



# The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh–Dole act of 1980

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## Abstract

Growth during the 1980s and 1990s in patenting and licensing by American universities is frequently asserted to be a direct consequence of the Bayh–Dole Act of 1980. However, there has been little empirical analysis of the effects of this legislation. This paper uses previously unexploited data to consider the effects of Bayh–Dole at three leading universities: the University of California, Stanford University, and Columbia University. Two of these universities (California and Stanford) were active in patenting and licensing before Bayh–Dole, and one (Columbia) became active only after its passage. The evidence suggests that Bayh–Dole was only one of several important factors behind the rise of university patenting and licensing activity. Bayh–Dole also appears to have had little effect on the content of academic research at these universities. A comparison of these three universities reveals remarkable similarities in their patent and licensing portfolios 10 years after the passage of the Bayh–Dole Act. The concluding section raises several questions about the effects of Bayh–Dole and related policy shifts that are not addressed by this analysis but that deserve attention in future research. © 2001 Elsevier Science B.V. All rights reserved.

*Keywords:* Bayh–Dole; University Research; Technology Transfer; Patents; Licenses

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## 1. Introduction

The U.S. research university and the organized pursuit of R&D in industry both originated roughly

125 years ago and have grown in parallel throughout the 20th century (Mowery and Rosenberg, 1998). Although university–industry research collaboration has a long history, recent changes in the character of this relationship, especially the growth in university patenting and licensing of technologies to private firms, have attracted considerable attention. The ex-

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panded licensing activities of U.S. universities have occasioned both expressions of enthusiasm by some for the enhanced contributions of university research to U.S. economic growth that they believe are associated with increased licensing, and expressions of concern by others over the effects of such activities on the culture and norms of academic research.

The recent increases in university patenting and licensing are frequently asserted to be direct consequences of the federal policy initiative known as the Bayh–Dole Act of 1980. Although the Act's importance is widely cited, its effects on U.S. research universities and on the U.S. innovation system have been the focus of little empirical analysis (Henderson et al., 1998 is an important exception). In this paper, we undertake such an analysis, examining three academic institutions that have been the leading recipients of licensing and royalty income for much of the 1990s: Columbia University, the University of California, and Stanford University.<sup>2</sup> Two of the three, Stanford and the University of California, were active in technology licensing well before the passage of the Bayh–Dole Act, as were such universities as the University of Wisconsin and MIT, while Columbia and many other research universities (for example, Harvard and Yale) were not. A combined analysis of data from Columbia, Stanford, and the UC system thus allows us to consider the effects of these new Federal policies on both universities such as Columbia, which became large-scale patenters and licensors only after 1980, and those such as UC and Stanford, active in patenting and licensing well before 1980.

We use previously unexploited data from each of these universities to compare their patenting and

licensing activities and address the following broad questions:

1. How have Bayh–Dole and other factors affected the allocation among disciplines and the content of academic research?
2. Is the Bayh–Dole Act the basic cause of the rise of university patenting and licensing, or have other factors influenced growth in these activities?

The evidence presented below suggests that the Bayh–Dole Act itself has had little impact on the content of academic research. The portfolio of university research has shifted somewhat in recent years independently of Bayh–Dole, and these changes are important factors behind the increased patenting and licensing activity. In particular, the growth in federal financial support for basic biomedical research in universities that began in the late 1960s, along with the related rise of research in biotechnology that began in the early 1970s, contributed to growth in university patents and licenses.

These patenting and licensing activities also benefited from court rulings and shifts in federal policy that made it easier to patent research results in the biomedical field. Thus, before and after Bayh–Dole, judicial decisions declared that “engineered molecules” were patentable, the U.S. Congress passed a series of laws strengthening intellectual property protection, and the U.S. government expanded its efforts to gain stronger international protection for intellectual property.

Bayh–Dole had nothing to do with these developments. Indeed, the rise in biomedical research and the growth of its associated inventions predate the passage of Bayh–Dole in both of the universities (UC and Stanford) for which we have reliable pre-1980 data, and more fragmentary evidence indicates a similar trend at Columbia. Even without the Bayh–Dole Act, the evidence presented below suggests that U.S. universities would have increased their patenting and licensing activities. Indeed, our data indicate such growth before Bayh–Dole at the two universities in our study active in patenting and licensing before its passage. At Columbia, internal discussions of the feasibility of expanded institutional patenting of faculty research results were well underway by 1980, and a key patent application was filed before the passage of the Bayh–Dole Act. The

<sup>2</sup> According to the annual report of the Association of University Technology Managers (AUTM), fiscal 1996 gross licensing revenues for the UC system, Stanford University, and Columbia University amounted to US\$63,200,000, US\$43,752,059, and US\$40,631,982 respectively. The fourth and fifth leading universities, Michigan State and Wisconsin, earned US\$17,232,000 and US\$13,091,708 respectively. (Association of University Technology Managers, 1996).

Act nevertheless hastened the entry into patenting and licensing by many universities (such as Columbia) that had formerly avoided these activities. Even at the universities in our study that had long been active in patenting and licensing of faculty inventions, administrators intensified their efforts to gain access to and/or market these inventions.

Supporters of the Bayh–Dole Act argued that stronger intellectual property rights would accelerate the commercial exploitation of university research results. Has the increased propensity of universities to patent and license research outputs had this effect, compared with a situation in which results simply were placed in the public domain? The research reported in this paper sheds little light on this question, and the effects of the new regime on technology transfer vary depending on the nature of the research output. Nevertheless, widespread patenting and licensing of the results of fundamental research or of tools whose principal use is in further research could hinder the advance of science, and this area deserves particular attention in future research.

Immediately below, we discuss the background to the Bayh–Dole Act, in order to underscore the point that university–industry research linkages, university patenting, and university licensing of these patents are not new features of the U.S. innovation system. We then discuss our data for these three universities, present the comparative analysis, and consider the implications of our findings for the academic research enterprise and the U.S. innovation system.

## 2. Historical background

The historic involvement of publicly funded universities in the United States with agricultural research, much of which was applied in character, and the involvement of these universities with the agricultural users of this research, are well-known aspects of U.S. economic history. But throughout this century, the decentralized structure of U.S. higher education and the dependence of public and private universities on local sources of funding also meant that in a broad array of non-agricultural fields, ranging from engineering to physics and chemistry, col-

laborative research relationships between university faculty and industry were common (Rosenberg and Nelson, 1994). Indeed, the Research Corporation, which served for many years as a leading “broker” and licensor of university inventions for many U.S. universities, was founded in 1912 by Frederick Cottrell, a U.C. Berkeley professor, to commercialize his electrostatic antipollution innovations.<sup>3</sup>

Thus it is a fallacy to think of U.S. university research as traditionally “basic” and conducted with no attention to practical objectives. Many important advances in applications have emerged from academic research in the United States, and much industry–university collaboration historically has focused on the engineering and applied sciences. University researchers have contributed to innovations in scientific instrumentation, medical devices, and computer software, reflecting the fact that university researchers are demanding “users” of these technologies, and their research activities frequently create new advances in applications in these and other areas (Rosenberg, 1992, discusses the contributions of academic researchers to innovation in scientific instruments).

Throughout the 1900–1940 period, U.S. universities, especially public universities, pursued extensive research collaboration with industry. Indeed, the academic discipline of chemical engineering was largely developed through collaboration between U.S. petroleum and chemicals firms and MIT and the University of Illinois (Rosenberg, 1998). The Second World War transformed the role of U.S. universities as research performers, as well as the sources of their research funding. Universities’ share of total U.S. R&D performance grew from 7.4% in 1960 to nearly 14.5% in 1997, and universities accounted for 59% of the basic research performed within the United States in 1997 (National Science Foundation, 1998). The share of industry funding declined within the greatly expanded research budgets of postwar U.S. research universities through the 1950s and

<sup>3</sup> The Corporation’s licensing activities now are managed by an independent organization, Research Corporation Technologies, founded in 1987.

1960s. Much university research nevertheless retained an applied character, reflecting the importance of research support from such federal “mission agencies” as the Defense Department.

Beginning in the 1970s, the share of industry funding within academic research began to grow again. In 1970, federal funds accounted for 70.5% of university-performed research and industrial support 2.6%; by 1997, federal funds accounted for 59.6% of total university research, and industry’s contribution had increased to 7.1% (National Science Board, 1998). Most of the increase in industry funding occurred during the 1980s, remaining roughly constant after 1990.

In view of the applied character of a good deal of their research, it is not surprising that a number of U.S. research universities were active in patenting and licensing faculty inventions long before 1980. Beginning in 1926, the University of California required all employees to report patentable inventions to the university administration. Other universities, such as MIT and the University of Wisconsin, developed administrative units to help patent and license inventions resulting from research. During the pre-1940 period, most of this patenting and licensing activity was conducted directly with industrial sponsors of academic research and through organizations such as the Research Corporation.

Expanded federal research funding during the postwar period rekindled the debate over the disposition of the results of academic research (See Eisenberg, 1996, for a review of the history of these policy debates). Beginning in the 1960s, the Department of Defense began allowing universities with approved patent policies to retain title to any patents resulting from Department of Defense (DoD)-funded research (DoD retained control of these patents for military applications). During the 1960s and early 1970s, both the Department of Health, Education and Welfare (now Human and Health Services, the agency housing the National Institutes of Health) and the National Science Foundation allowed academic institutions to patent and license the results of their research under the terms of Institutional Patent Agreements (IPAs) negotiated by individual universities with each federal funding agency. IPAs eliminated the need for case-by-case reviews of the disposition of individual academic inventions. Although

they facilitated licensing of such inventions on an exclusive or non-exclusive basis, tensions between some major IPA participants, such as the University of California, and federal sponsors remained.<sup>4</sup> These debates intensified in the late 1970s, when HEW in particular began to question the use by some U.S. universities of exclusive licenses under IPAs and proposed limiting the ability of some universities to adopt such policies.

The Bayh–Dole Patent and Trademark Amendments Act of 1980 provided blanket permission for performers of federally funded research to file for patents on the results of such research and to grant licenses for these patents, including exclusive licenses, to other parties. The Act facilitated university patenting and licensing in several ways. First, it replaced the web of IPAs that had been negotiated between individual universities and federal agencies with a uniform policy. Second, the Act’s provisions represented a Congressional expression of support for the negotiation of exclusive licenses between universities and industrial firms for the results of federally funded research. Finally, it constituted a Congressional endorsement of the argument that failure to establish patent protection over the results of federally funded university research would limit the commercial exploitation of these results. The Bayh–Dole Act responded to a belief by policymakers (based on little or no evidence) that stronger protection for the results of publicly funded R&D would accelerate their commercialization and the realization

<sup>4</sup> According to the “Report on University Patent Fund and University Patent Operations for the Year ended June 30, 1968” of the Board of Regents of the University of California, “The United States Public Health Service (PHS) of the Department of Health, Education, and Welfare is revising its Institutional Agreements under which patent rights can be retained by educational institutions. The PHS intends to make these Institutional Agreements available to many more institutions than at present. At the same time, it is making its patent provisions more restrictive. Most objectionable of the provisions included in the draft under consideration are: (1) a limitation on the amount of royalty the University can share with its inventors, and (2) a requirement that the University and its licensees provide the Government with copies of all licenses, and that the University incorporate into commercial licenses the provisions of the Institutional Agreement.” (11/1/68, p. 4).

of these economic benefits by U.S. taxpayers.<sup>5</sup> Under the theory that the architects of Bayh–Dole had in mind, these new policies of support for patenting of the results of public R&D programs also appeared to promise increased economic returns for little additional investment of public funds, an attractive feature for policymakers dealing with severe fiscal constraints.

The passage of the Bayh–Dole Act was one part of a broader shift in U.S. policy toward stronger intellectual property rights.<sup>6</sup> Among the most important of these policy initiatives was the establishment of the Court of Appeals for the Federal Circuit (CAFC) in 1982. Established to serve as the court of final appeal for patent cases throughout the federal judiciary, the CAFC soon emerged as a strong champion of patentholder rights. Even before the establishment of the CAFC, however, an important U.S. Supreme Court decision in 1980, *Diamond vs. Chakrabarty*, upheld the validity of a broad patent in the new industry of biotechnology, opening the door to patenting the organisms, molecules, and research techniques emerging from biotechnology. The origins and effects of Bayh–Dole must be viewed in the context of this larger shift in U.S. policy toward intellectual property rights, and the effects of the Act are confounded with those of these intellectual property initiatives.

Although this point was ignored in the political debate over Bayh–Dole, the argument that stronger protection of intellectual property accelerates its

commercialization conflicted with an important strand of the economic analysis of the social returns to scientific research, which stressed that scientific knowledge was “not rivalrous in use” (Nelson, 1959; Arrow, 1962). When a good is non-rivalrous in use, use of that good by additional parties or in additional applications imposes no real economic costs. Policies impeding access to a scientific discovery by any party that can make good use of it impose costs on that party and on the economy as a whole. Where private investors are the primary source of financial support for scientific research, as is the case with industrial R&D, granting a patent on the results of such work may be necessary in order to induce private R&D investment. But the economic theory of scientific research that was ignored in Bayh–Dole argues that patenting the results of publicly funded research is unnecessary to induce the research investment and that any restrictions on use associated with patents reduce the social returns to this public investment.

In contrast, the advocates of Bayh–Dole argued that the findings of publicly financed university research require considerable additional investments in R&D and other activities before they can be commercialized; such investments are more likely if a firm is granted an exclusive license to do that work. But on the other hand, if the findings of publicly funded university research are placed in the public domain or are inexpensively licensed to anyone who wants to use them, competition alone may stimulate their widespread application. These complex issues cannot be resolved with the data presented in this paper. But our data provide a useful starting point for such an analysis.

### 3. The effects of Bayh–Dole

The Bayh–Dole Act is contemporaneous with a sharp increase in U.S. university patenting and licensing activity. The data in Table 1 reveal a large increase in university patenting after the passage of the Bayh–Dole Act in 1980. Having grown by approximately one-third between 1969 and 1974, the number of patents issued to U.S. universities and colleges more than doubled between 1979 and 1974, more than doubled again between 1984 and 1989, and doubled yet again between 1989 and 1997.

<sup>5</sup> The “evidence” of unsuccessful commercialization of federally owned patents consisted mainly of numerous citations to the tiny percentage of the 28,000–30,000 patents owned by the federal government that had been commercialized. Advocates of the Bayh–Dole Act overlooked the fact that title to most of these patents, which resulted from federal defense contracts, had been ceded to the federal government by private contractors who had not invoked their rights under the policies then prevalent in the Defense Department to retain title to the patents. In other words, as Eisenberg (1996) points out, the statistical data cited in support of the Bayh–Dole Act suffered from a serious selection bias.

<sup>6</sup> According to Katz and Ordover (1990), at least 14 Congressional bills passed during the 1980s focused on strengthening domestic and international protection for intellectual property rights, and the Court of Appeals for the Federal Circuit created in 1982 has upheld patent rights in roughly 80% of the cases argued before it, a considerable increase from the pre-1982 rate of 30% for the Federal bench.

Table 1  
Utility Patents Issued to U.S. Universities and Colleges, 1969–1997 (year of issue)

Year	Number of U.S. patents
1969	188
1974	249
1979	264
1984	551
1989	1228
1994	1780
1997	2436

Source: United States Patent and Trademark Office (1998).

Trajtenberg et al. (1994) noted that the share of all U.S. patents accounted for by universities grew from less than 1% in 1975 to almost 2.5% in 1990. Moreover, the ratio of patents to R&D spending within universities almost doubled during 1975–1990 (from 57 patents per US\$1 billion in constant-dollar R&D spending in 1975 to 96 in 1990), while the same indicator for all U.S. patenting displayed a sharp decline (decreasing from 780 in 1975 to 429 in 1990). In other words, universities increased their patenting per R&D dollar during a period in which overall patenting per R&D dollar was declining.

In tandem with increased patenting, U.S. universities expanded their efforts to license these patents. The Association of University Technology Managers (Association of University Technology Managers, 1996) reported that the number of universities with technology licensing and transfer offices increased from 25 in 1980 to 200 in 1990, and licensing revenues of the AUTM universities increased from US\$222 million in fiscal 1991 to US\$698 million in fiscal 1997 (Association of University Technology Managers, 1998).

Although U.S. universities thus have greatly expanded their patenting activities since 1981, the data in Table 1 (as well as similar data reproduced in Henderson et al., 1998) suggest that this growth represented an acceleration of a trend that predated the passage of Bayh–Dole. Moreover, this increased patenting was dominated by growth in biomedical patents—biomedical patents issued to U.S. universities increased by 123% during the 1969–1979 period, while non-biomedical patents grew by only 22%. Part of the growth in overall university patenting during the 1970s was accounted for by universities not previously active in patenting — the number

of U.S. universities with at least one patent increased from 36 in 1970 to 86 in 1980.

Along with increased patenting, U.S. universities expanded their efforts to license and market their inventions in the 1970s. As early as 1974, the Research Corporation, the leading third-party technology transfer agent for universities in the pre-Bayh–Dole era, expressed concern about increased competition from the growing number of technology transfer offices operated by universities (Research Corporation, 1974). AUTM data confirm that the number of universities devoting at least 0.5 full time equivalent employees to technology transfer activities began to grow in the mid-1970s, although this growth accelerated after Bayh–Dole (Association of University Technology Managers, 1996, Attachment E). In a number of instances, universities established independent technology transfer offices in order to qualify for IPAs from government agencies. The National Science Foundation began using IPAs in 1973, and by 1978 had IPAs with 19 institutions. The federal Department of Health, Education and Welfare negotiated its first IPA in 1968, and by 1978 had such agreements with no fewer than 72 institutions.

Thus, many U.S. universities had begun to expand their activities in patenting and licensing of faculty inventions before the effective date of Bayh–Dole in 1981. As Henderson et al. (1998) note, these expanded activities responded to the increased industrial interest in academic research that contributed to growth in industrial funding of academic research, the desire of many universities to exploit new sources of income, and the growth in academic basic research advances in areas (e.g., biotechnology, computer software) that appeared to have significant industrial applications. But growth during the 1970s in patenting, licensing, licensing income, or in the establishment of independent technology transfer offices was dwarfed by the surge in all of these activities after 1981.

### 3.1. *Columbia University*<sup>7</sup>

The essence of Columbia's pre-Bayh–Dole patent policy dates back to its 1944 Statement on Research

<sup>7</sup> Portions of this section are based on Crow et al. (1998).

**Policy and Patent Procedures.** This policy prohibited patents on the results of research (regardless of the source of funding for such research) at the medical school, although faculty members at the rest of the University were free to patent any inventions resulting from their research. In many cases, non-medical faculty turned to Research Corporation for assistance in patenting and administering their inventions. The 1944 policy remained substantially intact until 1975, when the stipulation against patenting medical inventions was dropped. Discussions within Columbia's administration and faculty over an institutional assertion of greater rights to faculty inventions began in the late 1960s and gained momentum in the 1970s, but produced no formal change in policy until the passage of Bayh–Dole.

This *laissez faire* policy toward patenting the results of faculty research during the three decades following World War II meant that Columbia had no administrative structure for managing patent matters. Beginning in the late 1970s, however, the University expanded its involvement in patent transactions between its inventors and Research Corporation, created a central archive of potentially patentable inventions, and petitioned government agencies for title to faculty inventions resulting from federally funded research. Indeed, Columbia filed a patent application on the patent responsible for the largest share of its

licensing revenues during the post-1981 period before the passage of Bayh–Dole or the establishment of a technology transfer office. Nevertheless, during the 1975–1981 period, fewer than 10 patents were issued to Columbia University.

Columbia changed its policies toward faculty patents and created an administrative apparatus for managing their prosecution and licensing only after the passage of Bayh–Dole. A new patent policy, which took effect on July 1, 1981 (the effective date of Bayh–Dole), stated that Columbia University could assert rights to faculty inventions created within University laboratories or research facilities, mandated the disclosure of such inventions to the University, and provided for royalty-sharing with the inventor and his or her department. In 1984, this policy was published in the University *Faculty Handbook*. In 1989, Columbia's policy on reserving rights to the University for faculty inventions created with University resources was extended to cover software. Inventions were to be disclosed to Columbia's Office of Science and Technology Development, which was founded in 1982.

Fig. 1 shows the rapid “ramping up” of Columbia invention reports during the 1980s. Since most academic research programs change only gradually, the initial surge of reports almost certainly reflects increased identification by university administrators

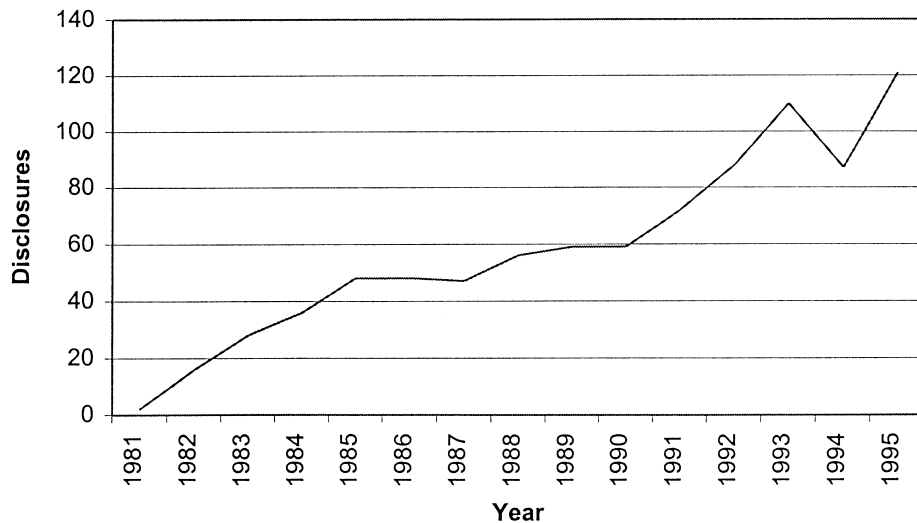


Fig. 1. Columbia University Disclosures, 1981–1995.

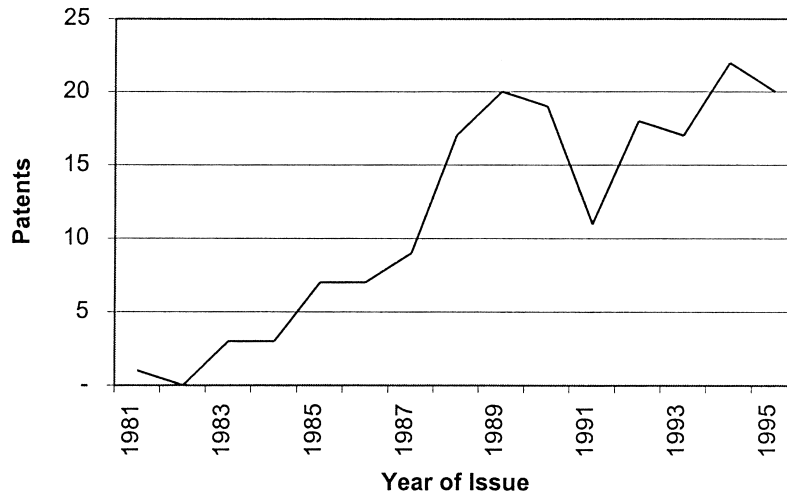


Fig. 2. Columbia University Patents, 1981–1995.

(based on a more intensive canvassing of the faculty) of potentially valuable inventions derived from research projects already under way. Almost 75% of the 877 invention reports disclosed between 1981 and 1995 are biomedical, and biotechnology figured prominently in these biomedical inventions. Biotechnology inventions accounted for 60% of these biomedical inventions, 45% of the biomedical inventions that resulted in patents, and nearly 70% of the

biomedical inventions that were licensed. Although our Columbia data on inventions and patenting do not extend back into the pre-1980 period, we believe that at this university, like Stanford and UC, the growth of post-1980 inventive activity in biomedical technologies was caused by more than just the passage of Bayh–Dole. The surge of inventive activity in the biomedical and biotechnology fields had been building up for some time, as a result (among other

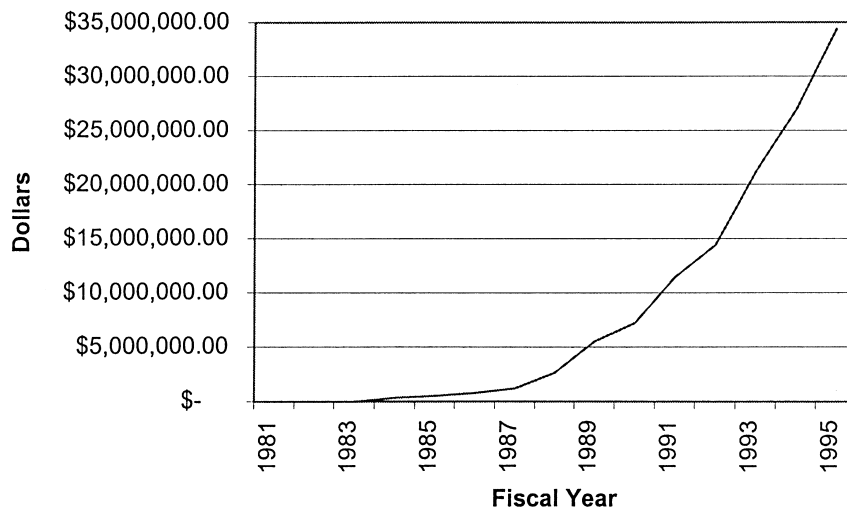


Fig. 3. Columbia University Licensing Revenues, 1981–1995.

Table 2

Selected Data on University of California, Stanford University, and Columbia University Licensing Income, FY1970–1995

	FY1970	FY1975	FY1980	FY1985	FY1990	FY1995
<i>UC</i>						
Gross income (1992 dollars: 000s)	1140.4	1470.7	2113.9	3914.3	13,240.4	58,556.0
Gross income from top 5 earners (1992 dollars: 000s)	899.9	1074.8	1083.0	1855.0	7229.8	38,665.6
share of gross income from top 5 earners (%)	79	73	51	47	55	66
share of income of top 5 earners associated with biomedical inventions (%)	34	19	54	40	91	100
share of income of top 5 earners associated with agricultural inventions (%)	57	70	46	60	09	0
<i>Stanford</i>						
		FY76				
Gross income (1992 dollars: 000s)	180.4	842.6	1084.4	4890.9	14,757.5	35,833.1
Gross income from top 5 earners (1992 dollars: 000s)		579.3	937.7	3360.9	11,202.7	30,285.4
share of gross income from top 5 earners (%)		69	86	69	76	85
share of income of top 5 earners associated with biomedical inventions (%)		87	40	64	84	97
<i>Columbia</i>						
Gross income (1992 dollars: 000s)				542.0	6903.5	31,790.3
Gross income from top 5 earners (1992 dollars: 000s)				535.6	6366.7	29,935.8
share of gross income from top 5 earners (%)				99	92	94
share of income of top 5 earners associated with biomedical inventions (%)				81	87	91

things) of the expansion of federal biomedical research funding from the National Institutes of Health and other sources.

Outside of the medical school, Columbia's "inventing" was concentrated in a few departments and research institutes that, like the medical school, relied heavily on federal R&D funding. Over 60% of the non-biomedical invention reports, and over 65% of the patenting associated with non-biomedical in-

vention reports during the 1981–1995 period, originated in two departments, electrical engineering and computer science, and two research centers, the Center for Telecommunications Research and the Lamont–Doherty Earth Observatory. Software inventions accounted for a significant share of Columbia faculty disclosures, increasing to more than 10% of disclosures by the 1990s; software inventions also account for a large share of Columbia licensing agreements.

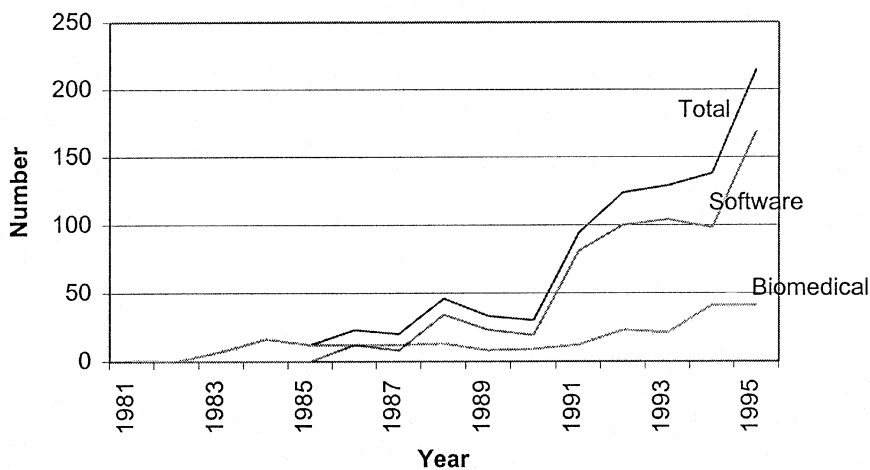


Fig. 4. Columbia University License Agreements, 1981–1995.

As the data in Fig. 2 suggest, increased invention reports generate increased patenting activity with a slight lag.

As Fig. 3 and the comparative data in Table 2 indicate, Columbia University's technology licensing activities have been associated with a surge in gross licensing revenues, which grew almost 60-fold (measured in 1992 dollars) in the decade between 1985 and 1995. This income was highly concentrated among a small number of inventions: the "top 5" accounted for more than 90% of gross revenues throughout this period. Turning to the number of licenses (a measure that heavily weights inventions licensed on a non-exclusive basis), Fig. 4 illustrates growth during the 1980s in the number of licenses for software inventions, which accounted for well over 50% of Columbia licensing agreements after 1988; the majority of these licenses (420 of a total of 648) were associated with one software invention.<sup>8</sup> Biomedical inventions accounted for more than 80% of the revenues of the "top 5" inventions during the 1985–1995 period (Table 2).

In assessing the effects of Bayh–Dole on Columbia University, we lack a compelling counterfactual: What would have happened in the absence of this federal law, given the other trends operating in university finances and research after 1980? We believe industrial interest in Columbia's research results, especially in the biomedical area, combined with the prospect of large licensing revenues, would have led Columbia to enact policy changes and develop some administrative machinery for patenting and licensing in the absence of this federal law. Indeed, as we noted earlier, some signs suggest that Columbia was already moving in that direction before Bayh–Dole. Nevertheless, it is likely that the change in federal policy embodied in Bayh–Dole led to a more dramatic change in policies, procedures, and rules than would otherwise have occurred.

Another piece of evidence relevant to an assessment of the effects of Bayh–Dole at Columbia concerns the significant role of software in Columbia's post-1980 licensing activities. Virtually all of the

software inventions licensed by Columbia are protected by copyright, a form of intellectual property never affected by Bayh–Dole, rather than by patents, the focus of this federal law. Software licensing is a new form of technology marketing that has resulted from the University's creation of a technology marketing operation and (like biomedical research) from exogenous changes in the academic research agenda, rather than from the specific policy shifts embodied in Bayh–Dole. Moreover, although the arguments for Bayh–Dole stressed the importance of exclusive licensing in technology transfer and commercialization, many of Columbia's licensed inventions, including its biggest single source of revenues, have been licensed widely on a non-exclusive basis.

### 3.2. *The University of California*

Unlike Columbia, the University of California established policies requiring faculty disclosure of potentially commercially useful research results long before Bayh–Dole. Mechanisms for supporting the commercial exploitation of any resulting patents were put in place in 1943, and assignment by faculty of their inventions to the university was determined on a case-by-case basis. Patenting and any licensing were the responsibility of the UC General Counsel's office, which oversaw the creation and gradual growth of the UC Patent Office. The UC Board of Regents established the "University Patent Fund" in 1952 to invest the earnings from University-owned inventions in the UC system's General Endowment Pool: earnings from the Fund also supported the expenses of UC patenting activities and faculty research.<sup>9</sup> In 1963, the UC Board of Regents adopted a policy stating that all "Members of the faculties and employees shall make appropriate reports of any inventions and licenses they have conceived or de-

<sup>8</sup> In addition, and similarly to the situation at Stanford University (see below), more than 300 of the 420 licenses for this software invention are academic licenses.

<sup>9</sup> According to a March 10, 1975 letter from UC President Charles J. Hitch to Governor Edmund G. Brown, Jr., "The possibility of developing a formal patent policy and program was first considered in the University in the Thirties. But the idea did not achieve full impetus until the war years when the Federal Government began to sponsor research in the University on a large scale and inventions began to be made under research contracts." (p. 1).

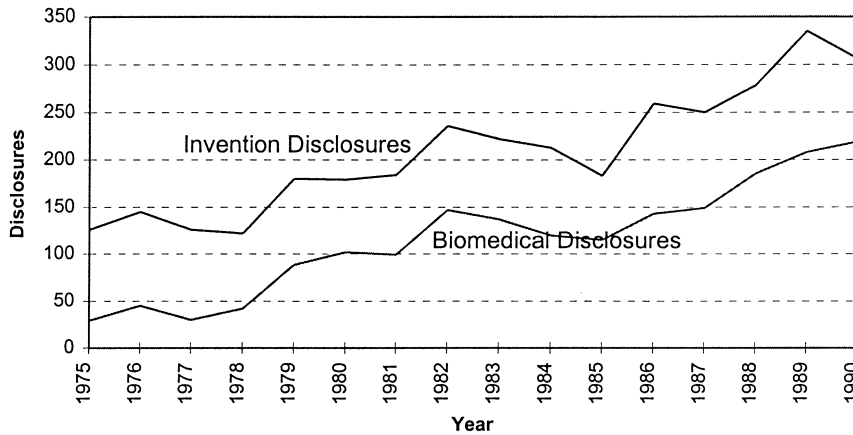


Fig. 5. UC Invention Disclosures, 1975–1990.

veloped to the Board of Patents,”<sup>10</sup> that latter being a committee of UC faculty and administrators charged with oversight of the Patent Office.

In 1976, responsibility for patent policy was transferred from the General Counsel to the Office of the President of the University, and the Patent Office was reorganized into the Patent, Trademark, and Copyright Office (PTCO). Only in 1980, however, was the PTCO staffed with experts in patent law and licensing, as part of a broader expansion in UC patenting and licensing activities. The Board of Patents was abolished in 1985, and new policies allowing for sharing by campuses in patent licensing revenues were adopted by the Office of the President and the campus Chancellors in 1986. Staff employment in the PTCO grew from 4 in 1977–1978 to 43 in 1989–1990, and the PTCO was renamed the Office of Technology Transfer (OTT) in 1991. In

1990, however, UC Berkeley and UCLA established independent patenting and licensing offices, relying on the systemwide Office of Technology Transfer selectively for expertise in patent and licensing regulations. By 1997, four UC campuses (in addition to Berkeley and UCLA, UC San Diego and UC San Francisco) had established independent licensing offices.<sup>11</sup>

Since the University of California was active in patenting and licensing well before the passage of the Bayh–Dole Act, a comparison of the 1975–1979 period (prior to Bayh–Dole) and 1984–1988, following the passage of the bill, provide a “before and after” test of the Act’s effects. The average annual number of invention disclosures during 1984–1988, following passage of the Bayh–Dole Act, is almost 237, well above their average level (140 annual disclosures) for the 1975–1979 period. The period following the Bayh–Dole Act thus is associated with a higher average level of annual invention disclosures (confirmed in Fig. 5); but the timing of the

<sup>10</sup> As revised in 1973, the “University Policy Regarding Patents” states that “An agreement to assign inventions and patents to The Regents of the University of California, except those resulting from permissible consulting activities without use of University facilities, shall be mandatory for all employees, academic and non-academic.” The policy statement goes on to emphasize that “The Regents is [sic] averse to seeking protective patents and will not seek such patents unless the discoverer or inventor can demonstrate that the securing of the patent is important to the University.” This latter sentiment notwithstanding, UC administrators were actively seeking patent protection for faculty inventions by the mid-1970s, as the historical data of the Office of Technology Transfer show.

<sup>11</sup> These “independent” licensing offices, which continue to pay a portion of their revenues to the state government, are in charge of invention disclosures (along with any revenues or expenses associated with these disclosures) occurring after their foundation. The centralized database maintained by the UC Office of Technology Transfer accordingly is most reliable for invention disclosures occurring through 1990, and we focus our analysis on the 1975–1990 period.

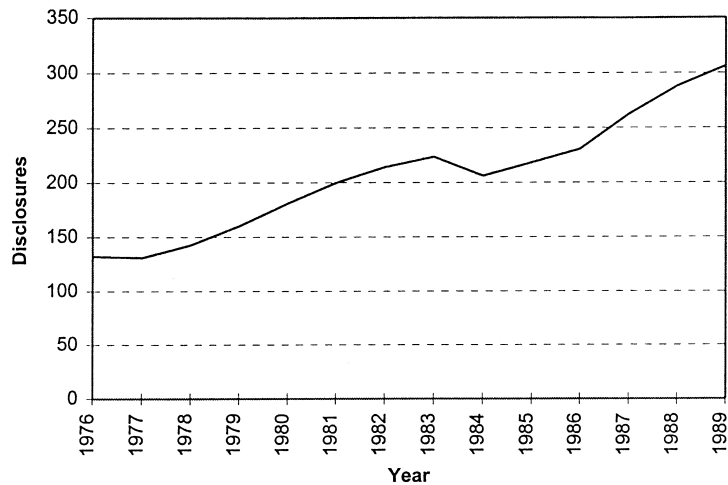


Fig. 6. UC Invention Disclosures (3-year moving average).

increase in annual disclosures suggests that more than the Bayh–Dole Act affected this shift.

Fig. 6 displays a 3-year moving average for annual invention disclosures by UC research personnel during the 1975–1990 period. The increase in the average annual number of invention disclosures in Fig. 6 predates the passage of the Bayh–Dole Act; indeed, the largest single year-to-year percentage increase in disclosures during the entire 1974–1988 period occurred in 1978–1979, before the Act’s passage. This increase in disclosures may reflect the important advances in biotechnology that occurred at UC San Francisco during the 1970s, or other changes in the structure and activities of the UC patent

licensing office that were unrelated to Bayh–Dole. For example, the Cohen–Boyer DNA splicing technique, the basis for the license that accounted for more licensing revenues than any other invention at either university, was disclosed in 1974 and the first of several patent applications for the invention was filed in 1978, well before the passage of Bayh–Dole (this patent issued in 1980).

Since biomedical inventions account for the lions share of UC patenting and licensing after 1980, our assessment of trends “before and after” Bayh–Dole focuses on biomedical inventions, patents, and licenses. Fig. 7 reveals that the shares of biomedical inventions within all UC invention disclosures began

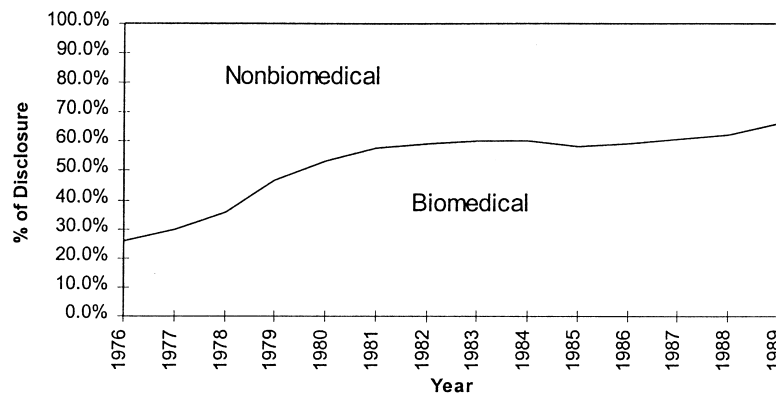


Fig. 7. UC Biomedical Disclosures as a percent of Total Disclosures, 1975–1990 (3-year moving average).

to grow in the mid-1970s, before the passage of Bayh–Dole. Moreover, these biomedical inventions accounted for a disproportionate share of the patenting activities of the University of California during this period: biomedical invention disclosures made up 33% of all UC disclosures during 1975–1979 and 60% of patents issued to the University of California for inventions disclosed during the period.<sup>12</sup> Biomedical patents accounted for 70% of the licensed patents in this cohort of disclosures, and biomedical inventions accounted for 59% of the UC licenses in this cohort that generated positive royalties. Biomedical inventions retained their importance during the 1984–1988 period, as they accounted for 60% of disclosures, 65% of patents, 74% of the licensed patents from this cohort of disclosures, and 73% of the positive-income licenses for this cohort of disclosures.

Growth in the number of biomedical disclosures, which dominated UC patenting and licensing throughout 1975–1990, thus predates the passage of the Bayh–Dole Act. Additional evidence on the shifting composition of the University of California technology licensing portfolio is displayed in Table 2. The UC data in Table 2 reveal the high concentration of licensing revenues among a small number of inventions throughout the pre-Bayh Dole period, as well as indicating remarkable growth (more than 50-fold) in constant-dollar gross revenues during 1970–1995. The share of gross licensing revenues accounted for by the UC system’s “top 5” inventions actually decreases throughout the 1970–1995 period, from nearly 80% in fiscal 1970 to 66% in fiscal 1995, having reached a low point of 47% in fiscal 1985.

Equally remarkable is the shift in the UC system’s “top 5” inventions from agricultural inventions (including plant varieties and agricultural machinery) to biomedical inventions. Among the three universities, only the University of California maintained a large-scale agricultural research effort. During the 1970s, agricultural inventions accounted for a majority of the income accruing to the “top 5” UC money

earners. Beginning in fiscal 1980, however, this share began to decline, and by fiscal 1995, 100% of the UC system’s licensing income from its “top 5” inventions, accounting for almost US\$40 million in revenues (in 1992 dollars), was derived from biomedical inventions, up from 20% in fiscal 1975. Moreover, and consistent with the discussion of the previous paragraph, this share increased sharply before the passage of Bayh–Dole in late 1980: the share of “top 5” licensing revenues associated with biomedical inventions jumped from less than 20% in fiscal 1975 to more than 50% in fiscal 1980.

### 3.3. *Stanford University*

Stanford University’s Office of Technology Licensing was established in 1970, and Stanford was active in patenting and licensing throughout the 1970s. Stanford’s patent policy, adopted in April 1970, stated that “Except in cases where other arrangements are required by contracts and grants or sponsored research or where other arrangements have been specifically agreed upon in writing, it shall be the policy of the University to permit employees of the University, both faculty and staff, and students to retain all rights to inventions made by them.” (Stanford University Office of Technology Licensing, 1982, p. 1). Disclosure by faculty of inventions and their management by Stanford’s OTL thus was optional for most of OTL’s first quarter-century.

In 1994 Stanford changed its policy toward faculty inventions in two important aspects. First, assignment of title to the University of inventions “... developed using University resources...” was made mandatory.<sup>13</sup> Second, the University established a policy under which “Copyright to software developed for University purposes in the course of employment, or as part of either a sponsored project or an unsponsored project specifically supported by University funds, belongs to the University.” (Stanford University Office of Technology Licensing,

<sup>12</sup> Figs. 9 and 11 indicate that biomedical inventions accounted for a growing share of UC patenting and licensing during the entire 1975–1990 period.

<sup>13</sup> Almost simultaneously with this shift in University patent policy, an internal study by the OTL Advisory Board in 1993 recommended that “OTL need not be constrained by the principle of ‘preference for non-exclusive licensing’...” (Stanford University Office of Technology Licensing, 1993, p. 2).

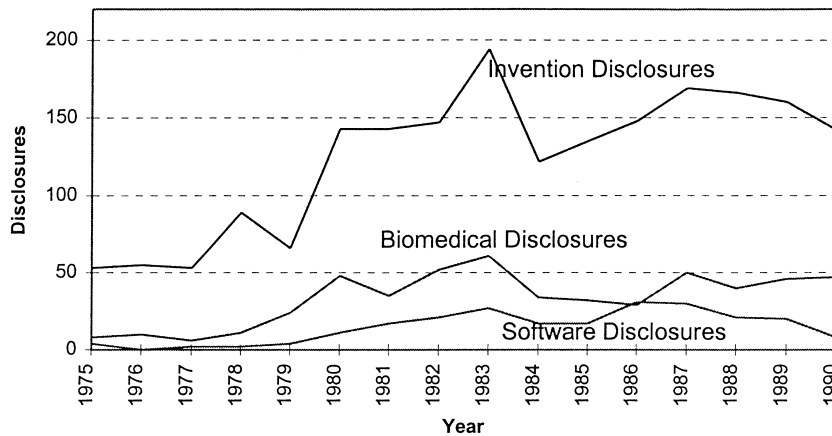


Fig. 8. Stanford University Invention Disclosures, 1975–1990.

1994a).<sup>14</sup> Faculty disclosure of inventions to university administrators was no more mandatory at Stanford before 1994 than at Columbia before 1984. Nevertheless, especially during the 1970–1980 period, Stanford operated a much more elaborate administrative apparatus for the patenting and licensing of inventions than did Columbia. The expanding scale of Stanford’s licensing operations during the 1970s and 1980s also suggests that a substantial fraction of faculty inventions in fact were disclosed to the OTL.

Data from the Stanford OTL provide some insight into the patenting and licensing activities of a major private research university before and after Bayh–Dole. And similarly to the situation at the University of California, these data suggest that the growth of Stanford’s patenting and licensing activities was affected by shifts in the academic research agenda that reflected influences other than Bayh–Dole. Figs. 8 and 9 display trends during 1975–1990 in Stanford invention disclosures. The average annual number of

disclosures to Stanford’s Office of Technology Licensing increased from 74 during 1975–1979, prior to Bayh–Dole, to 149 during 1984–1988. Moreover, the evidence of a “Bayh–Dole effect” on the annual disclosures (such as the jump in disclosures between 1979 and 1980 in Fig. 8) is stronger in the Stanford data than in the UC data, although the smoothed trends in Fig. 9 (computed as a 3-year moving average) suggest that the annual number of invention disclosures was growing prior to Bayh–Dole.

The data in Figs. 8 and 10 also suggest that the importance of biomedical inventions within Stanford’s invention portfolio advances had begun to expand before the passage of Bayh–Dole. Fig. 8 indicates that the annual number of biomedical invention disclosures began to increase sharply during the 1978–1980 period, and the share of all disclosures accounted for by biomedical inventions (see Figs. 8 and 10) increased steadily from 1977–1980, leveling off after 1980 and declining after 1983. A similar but lagged increase in the share of Stanford patents accounted for by biomedical inventions is apparent in Fig. 11. The magnitude of these increases in biomedical inventions prior to Bayh–Dole is more modest than at the University of California, but the trend is similar.

The data in Fig. 12 suggest that similarly to the UC system, biomedical inventions increased somewhat as a share of Stanford’s (non-software) licenses during the 1975–1990 period, although the upward trend is less pronounced and fluctuates more widely

<sup>14</sup> Reflecting faculty sensitivity over assignment to the University of all ownership of all copyrighted material produced under University sponsorship, Stanford’s OTL explicitly exempted ownership of “books, articles, popular non-fiction, novels, poems, musical compositions, or other works of artistic imagination which are not institutional works” from the policy governing software (Stanford University Office of Technology Licensing, 1994b, p. 1).

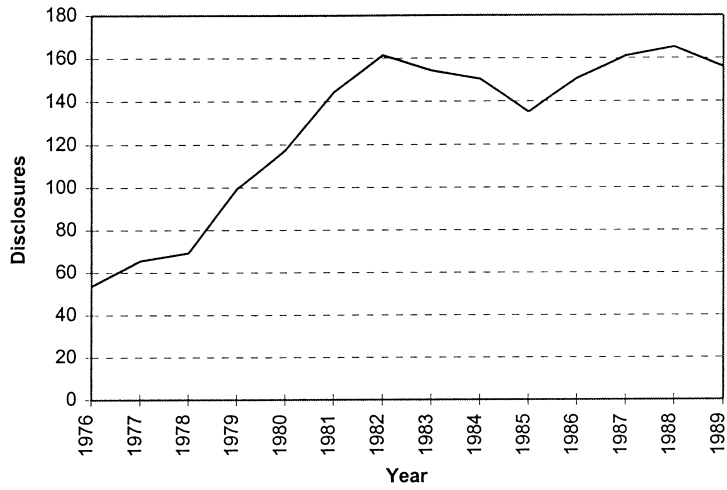


Fig. 9. Stanford University 1975–1990 Invention Disclosures (3-year moving average).

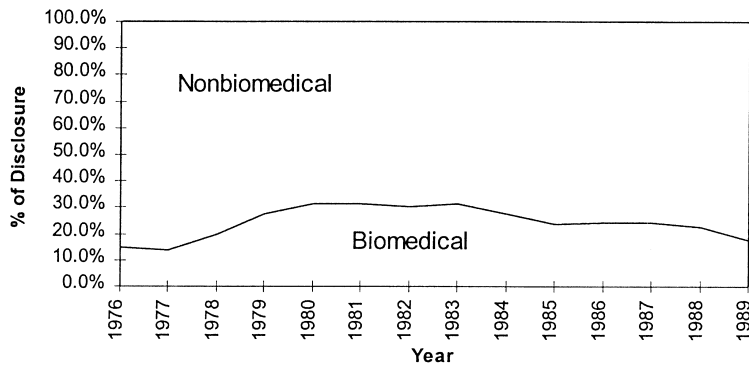


Fig. 10. Stanford University Biomedical Disclosures as a percent of Total Disclosures, 1975–1990 (3-year moving average).

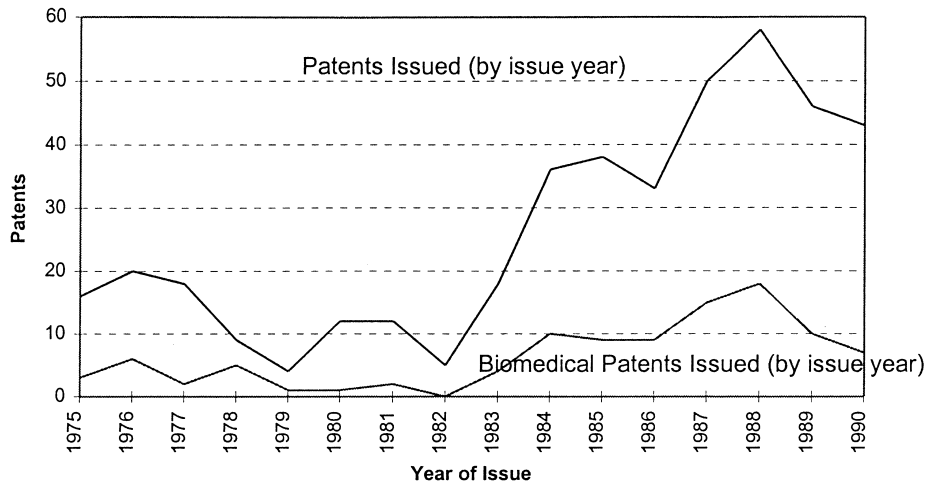


Fig. 11. Stanford Patents by year of issue, 1975–1990.

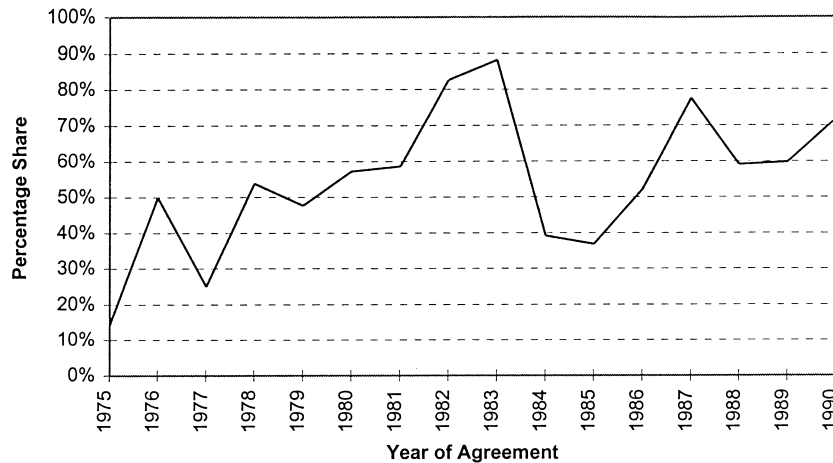


Fig. 12. Biomedical Technology share of Stanford License Agreements (excluding Cohen–Boyer and Software Licenses).

than in the UC data.<sup>15</sup> Table 2 indicates that as of fiscal 1980, slightly more than 40% of the income from Stanford's "top 5" inventions was attributable to biomedical inventions, suggesting the considerable importance of these inventions prior to Bayh–Dole. This share increases to more than 96% by fiscal 1995. Stanford's licensing revenues grew by almost 200-fold (in constant dollars) during 1970–1995, and its "top 5" inventions account for a larger share of gross income for the 1980–1995 period than do the "top 5" UC inventions.

Both Stanford and the UC system thus experienced a shift in the composition of their invention and licensing portfolio towards biomedical inventions prior to Bayh–Dole. Bayh–Dole was an important, but not a determinative, factor in the growth and changing composition of patenting and licensing activity at these institutions.

Like the Columbia University data, Stanford's invention disclosures includes a number of software inventions, which account for 10–15% of annual

disclosures. As is the case at Columbia during the 1980s, the majority of these inventions were not patented and therefore cannot be traced through annual patent counts. The importance of software disclosures in Stanford's licensing activity has grown over time. Only two of the 41 inventions disclosed during 1974–1979 (less than 5%) that were licensed within eight years of their disclosure were software inventions fraction increased to more than 20% for the 1984–1988 period. Many of these software inventions (for example, the WYLBUR operating system) were licensed on a non-exclusive basis to academic institutions through Stanford's Software Distribution Center during the 1980s. The majority of these licenses involved a small, one-time payment by the licensee institution.<sup>16</sup> Partly because of the large number of such "site licenses," the coverage

<sup>15</sup> Figs. 16 and 17 exclude licenses for the Cohen–Boyer patents, which were managed by Stanford's OTL on behalf of the UC system and Stanford University. Strictly speaking, since the revenues from these licenses are split between the UC system and Stanford University, the licenses also should be allocated between the two institutions. Exclusion of this heavily licensed invention understates the growth in the biomedical share of Stanford and UC licensing agreements during the 1980s in Fig. 11 and Fig. 17.

<sup>16</sup> Some indication of the relative magnitudes of licensing revenues from these "site licenses," which for some years were administered by the OTL Software Distribution Center, is given by the following data cited in the 1988–1989 report of Stanford's Office of Technology Licensing, which separated software licensing revenues into those derived from "...direct software distribution through OTL's Software Distribution Center (US\$453,581 from 515 use licenses) and from royalties paid by commercial distributors (US\$420,000 from 40 distribution licenses to software firms, computer companies, and publishers)." (Stanford University Office of Technology Licensing, 1990, p. 4). Unfortunately, we have been unable thus far to consistently separate software licenses between these two channels of distribution.

by our data of Stanford software licensing agreements is spotty and our estimate of the share of all Stanford licensing agreements accounted for by software is less accurate. Nonetheless, like Columbia University, a significant portion of Stanford's licensed inventions (at least 10–20% of annual licensing agreements, and a smaller share of gross revenues) cover non-patented inventions, Bayh–Dole notwithstanding.

### *3.4. Comparing invention disclosures and licenses at all three universities in the late 1980s*

In addition to comparing the periods before and after Bayh–Dole for two of these three universities, we compared the disclosure, patenting, and licensing activities across all three universities for the 1986–1990 period to assess the similarities and differences among them well after the passage of the Bayh–Dole Act.<sup>17</sup> The data in the top panel of Table 3 suggest that there is considerable similarity among these three universities in the characteristics of their invention disclosures, though a larger share of Stanford University's disclosures are licensed and a larger fraction of Stanford's invention disclosures yield positive licensing income than is true of either Columbia or the University of California.<sup>18</sup>

<sup>17</sup> In order to deal with the problems of “truncation bias” while accommodating the fact that our data end in 1997, we have imposed a 6-year “trailing window” on our invention disclosures. In other words, the analysis includes issued patents or licenses only if these events occur within 6 years after the date of disclosure of the invention. This convention is used to avoid unfairly biasing the indicators of “productivity” in favor of older disclosures, which have much longer time periods during which to produce patents or licenses.

<sup>18</sup> As we noted earlier, a large fraction of Stanford's software licenses cover low-cost “site licenses” at other academic institutions, which may well raise the shares of Stanford disclosures that yield licensing income without necessarily having a significant effect on overall licensing income. In addition, the Stanford invention disclosures and licensing data contain a large number of agreements covering “clones” of various pieces of genetic material—such agreements are much less common in the Columbia or UC data. These licenses are somewhat more formal than Materials Transfer Agreements, and often involve the payment of modest licensing fees. But like the Stanford software licenses, the effect of including these agreements drives up the shares of disclosures that are licensed or that yield licensing income without having much effect on overall licensing income.

Restricting the focus to biomedical inventions does little to change the conclusions of this comparison among our three universities (the second panel of Table 3).

The comparison of software inventions for the two universities within our sample (Stanford and Columbia) that have been active licensors of these technologies suggests that, as we noted above, software licenses rarely involve patented inventions: 100% of the software inventions disclosed at Stanford during 1986–1990 and 83% of Columbia's software inventions disclosed during this period that were licensed within six years of disclosure were not patented.

A final issue for consideration in our comparative evaluation of licensing in the post-Bayh Dole era at these three universities concerns the fraction of inventions that are licensed through “exclusive” contracts, which we define here as contracts that are globally exclusive or that contain specified field of use or market restrictions. A relatively high fraction of all inventions that are licensed—as high as 90% for UC licenses and no less than 58.8% for Stanford licenses of “all technologies” during this period—is licensed on a relatively exclusive basis, and these shares are similar for biomedical inventions. Perhaps because of the weaker formal protection for this technology (during much of this period, the lack of patent protection), software inventions are less frequently licensed on an exclusive basis: 46% and 17%, respectively, of software invention disclosures at Stanford and Columbia were licensed exclusively during 1986–1990.

Nevertheless, the licenses accounting for the largest share of revenues at all of these universities are non-exclusive licenses. The Stanford–UC Cohen–Boyer patents were licensed widely and non-exclusively.<sup>19</sup> Columbia University's Axel biotechnology patent also was licensed on a non-exclusive basis.

Although many proponents of patent protection for university inventions argue that would-be com-

<sup>19</sup> See the case study of Cohen–Boyer in the recently published summary of a National Research Council workshop on “Intellectual Property Rights and Research Tools in Molecular Biology” (National Research Council, 1997).

Table 3

Comparative evidence on Invention Disclosures and Licenses at Stanford University, Columbia University, and the University of California, 1986–1990

	Stanford	Columbia	UC
<i>1986–1990 (6-year “trailing window”): ALL TECHNOLOGIES</i>			
percent of disclosures yielding patents	23.2	18.6	20.4
percent of disclosures that are licensed	33.2	16.4	12.3
disclosures with licensing income > 0/all disclosures	22.4	12.3	7.4
licensed disclosures with licensing income > 0/number of disclosures that are licensed	67.4	75.0	60.6
percent of licensed disclosures that are licensed exclusively	58.8	59.1	90.3
<i>1986–1990 (6-year “trailing window”): BIOMEDICAL TECHNOLOGIES</i>			
percent of disclosures yielding patents	17.5	15.3	15.7
percent of disclosures that are licensed	38.7	17.3	14.8
disclosures with licensing income > 0/all disclosures	33.5	13.9	10.0
licensed disclosures with licensing income > 0/number of disclosures that are licensed	86.6	80.0	67.2
percent of licensed disclosures that are licensed exclusively	54.9	62.9	90.3
<i>1986–1990 (6-year “trailing window”): SOFTWARE TECHNOLOGIES</i>			
percent of disclosures yielding patents	0	17.6	NA
percent of disclosures that are licensed	53.6	35.3	NA
disclosures with licensing income > 0/all disclosures	45.5	23.5	NA
licensed disclosures with licensing income > 0/number of disclosures that are licensed	84.7	66.7	NA
percent of licensed disclosures that are licensed exclusively	46.3	16.7	NA

mercial developers of these technologies needed exclusive title to this intellectual property in order to obtain a clear “prospect” for their significant investments in this activity, these cases suggest that for inventions of broad promise and potential widespread use, non-exclusive licenses can accommodate both universities’ interest in revenues and the needs of commercial users for access to the essential intellectual property.

#### 4. Conclusions and concerns

The effects of the Bayh–Dole Act on U.S. research universities have received extensive rhetorical attention but modest empirical analysis. In this paper, we have used an invaluable byproduct of the Act, the records of faculty inventions, patents, and licenses compiled by three leading U.S. research universities, in an analysis of some of the Act’s effects. Our data on the University of California and Stanford University suggest that for universities already active in patenting and licensing, Bayh–Dole resulted in expanded efforts to market academic

inventions. The Act also led Columbia, along with many other research universities formerly inactive in this area, to revise its longstanding policies and enter into large-scale patenting and licensing of faculty inventions.

But several factors in addition to Bayh–Dole stimulated the post-1980 upsurge in patenting and licensing at U.S. research universities, and it is difficult to separate their effects from those of the Act. These additional factors were especially influential in biomedical research. In particular, by the mid-1970s biomedical technology, especially biotechnology, had increased significantly in importance as a productive field of university research that yielded research findings of great interest to industry. The feasibility of technology licensing in biotechnology was particularly advanced by the *Diamond vs. Chakrabarty* decision, while the broader shift in U.S. policy to strengthen intellectual property rights elevated the economic value of patents and facilitated patent licensing.

An array of developments in academic research, industry and policy thus combined to increase U.S. universities’ activities in technology licensing, and Bayh–Dole, while important, was not determinative.

We believe that even without Bayh–Dole, both Stanford and the UC system would have expanded their patenting and licensing activities, and their licensing revenues would have grown significantly. Columbia University also expanded its patenting activities and reconsidered its policies toward patenting and licensing inventions in the period immediately prior to Bayh–Dole, and likely would have expanded its licensing activities in the absence of Bayh–Dole.

By the end of the first decade of Bayh–Dole, these three universities display remarkable similarities in their patent and licensing portfolios, as illustrated by the data in Tables 2 and 3. A very small share of all patented inventions account for the majority of gross licensing revenues at all three universities. Moreover, these leading earners are concentrated in the biomedical area, a technology field characterized by relatively strong patents that are economically significant (Levin et al., 1987). A second important area of licensing at two of these three universities, however, is software, for which formal patent protection is less important.

A number of observers have expressed concern that the upsurge of patenting and licensing has shifted university research toward applied questions and away from basic research. As we noted earlier, the content of U.S. universities' research has shifted toward biomedical research, but this shift does not on its face represent a move out of fundamental research. The areas in which university research has grown rapidly have been rich in results with commercial promise; but much of the research that generated them has been quite fundamental in nature. Although the propensity to patent research results in these areas has been high, Bayh–Dole is only one of several factors behind increased patenting and licensing.

In addition, the effects of any change in university research "culture" and norms wrought by Bayh–Dole appear to be limited to relatively few units in these universities. Increased post-1980 patenting and licensing activity has affected a relatively small number of departments and institutes at Columbia University, the only one of our three universities for which we have data on the departmental origins of invention disclosures. Were they available, similar data from Stanford and the UC system would likely support a similar conclusion.

This shift in university policies raises two other concerns that are not addressed by the data presented in this paper. First, are universities' patenting and licensing efforts increasing or reducing the speed and effectiveness with which university research results are picked up by industry and brought to practice? Second, are universities' expanded efforts to patent inputs into the scientific research process impeding progress in science itself?

The theory behind Bayh–Dole was that companies needed exclusive patent rights to develop and commercialize the results of university research, a theory that flies in the face of the position that patents tend to restrict use of scientific and technological information, and that open publication facilitates wider use and application of such inventions and knowledge. Are patents or restrictive licenses necessary to achieve application? Should such licenses be negotiated by universities, institutions not always known for their commercial expertise? Do a university-assigned patent and a licensing agreement delay or accelerate technology transfer? In future research, we plan to compile case studies of the commercialization of university inventions, examining whether an exclusive license facilitated the transfer of a given technology transfer, or whether technology transfer would have proceeded just as rapidly and widely had the results simply been placed in the open literature. The answers to these questions will vary considerably among inventions, technologies, and time periods.

As we noted earlier, the shifts in these universities' post-1980 research activities cannot be characterized as a shift from basic to applied research. But a very different debate over the effects of Bayh–Dole concerns these policies' effects on the dissemination of basic research results by universities. Put simply, more of what universities formerly would have placed in the public domain—including "research tools"—now is patented and subject to administrative procedures that could restrict the diffusion of these research results. A number of universities have extended patenting and licensing policies since 1980 to cover the results of scientific research, rather than focusing their patenting on the results of applied research. These policies may raise the costs of use of these research results in both academic and non-academic settings, as well as limiting the diffusion of these

results. These tendencies are most apparent in “research tools” in molecular biology and biotechnology (See National Research Council, 1997). Universities and private firms alike are now patenting genetic materials far more extensively and requiring licensing and royalty payments for their use, raising the costs and administrative complexity associated with scientific research in this area.

In these three universities, biotechnology research tools have been licensed widely, and the transaction costs involved in taking out a license appear to be relatively low. But this issue merits continuing attention: although universities now can collect revenues from patenting and licensing research tools that in an earlier era likely would have simply been placed in the public domain, this practice does not spur technology transfer. The argument that allowing universities to patent and exclusively license the results of university research will enhance technology transfer may not apply to this class of inventions.

The principal risk posed by the Bayh–Dole Act and related initiatives in U.S. science and technology policy flows from the premise that underpins many of these legislative and policy initiatives. All too often, these initiatives assume that patents and exclusive licensure of the results of federally sponsored research are the best approach to maximize the social returns to the federal R&D investments. This premise appears to understate the effectiveness of publication and other, more open channels for information dissemination and access in enabling society to benefit from publicly funded academic research. Indeed, a recent survey of firms in the manufacturing sector indicates that the four most important channels through which firms benefit from university research are publications, conferences, informal information channels, and consulting (Cohen et al., 1998). Even in pharmaceuticals, where patents and licenses are more important than in other industries, firms rely heavily on these other channels of knowledge and technology transfer (Gambardella, 1995).

We conclude by reiterating two concerns over the effects of Bayh–Dole and related policy shifts that are not addressed by our data but deserve attention in future research. First, widespread patenting and restrictive licensing terms may in some cases hamper, rather than promote, technology transfer from universities to industry. These policies may also ob-

struct the process of scientific research. Second, an administrative emphasis on patenting and licensing may interfere with the operation of other effective channels through which university inventions reach commercial application. Although administrators and licensing professionals at the universities discussed in this paper are aware of these potential pitfalls, these issues merit continued attention. The U.S. university system has compiled an admirable record of teaching, research, public service, and contributions to the U.S. and global economies during this century. A key challenge for the next century is maintaining a balance among these missions. In the long run, we believe that such a balanced approach, which in some cases may involve lower financial returns on university patents and licenses, will enhance universities’ contributions to domestic and global economic welfare.

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