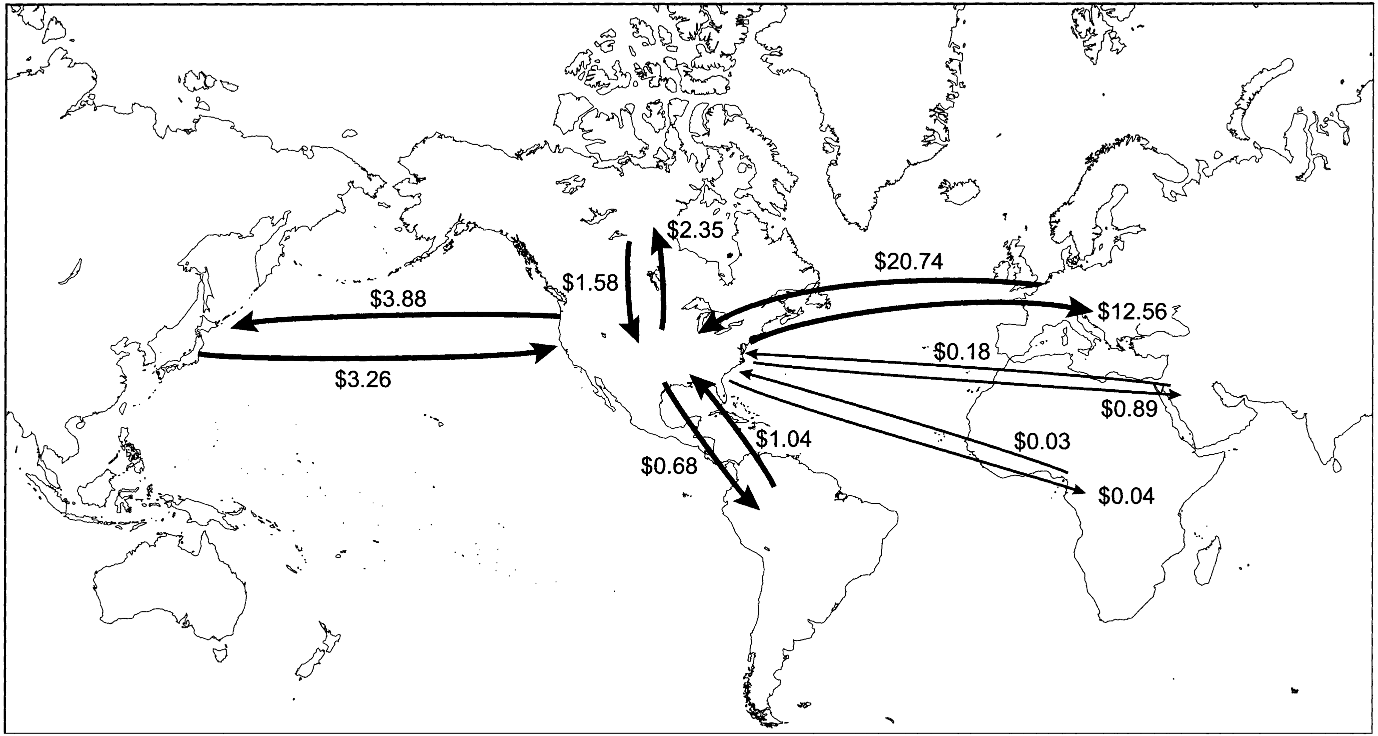

Figure 2.6
R&D investment flows by U.S. and foreign multinational corporations (billions of current dollars).
Notes: Preliminary estimates are for 2002. Regional totals are for foreign affiliates of U.S. multinational corporations located in Europe and in Latin America and other Western Hemisphere are sums computed by the National Science Foundation, based on available country data for those regions. Data for foreign affiliates located in Africa and U.S. affiliates of foreign companies from Middle East are for 2001.
Source: National Science Foundation (2006).

Table 2.1
Relative factor importance in choosing where to locate R&D facilities

Factor[a]	Rank
University collaboration	1
Faculty expertise	2
Costs	3
Growth	3
Supporting sales	5
Intellectual property protection	Not important
Ease of ownership	Not important
Quality R&D personnel	Not important

[a]Costs of R&D are exclusive of tax breaks and government assistance; growth refers to market growth potential in that country; ease of ownership is the ease of negotiation for ownership of intellectual property (IP) from research relationships; and IP protection refers to its strength.
Source: Thursby and Thursby (2006).

could use his invention, and possibly do harm, unless he brought it to market with legal protection—that is, a patent. The University of Wisconsin, where Steenbock worked at the time, declined his offer of patent ownership. Working with alumni, Steenbock instead created the Wisconsin Alumni Research Foundation (WARF), a separate entity that was university-affiliated and could accept patents, license them out, and disperse revenues back to the inventor and the university without exposing the university to potential financial and political liability. And thus, in 1924, the nation's oldest TTO was conceived (Sampat 2006), although in unusual fashion as WARF does not operate directly under university control.

It took another fifty years for the confluence of changing federal law, patterns of R&D investment, knowledge-intensive emerging industries, shifting focus in regional economic development, growing knowledge of commercialization success stories, and declining levels of public support for universities to rapidly accelerate the practice that Steenbock helped to establish (figure 2.7).

By the 1960s and 1970s, formal endorsement of technology transfer from federally-funded research was bubbling up on the federal policy agenda. The Department of Health, Education, and Welfare; the National Institutes of Health; and the Department of Defense began to grant to selected universities the rights to patent inventions resulting from their funded research. But these rights were often negotiated, and

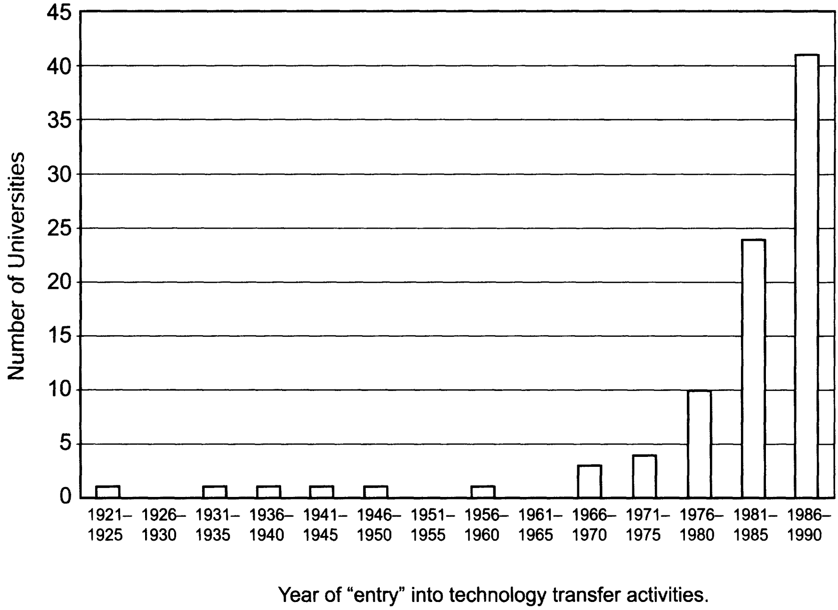

Figure 2.7
Age of technology transfer programs.
Source: Sampat (2006).

the seeming bureaucracy that this created frustrated many, including then Senator Robert Dole who commented "rarely have we witnessed a more hideous example of over management by the bureaucracy" (Sampat, 2006, 779).

Congress enacted the Bayh-Dole Act of 1980 largely to address this problem and to accelerate the commercialization of federally funded research at universities that yielded promising new technologies. When it came into law, Bayh-Dole had the practical effect of standardizing patenting rules for universities and small businesses, something that previous conflicting laws had not done. The federal government was off the hook, and the universities were given the opportunity and obligation to commercialize innovations resulting from federal funding. While Bayh-Dole didn't create technology transfer as a university practice, the explicit endorsement of these activities by policymakers seems to have pushed the last remaining campuses without explicit technology transfer functions to establish them (Sampat 2006; Rogers, Yin, and Hoffmann 2000).

Other trends or forces that were prevalent or emerging around and after the passage of Bayh-Dole helped establish technology transfer as a primary part of many university missions (Mowery et al. 2001), at a time when public support for universities began to decline (Feller 2004). It is understandable, therefore, that many universities began to look to technology transfer—and the offices that were in charge of it, the TTOs—as new potential sources of revenue.

It should be clear, however, that the development and growing importance of TTOs that followed Bayh-Dole were not the stated goals of the legislation. The TTOs instead were the *product*—more than likely the *unintended consequence* of the act.

IV. Today's Technology Transfer "System"

While there is evidence that some investments made in basic research at universities have been successfully commercialized through the technology transfer process, there is a plausible, if not convincing, case to be made that the results could be better. Commercialization of university research (whether judged by numbers of patents, licensing of revenue, or new companies formed) remains differentially successful, and as shown in figure 2.8, largely concentrated in just a handful of universities. Thursby and Thursby, in analyzing 2004 statistics from the Association of University Technology Managers (AUTM), find that 40 percent of responding TTOs earned less than $600,000 after accounting for payments to other universities and legal fees *but before* accounting for the salaries of TTO employees (Thursby and Thursby, forthcoming). This is not an outcome one would expect from a nation rich in scientific talent at many universities.

Ironically, this outcome nonetheless is one *product* of the prevailing model of commercialization activities that took root in the 1980s. Many universities have established the TTO as a monopoly, centralizing all university invention and commercialization activities. They do this by requiring all university faculty members to work through these offices by notifying them of their discoveries and delegating to them all rights to negotiate licenses on their behalf. In addition, many university administrations often have rewarded TTO offices and their personnel based on the revenues they generate rather than on the volume of the inventions the universities transfer or commercialize. We label this current system the *revenue maximization model* of technology transfer, even though

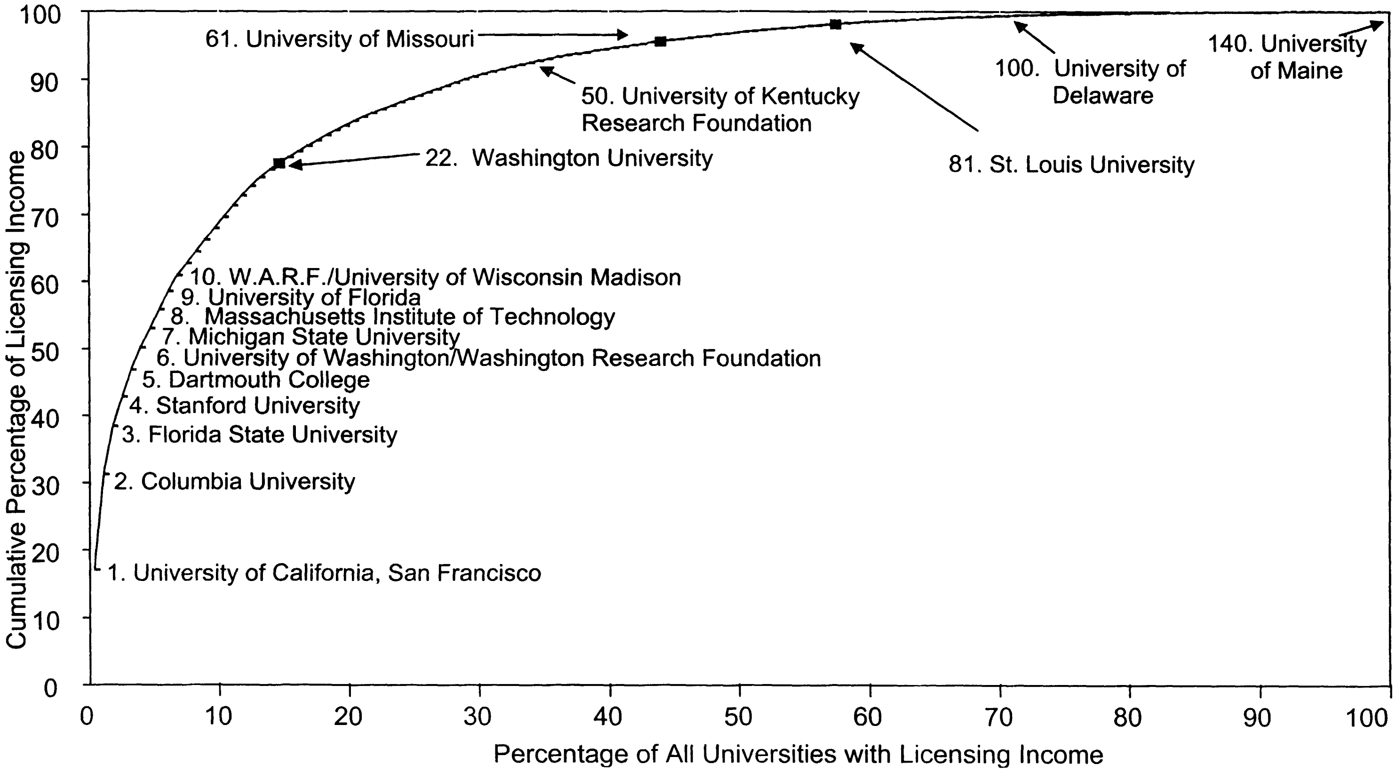

Figure 2.8
Cumulative distribution of licensing income among universities, 1999 and 2000.
Note: $N = 140$.
Source: AUTM technology transfer data for two-year recurrent respondents.

Table 2.2
Technology transfer office mission statements

Primary objectives of the UTTO	Percentage of times appeared in mission statement
Licensing for royalties	78.72
Intellectual property protection/management	75.18
Facilitate disclosure process	71.63
Sponsored research and assisting inventors	56.74
Public good (disseminate information/technology)	54.61
Industry relationships	42.55
Economic development (region, state)	26.95
Entrepreneurship and new venture creation	20.57

N = 128 UTTOs.
Source: Markman, Phan, et al. (2005).

there is some evidence to suggest that universities structure their TTO operations only to maximize revenues in the short term.[1]

We believe that there are several flaws in the revenue maximization model of university technology transfer. One is that the current reward structure and the centralization that accompanies it have encouraged TTOs to be gatekeepers rather than facilitators of commercialization. This is less the fault of the TTO staffs than it is of how their offices were structured, with the majority of financial and human resources dedicated to patent licensing and minimal resources dedicated to nonpatented innovations, that is, materials, tools, or software. But the net effect is that TTOs, like any monopoly, do not have incentives to maximize "output"—or the actual numbers of commercialized innovations—but instead to maximize only revenues earned by the university (table 2.2).

This, in turn, leads to a "home run" mentality, whereby many TTOs focus their limited time and resources on the technologies that appear to promise the biggest, fastest payback. Technologies that might have longer-term potential—or that might be highly useful for society as a whole, even if they return little or nothing in the way of licensing fees (such as many "research tools" used mainly by other researchers)—tend to pile up in the queue, get short shrift, or be overlooked entirely.

How predominant is the revenue maximization model among TTOs? Markman, Phan, et al. (2005) found that the principle mechanism favored by most TTOs was licensing for cash (72 percent), with licensing for an equity stake and sponsored research less popular at 17 percent and 11 percent, respectively. These interview-based findings were confirmed by the researchers in a review of TTO mission statements that showed a heavy focus on licensing and protection of the university's intellectual property (Markman, Phan, et al. 2005). Other research in this area has found that revenue, licensing, and inventions commercialized all drive TTOs, indicating a slightly broader prevailing set of goals (Thursby, Jensen, and Thursby 2001).

With revenue maximization as a central goal, it also is not surprising that most depictions of technology transfer activities are portrayed as very linear processes in which research is performed, inventions are disclosed, technology licenses are executed, income is received, and wealth is generated (Siegel et al. 2004).

But the process of technology transfer actually is much more complex. Patenting and licensing of research are not the only means—or even the most important means—of "transferring" new knowledge from universities to the market. Universities have a *range* of outputs, including information, materials, equipment and instruments, human capital, networks, and prototypes (Siegel et al. 2004). The means by which these outputs are diffused, especially to industry, vary across universities (Sampat 2006). The Carnegie Mellon Survey of Industrial R&D found that the most commonly reported mechanisms for diffusion of public research to industry were publications, conferences, and informal exchanges. Patents ranked low in most industries except for pharmaceuticals (Cohen, Nelson, and Walsh 2002). Measuring university success in spawning innovation solely by licensing or patenting activities, therefore, almost certainly masks the importance of these other means of knowledge diffusion.

These other means include nonpatent innovations, start-up companies launched by university faculty or related parties, and consulting engagements between industry and faculty. One recent study, for example, indicated that approximately 29 percent of patents with public university faculty inventors were assigned to firms rather than the university (Thursby and Thursby 2005a), which indicates a significant degree of faculty-industry engagement, whether formally through TTOs or informally through other pathways (Siegel et al. 2004).

Meanwhile, university faculty members are learning ways to maximize their own self-interest within a general environment that impels TTOs to maximize revenue. In particular, and not surprisingly, faculty engaged in commercialization activities are becoming more competent in these endeavors. One measure of this is the significant increase in rates of disclosure of innovations over time by faculty, perhaps the best indicator of university-based technology transfer at the faculty level (Thursby and Thursby 2003; see table 2.3).

Still, university commercialization activity remains highly concentrated within the university itself—with somewhat less than 20 percent of university faculty rarely engaged in patent disclosure of any kind—even less than the proverbial "80/20" rule (Thursby and Thursby 2003). Further, there is a trend toward greater university ownership of research and commercialization, reflected in the significant increases in university patenting (Coupe 2003), increased contributions to R&D spending, and the proliferation of university spin-offs and research parks (Mowery et al. 2004).[2] University spin-offs, in this context, are defined as "firms founded on a contractual agreement, such as an option of a license, regarding intellectual property for which the university maintains title" (Lowe 2002, 6). Some spin-offs reside in incubators near campuses, but this is not always the case.

Spin-offs pursue paths and opportunities that larger, more established companies may be precluded from or less equipped to develop.

Table 2.3
Trends of faculty engagement in entrepreneurship

	Percent disclosing		
Years	Female	Male	Ratio (male/female)
1983–85	2.04	3.13	1.53
1984–86	2.18	3.49	1.60
1985–87	2.75	4.60	1.67
1986–88	2.96	5.80	1.96
1987–89	3.08	6.64	2.16
1988–90	3.91	6.82	1.74
1989–91	4.68	7.46	1.59
1990–92	5.40	8.10	1.50
1991–93	6.63	9.14	1.38
1992–94	7.70	9.81	1.27
1993–95	8.89	10.28	1.16
1994–96	8.62	10.73	1.25
1995–97	9.07	11.23	1.24
1996–98	9.73	11.79	1.21
1997–99	10.58	11.88	1.12

Source: Thursby and Thursby (2005b).

Of the inventions licensed in the previous five years, TTOs reported that 45 percent were at the proof-of-concept stage, 37 percent were lab scale prototypes, 15 percent were manufacturing-ready technologies, and 12 percent were market-ready inventions (Thursby, Jensen, and Thursby 2001). Another survey of sixty-two universities found that new and small companies tend to license early stage technologies that are passed over by large firms (Thursby, Jensen, and Thursby 2001). With venture capital firms moving toward later stage investments (Price Waterhouse and National Venture Capital Association 2007), the role of universities in nurturing early stage start-ups may be increasing in importance.

While spin-offs from universities are few in number, they are disproportionately high performing companies and often serve as a mechanism to bridge the development gap between university technology and existing private-sector products and services. A quick look at the data confirms this point. Although only 3,376 academic spin-off companies were created in the United States from 1980 to 2000, fully 68 percent of these companies remained operational in 2001 (AUTM 2002). One study has estimated that 8 percent of all university spin-offs had gone public, 114 times the "going public rate" for U.S. enterprises generally (Goldfarb and Henrekson 2003). As impressive as these figures are, they understate the extent of university-based entrepreneurship because they do not include start-up companies represented in business plan competitions, back-door entrepreneurial activities emerging out of faculty consulting, and general spillovers from graduate students creating companies tied to outcomes of university research.

One other important measure of technology transfer is the time between discovery and commercialization. Accelerating the pace of commercialization provides more benefit to both the university (quicker return to R&D) and the commercializing agent (more flexibility with time in terms of testing or bringing to market; Markman et al. 2005a). In reviewing the commercialization time of patented protected inventions in ninety-one universities, Markman, Gianiodis, et al. (2005) found that speed had a positive effect on licensing income or start-up creation (Markman, Gianiodis, et al. 2005). Still, even in this study, the average commercialization speed—from discovery to licensing or spin-off—was just over four years.

We believe there must be a better way of advancing university inventions. Commercialization policies can and must be structured to realize the social benefits of a wider number of innovations. The question is how, and it is to this subject that we next turn.

V. Proposed Models for Advancing University Innovation

Universities commercialize the innovations developed by their faculty largely by licensing the intellectual property in these breakthroughs (typically patents) to entrepreneurs, to the faculty members themselves, or to established companies. Historically, university faculty and students have generated a range of innovations that have found their way into the market and have helped launch new companies. The Internet browser (Netscape), Internet search engine (Google), and various biotechnologies (Genentech) are just a few examples (Association of American Universities 1998). There are, however, strong reasons to believe that the objectives of Bayh-Dole could be met even more effectively.

During the 1980s and 1990s, most universities had little experience negotiating with industry and considering commercialization activities. With time and experience, however, universities and, more importantly, faculty have gained expertise in the invention and innovation processes. As individual university cultures and disciplinary practices have evolved, some universities have begun to recognize that commercialization and innovation activities are larger than what can run through a single office and require cross-university programmatic initiatives in the classroom and the laboratory. Examples of universities that have moved in this direction include MIT, with a high number of faculty who have been founders of start-up companies; the University of Arizona; and the University of California. Examples at the University of California include the BioInfoNano R&D Institute, which is an effort to create a commons around shared work while still respecting the interests of member companies and start-ups; and Berkeley's one-stop shop for industry research partners and their leadership in implementing the socially responsible licensing program.

As these new forms emerge or, more accurately, as TTOs become just one component of the innovation and commercialization ecosystem, technology transfer will increase in efficiency, volume, and quality on most college campuses. Indeed, technology will be best diffused by recognizing and taking advantage of the decentralized nature of innovation and university faculty who participate in this process.

In his classic work, *Diffusion of Innovations,* Rogers delineates two models of technology diffusion systems: "Centralized diffusion systems are based on a more linear, one-way model of communication. Decentralized diffusion systems more closely follow a convergence model of communication, in which participants create and share information with one another in order to reach mutual understanding" (Rogers 2003, 398). If this distinction is right, and we believe it is, then a change in the practice of innovation and commercialization will not be achieved simply by creating a single, central office. Instead, technology will be best diffused by recognizing and taking advantage of the decentralized nature of innovation and university faculty who participate in this process.

It is also important to consider university culture in fostering or supporting entrepreneurial activity among faculty. The shrinking gap in disclosure and other entrepreneurial activities by women, for example, is evidence that incremental changes in culture and practice can have important effects on university culture (Thursby and Thursby 2005b). Bercovitz and Feldman also found strong evidence for the impact of the micro-level work environment on faculty patterns of invention disclosure in a study of a group of matched faculty at two prominent medical schools. In this study, disclosure increased when a faculty member was at an institution with a tradition of disclosure, observed others in a department disclosing, and worked in a department with a chair who actively disclosed. The authors also found evidence that the institutional norms where academics completed their training influenced future technology transfer proclivity, but they determined that individuals ultimately were most likely to alter their activities to conform to local norms (Bercovitz and Feldman 2006).

Not only do research faculty members appear to have a profound influence on the innovation and commercialization of other academic researchers at their universities, but also these individuals are the key agents of knowledge transfer (Markman, Gianiodis, et al. 2005). Many technologies licensed from universities are nascent in their development, and much of the value in the innovation lies in the tacit knowledge of their inventors (Jensen and Thursby 2001). Faculty members also tend to become more attuned to the potential for application and commercialization of their research over time. Experience with invention and commercialization, as well as consulting, advisory board service, industry-sponsored research, and formal commercialization activities, allow faculty members to become more familiar with the process and affect the direction of their future research (Mansfield 1995).

Given the importance of faculty researchers to innovation and commercialization, a university culture that is accepting of entrepreneurial activities is best built from the ground up by researchers who promote and connect other colleagues both inside and outside of academe. But how can universities support the development of entrepreneurial capabilities in their faculty? The answer does not lie, in our view, in expanding the role for TTOs. Many research faculty members are likely to have better opportunity recognition skills—both scientific and entrepreneurial—than TTO professionals. After all, academic researchers have spent years working in their fields, and they have incentives within their disciplines to recognize avenues for scientific advances and breakthroughs. Furthermore, researchers' "social capital"—their professional relationships with their peers inside and outside the academy—give them a greater ability to link scientific opportunity recognition to entrepreneurial opportunity recognition.

To be sure, these opportunity recognition skills—particularly for commercial opportunities—take time to develop. One does not expect to achieve cultural transformation overnight. Many university campuses have experienced a gradual cultural change since the passage of Bayh-Dole, and they now face the challenge of defining multiple pathways to support university innovation and commercialization and redefining the role of TTOs.

It has been suggested that TTOs should reorganize in ways that would reduce the potentially significant "transactions costs" involved in moving scientific discoveries more rapidly into the marketplace. These costs include tangible and intangible expenses related to the identification, protection, and modification of innovation and commercialization as well as the administrative expenses and the opportunity costs for the time that would be required by researchers. To reduce these costs, it has been suggested that TTOs adopt something like a value-chain model (Phan and Siegel 2006) that encourages universities to disaggregate their functions, slicing and dicing a range of what are considered to be technology transfer functions and assigning them to specialists, while leveraging outside organizations and other partners in the process.

We build on this basic concept, recognizing both the comparative advantage of faculty in opportunity recognition and the limited budgets of university administration. In particular, we believe universities must recognize that patenting is only one of many pathways from innovation to marketplace. We argue, therefore, for a change in the *objective* of "managing technology" and in the "model" of the innovation advancement and commercialization process. Specifically, we suggest a move from a "licensing model" that seeks to maximize patent licensing income to a "volume model" that emphasizes the number of university innovations and the speed with which they are moved into the marketplace.

In fact, there are multiple volume models, but they share several features:

- They provide rewards for moving innovations into the marketplace, rather than simply counting the revenue they may return.
- They focus on faculty as the key agents of innovation and commercialization.
- They emphasize further standardization in the interactions of campuses with their faculty and with industry.

In the following, we consider four variations of the volume model and discuss their advantages and drawbacks.

Free Agency

The first volume model is "free agency," a term we borrow from the sports world. Under this approach, faculty members are given the power to choose a third party (or themselves) to negotiate license arrangements for entrepreneurial activities, provided that they return some portion of their profits to the university. The TTOs can be one of the third parties offering services, but other parties can also compete on a range of services and experience offered.

The WARF is an exemplar of such a model. As we have noted, WARF is independent of the university, and Wisconsin faculty are under no obligation to use it except in the case of federal funding. As a practical matter, however, nearly all of them use WARF because the organization has acquired expertise over time that is viewed to be valuable.

Free agency introduces a strong dose of competition to the university TTO, while giving academic researchers the freedom to seek out the best arrangement on the speediest terms to commercialize their innovation. This model is best suited for innovations in which faculty members have deep commercial expertise and social networks to facilitate commercialization.

One drawback to free agency, however, is that university faculty members often lack the resources to pay for patent searches and applications, functions now performed by the TTO. This problem might be overcome through profit-sharing arrangements between researchers and their lawyers or third-party commercialization agents.

Faculty members also could license their inventions to third parties who, as part of the agreement, would bear the patent-related costs. This free-agent model requires further consideration in order to determine if it is consistent with existing legislation and to evaluate the degree to which regulation to overcome information barriers would be necessary.

Regional Alliances

A second possible model provides more technology transfer activities via regional alliances, provided those alliances operate in ways to maximize volume rather than licensing income. Under this approach, multiple universities form consortia that develop their mechanisms for commercialization. Economies of scale allow for lower costs of the commercialization functions overall, and the universities are able to share these costs among the multiple participants.

This model may prove particularly attractive for smaller research universities that may not have the volume to support a seasoned and highly able licensing and commercialization staff independently. The WARF, through the WiSys Technology Foundation, is experimenting with more of a regional approach to technology transfer and has had positive results so far. This type of hub-and-spoke model is effective when supported by experienced staff and dedicated local resources.

There are two principal concerns with the regional alliances model, however. First, a regional TTO with insufficient resources may try to behave like a "super TTO," seeking to maximize licensing revenue for the consortium as a whole rather than the number of commercialization opportunities and the speed with which they are moved out the door. In addition, regional models may face coordination challenges or disputes over attribution of inventiveness, with one or more universities pitted against others when a commercial opportunity is realized through the joint work of several researchers at different universities. The probability of disputes is likely related to the amount of money at stake.

Internet-Based Approaches

Closely related to the regional alliance model, Internet-based approaches use the Web to facilitate commercialization. Given their structure, Internet "matchmaking" approaches—which seek to match those who have ideas and those who want to implement them—are inherently built to maximize volume rather than licensing income.

An example of an Internet-based approach is www.ibridgenetwork.com, a Web-based platform launched in January 2007, operated by the Kauffman Innovation Network, Inc., and funded by the Kauffman Foundation. Universities joining the iBridge Network are able to post information about their innovations directly to the site, which provides an alternative pathway to research tools, materials, and nonexclusive licensed technologies that should accelerate university innovation and lower transaction costs. Its success remains to be seen, but initial Web traffic suggests that the program has had an auspicious start.

Faculty Loyalty

The last—and perhaps the most radical—model for many universities to consider is for universities to give up their intellectual property rights, anticipating instead that loyal faculty will donate some of the fruits of their success back to the university. While surrendering rights to faculty may seem drastic, this strategy offers the ultimate incentive for the external agents of commercialization to engage in the process.

In fact, the United States has a great tradition of philanthropy, and this model allows university administration to focus on the core activities of a university while securing additional university operational dollars through the virtuous cycle of giving. There is a history of successful faculty members donating some of their profits back to the university. Jan T. Vilcek, for example, pledged $105 million to the New York University School of Medicine in 2005, largely as the result of royalties earned from Remicade, a drug invented by Dr. Vilcek and a colleague while working at the school's Department of Microbiology (New York University Medical Center 2005). Other examples abound, including George Hatsoupoulos' gift to the Massachusetts Institute of Technology (MIT; 2005) and James Clark's generosity with Stanford (Stanford University 1999).

The obvious downside to the "loyalty" model is the inherent—and significant—risk. There is always the possibility that successful academic entrepreneurs will not voluntarily share their success with their employers. This risk is even greater for universities that have difficult relationships with their faculty.

We believe, however, that this risk is worth taking for most universities. Academics pursue their work in large part because they have a thirst for knowledge and discovery. While they may also be motivated by money, most faculty members are determined to move commercially viable innovations to the market. And as monetarily successful professors give back to their universities, they set positive examples for their colleagues to follow. Furthermore, the loyalty model avoids the haggles associated with Intellectual Property (IP) rights and, therefore, would theoretically promote more rapid commercialization of inventions than either of the other two models. In particular, the loyalty model should entail very low risks for well-run universities that promote collegiality.

VI. Discussion and Conclusion

"When you ask 'Where are tomorrow's ideas?' they are things you and I would look at and say, 'That's not going anywhere. That's worthless.'"

—William R. Brody, president of Johns Hopkins University (quoted in Holstein 2006; retrieved from http://www.nytimes.com/2006/11/05/jobs/05advi.html?_r=1&oref=slogin).

U.S. universities today are not only competing with other U.S. institutions for collaborative relationships with industry, they are both also collaborating and competing within a global economy. Our institutions must continue to be leaders in research, the advancement of innovation, and the commercialization of our ideas in order to remain competitive.

The majority of university-industry agreements relate to technologies that are many years away from being commercialized (Jensen and Thursby 2001), and universities cannot take on the burden of forecasting uncertain commercial returns. This function is best performed by the private sector. In the end, society will be best served by a knowledge transfer system that encourages interactions between universities and industry and also inspires each party to capitalize on its relative advantage—with universities focusing on discovery and entrepreneurs devoting their efforts to commercialization.

This discussion of how innovations are transferred from universities to industry is an important part of the national conversation about U.S. economic competitiveness. We are now at a critical time in which the incentives of some universities (or specific officials within the universities) may lead to the codification of a system that would inhibit rather than promote commercialization of technological breakthroughs. We have argued that the most important way to avoid this outcome is to refocus university administration away from the historic "patent-licensing big hit" model to one or more "volume models" that concentrate on the number of and the speed with which university innovations are sent out the door and into the marketplace. These models will include open-source collaborations, copyright, nonexclusive licensing, and a focus on developing the social networks for graduate students and faculty to commercialize all types of innovations.

The federal government, as the funding source for university-based research, is in an ideal position to encourage experimentation with these—and other—alternative arrangements. At a minimum, the government can help educate universities regarding the importance of providing a more fluid environment that will allow for more rapid commercialization of ideas developed by students and faculty. More ambitiously, agencies of the federal government can condition their research grants on university demonstrations that they are experimenting with and use multiple pathways to provide competition or to advance innovations into the commercial market.

Endnotes

Robert E. Litan is vice president for Research and Policy at the Ewing Marion Kauffman Foundation and a senior fellow in the Economic Studies and the Global Studies programs at the Brookings Institution. Lesa Mitchell is vice president for Advancing Innovation at the Ewing Marion Kauffman Foundation. E. J. Reedy is a manager at the Ewing Marion Kauffman Foundation. We would like to thank Carl Schramm, president and CEO of the Foundation, for his original insights that helped lead to this paper and the research behind it; Robert Strom, David Audretsch, Ronnie Phillips, Don Siegel, Marie Thursby, Jerry Thursby, and Jim Spohrer for their comments; and Alyse Freilich, Marisa Porzig, Dane Stangler, and Derek Ozkal for their research and insights. Additionally, we would like to thank the organizers of the Innovation Policy and the Economy Working Group at the National Bureau of Economic Research (NBER), Josh Lerner and Scott Stern.

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1. In considering longer-term financial returns to universities from licensing for cash versus other forms of equity arrangements, at least one group of researchers has shown equity to outpace cash arrangements (Bray and Lee 2000). Full consideration of the short-versus long-term theoretical effects of different university technology transfer mechanisms remains an area open for future research, particularly when societal measures for benefit are taken into consideration in terms of diffusion of innovation within the marketplace and other similar issues.

2. In 2000, 19 percent of the R&D performed on university campuses was university funded, up from 10 percent in 1960 (National Science Foundation 2006).

References

Association of American Universities. 1998. University technology transfer of government-funded research has wide public benefits. Retrieved from http://www.aau.edu/research/TechTrans6.3.98.html.

Association of University Technology Managers (AUTM). 2002. *AUTM Licensing Survey: FY 2001.* Northbrook, IL: AUTM.

Baumol, William J. 2002. *The free-market innovation machine: Analyzing the growth miracle of capitalism.* Princeton, NJ: Princeton University Press.

Bray, Michael J., and James N. Lee. 2000. University revenues from technology transfer: Licensing fees vs. equity positions. *Journal of Business Venturing* 15 (5–6): 385–92.

Cohen, Wesley M., Richard R. Nelson, and John P. Walsh. 2002. Links and impacts: The influence of public research on industrial R&D. *Management Science* 48 (1): 1.

Coupe, Tom. 2003. Science is golden: Academic R&D and university patents. *Journal of Technology Transfer* 28 (1): 31–46.

Feller, Irwin. 2004. Virtuous and vicious cycles in the contributions of public research universities to state economic development objectives. *Economic Development Quarterly* 18 (2): 138–50.

Feldman, M. P., and J. Bercovitz. Forthcoming. Academic entrepreneurs: Organizational change at the individual level. *Organization Science.*

Goldfarb, Brent, and Magnus Henrekson. 2003. Bottom-up versus top-down policies towards the commercialization of university intellectual property. *Research Policy* 32 (4): 639–58.

Holstein, William J. 2006. Putting bright ideas to work off campus. *New York Times.* November 5, 2006.

Jensen, Richard A., and Marie Thursby. 2001. Proofs and prototypes for sale: The licensing of university inventions. *American Economic Review* 91 (1): 240–59.

Lemley, Mark A. 2007. Are universities patent trolls? Stanford Public Law Working Paper no. 980776. Stanford, CA: Stanford Law School.

Lowe, Robert. 2002. The role and experience of inventors and start-ups in commercializing university research: Case studies at the University of California. *Center for Studies in Higher Education,* Paper CSHE6=02.

Mansfield, Edwin. 1995. Academic research underlying industrial innovations: Sources, characteristics, and financing. *Review of Economics and Statistics* 77 (1): 55.

Markman, Gideon D., Phillip H. Phan, David B. Balkin, and Peter T. Gianiodis. 2005. Entrepreneurship and university-based technology transfer. *Journal of Business Venturing* 20 (2): 241–63.

Markman, Gideon D., Peter T. Gianiodis, Phillip H. Phan, and David B. Balkin. 2005. Innovation speed: Transferring university technology to market. *Research Policy* 34 (7): 1058–75.

Massachusetts Institute of Technology (MIT). 2005. Entrepreneur alumnus to bankroll winning thesis idea. http://web.mit.edu/newsoffice/2005/hatsopoulos.html.

Mowery, David C., Richard R. Nelson, Bhaven N. Sampat, and Arvids A. Ziedonis. 2001. The growth of patenting and licensing by U.S. universities: An assessment of the effects of the Bayh-Dole Act of 1980. *Research Policy* 30 (1): 99–119.

———. 2004. *Ivory tower and industrial innovation: University-industry technology transfer before and after the Bayh-Dole Act in the United States.* Innovation and Technology in the World Economy. Stanford, CA: Stanford Business Books.

National Academy of Sciences and National Academy of Engineering. 2006. *Rising above the gathering storm: Energizing and employing America for a brighter economic future.* Washington, DC: National Academies Press.

National Science Foundation. 2006. *Science and engineering indicators 2006.* http://www.nsf.gov/statistics/seind06/toc.htm.

New York University Medical Center. 2005. Remicade co-inventor and NYU professor of microbiology Jan Vilcek, M.D., Ph.D. pledges $105 million to NYU school of medicine. http://www.med.nyu.edu/communications/news/pr_118.html.

Phan, Phillip H., and Donald Siegel. 2006. The effectiveness of university technology transfer: Lessons learned, managerial and policy implications, and the road forward. Retrieved from http://www.papers.ssrn.com/sol3/papers.cfm?abstract_id=900605.

Price Waterhouse and National Venture Capital Association. 2007. *MoneyTree survey report.* Available at pwcmoneytree.com

Rapoport, Alan I. 2006. *Where has the money gone? Declining industrial support of academic R&D.* Arlington, VA: National Science Foundation, Directorate for Social, Behavioral, and Economic Sciences. Retrieved from http://www.nsf.gov/statistics/infbrief/nsf06328/

Rogers, Everett M. 2003. *Diffusion of innovations.* 5th ed. New York: Free Press.

Rogers, Everett M., Jing Yin, and Joern Hoffmann. 2000. *Assessing the effectiveness of technology transfer offices at U.S. research universities.* Association of University Technology Managers. Retrieved from http://www.unl.edu.ar/transfer/bpcue/archivos/bibliograf/assessing.pdf

Sampat, Bhaven N. 2006. Patenting and US academic research in the 20th century: The world before and after Bayh-Dole. *Research Policy* 35 (6): 772–89.

Siegel, Donald S., David Waldman, L. Atwater, and Albert N. Link. 2004. Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the commercialization of university technologies. *Journal of Engineering and Technology Management* 21 (1–2): 115–42.

Stanford University. 1999. Entrepreneur Jim Clark to donate $150 million to Stanford. http://www.stanford.edu/dept./news/pr/99/991027/Clark.html.

Thursby, Jerry G., Richard A. Jensen, and Marie C. Thursby. 2001. Objectives, characteristics and outcomes of university licensing: A survey of major U.S. universities. *Journal of Technology Transfer* 26 (1): 59–72.

Thursby, Jerry G., and Marie C. Thursby. 2003. Patterns of research and licensing activity of science and engineering faculty. *Science and the University*

———. 2005a. *Faculty patent activity and assignment patterns.* Kansas City, MO: Ewing Marion Kauffman Foundation.

———. 2005b. Gender patterns of research and licensing activity of science and engineering faculty. *Journal of Technology Transfer* 30:343–53.

———. 2006. Where is the new science in corporate R&D? *Science* 314 (December): 1547.

———. Forthcoming. Knowledge creation and diffusion of public science with intellectual property rights. *Intellectual property rights and technical change,* Frontiers in Economics 2. Amsterdam: Elsevier.