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Chapter Author: David C. Mowery, Arvids A. Ziedonis

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Numbers, Quality, and Entry: How Has the Bayh-Dole Act Affected U.S. University Patenting and Licensing?

David C. Mowery, *University of California, Berkeley*
Arvids A. Ziedonis, *University of Pennsylvania*

Executive Summary

This paper summarizes the results of empirical analyses of data on the characteristics of the pre- and post-1980 patents of three leading U.S. academic patenters—the University of California, Stanford University, and Columbia University. We complemented this analysis of these institutions with an analysis of the characteristics of the patents issued to all U.S. universities before and after 1980. Our analysis suggests that the effects of the Bayh-Dole Act on the content of academic research and patenting at Stanford and the University of California were modest. The most significant change in the content of research at these universities, one associated with increased patenting and licensing at both universities before and after 1980, was the rise of biomedical research and inventive activity, but Bayh-Dole had little to do with this growth. Indeed, the rise in biomedical research and inventions in both of these universities predates the passage of Bayh-Dole. Both UC and Stanford university administrators intensified their efforts to market faculty inventions in the wake of Bayh-Dole. This enlargement of the pool of marketed inventions appears to have reduced the average "yield" (defined as the share of license contracts yielding positive revenues) of this population at both universities. But we find no decline in the "importance" or "generality" of the post-1980 patents of these two universities. The analysis of overall U.S. university patenting suggests that the patents issued to institutions that entered into patenting and licensing after the effective date of the Bayh-Dole Act are indeed less important and less general than the patents issued before and after 1980 to U.S. universities with longer experience in patenting. Inexperienced academic patenters appear to have obtained patents that proved to be less significant (in terms of the rate and breadth of their subsequent citations) than those issuing to more experienced university patenters. Bayh-Dole's effects on entry therefore may be as important as any effects of the Act on the internal "research culture" of U.S. universities in explaining the widely remarked decline in the importance and generality of U.S. academic patents after 1980.

I. Introduction

The U.S. research university has played a central role in the evolution of the U.S. innovation system during this century. Indeed, both the U.S. research university and the organized pursuit of R&D in industry trace their origins back roughly 125 years, and have grown in parallel throughout the 20th century (Mowery and Rosenberg 1998). Although links between R&D in U.S. industry and research in U.S. universities have a long history, recent developments in this relationship, especially the growth in university patenting and licensing of technologies to private firms, have attracted considerable attention.

U.S. university patenting and licensing have grown significantly in the wake of an important 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 and Trajtenberg et al. 1997 are important exceptions). This paper summarizes the results of empirical analyses of data on the characteristics of the pre- and post-1980 patents of three leading U.S. academic patenters—the University of California (UC), Stanford University, and Columbia University. We complemented this analysis of these institutions with an analysis of the characteristics of the patents issued to all U.S. universities before and after 1980 (See Mowery et al. 1999 and Mowery and Ziedonis 2000 for the detailed analyses).

We undertook this empirical research to assess the effects of Bayh-Dole on patenting and licensing at two universities (UC and Stanford) with substantial pre-1980 experience in these activities, and to compare these universities with Columbia University, a post-1980 entrant into patenting and licensing. This research examined the widespread assertion that the increased patenting activity of U.S. universities during the 1980s was due to the Bayh-Dole Act. The second piece of empirical research that is summarized in this paper examined Bayh-Dole's effects on the content of academic research. We analyzed Bayh-Dole's effects on UC and Stanford's technology marketing efforts, as well as the "importance" and "generality" of the patents issuing to these universities, before and after 1980. Finally, we compared these characteristics of the patents issuing to these two universities with those of Columbia University, and examined the characteristics of patents issuing to all U.S. universities before and after 1980.

Our before and after analysis suggests that the effects of Bayh-Dole on the content of academic research and patenting at Stanford and the University of California were modest. The most significant change in the content of research at these universities, one associated with increased patenting and licensing at both universities before and after 1980, was the rise of biomedical research and inventive activity, but Bayh-Dole had little to do with this growth. Indeed, the growth in biomedical research and inventions in both of these universities predates the passage of Bayh-Dole. Both UC and Stanford university administrators intensified their efforts to market faculty inventions in the wake of Bayh-Dole, expanding the pool of university inventions for which patent applications were made and licensees sought. This enlargement of the pool of marketed inventions appears to have reduced the average yield (defined as the share of license contracts yielding positive revenues) of the intensified technology marketing efforts of both universities after 1980. But we find no decline in the importance or generality of the post-1980 patents of these two universities.

The analysis of overall U.S. university patenting suggests that the patents issued to institutions that entered into patenting and licensing after the effective date of the Bayh-Dole Act are indeed less important and less general than the patents issued before and after 1980 to U.S. universities with longer experience in patenting. In other words, an important factor in any assessment of Bayh-Dole's effects on U.S. academic patenting is the entry by universities with little experience into patenting and licensing after 1980. These inexperienced academic patenters appear to have obtained patents that proved to be less significant (in terms of the number and breadth of their subsequent citations) than those issuing to more experienced university patenters. Bayh-Dole's effects on entry therefore are at least as important as any effects on the internal research culture of U.S. universities in explaining the widely remarked decline in the importance and generality of U.S. academic patents after 1980 (See Henderson et al. 1998).

Immediately below, we discuss the background to the Bayh-Dole Act, in order to highlight the point that university-industry 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 universities, present the comparative analysis, and consider the implications of our findings for the academic research enterprise and the overall innovation system of the United States.

II. 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.[1] 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 nonagricultural fields, ranging from engineering to physics and chemistry, collaborative research relationships between university faculty and industry were common (Rosenberg and Nelson 1994).

World War II transformed the role of U.S. universities as research performers and the sources of U.S. universities' research funding. The share of industry funding declined within the expanded research budgets of postwar U.S. research universities during the 1950s and 1960s, and by the early 1970s, federal funds accounted for more than 70% of university-performed research and industrial funding accounted for 2.6%. 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. By 1997, federal funds accounted for 59% of total university research, and industry's share of the overall U.S. university research budget had tripled to more than 7% (all data are from National Science Board, 1996, and National Science Foundation, 2000). Most of the increase in industry funding occurred during the 1980s, and the industry share of university research funding has changed very little since 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 well before 1980. Beginning in 1926, the University of California required all employees to report patentable inventions to the university administration. Other universities, like MIT and the University of Wisconsin, also developed administrative units to help patent and license inventions resulting from research. But relatively few academic institutions assumed direct responsibility for management of these activities, choosing instead to leave them in the hands of individual faculty or relying on external

organizations such as the Research Corporation (Mowery and Sampat 1999).

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). During the 1960s, both the Defense Department and the Department of Health, Education and Welfare (now HHS, the agency housing the National Institutes of Health), which were among the leading sources of federal academic research funding, 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 and facilitated licensing of such inventions on an exclusive or nonexclusive basis, but tensions between some major IPA participants, such as the University of California, and their federal research sponsors remained.[2] These debates intensified in the late 1970s, when HEW 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 at least two 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 expressed Congressional support for the negotiation of exclusive licenses between universities and industrial firms for the results of federally funded research.

The passage of the Bayh-Dole Act was one part of a broader shift in U.S. policy toward stronger intellectual property rights.[3] 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.[4] But even before the establishment of the CAFC, the 1980 U.S. Supreme Court decision in *Diamond v. Chakrabarty* upheld the validity of a broad patent in the new industry

of biotechnology, facilitating the patenting and licensing of inventions in this sector. The effects of Bayh-Dole thus must be viewed in the context of this larger shift in U.S. policy toward intellectual property rights.

The period following the passage of the Bayh-Dole Act was characterized by a sharp increase in U.S. university patenting and licensing activity. The data in table 6.1 reveal a large increase in university patenting after 1980—the number of patents issued to the 100 leading U.S. research universities (measured in terms of their 1993 R&D funding) more than doubled between 1979 and 1984, and more than doubled again between 1984 and 1989. Henderson, Jaffe, and Trajtenberg (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 $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 (AUTM) 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 $183 million to $318 million in the 3 years from 1991 to 1994 alone (Cohen et al. 1998). As these data suggest, the Bayh-Dole Act triggered the entry by many universities into patenting and licensing. But even at incumbent academic patenters and licensors, the 1980s were marked by intensified technology licensing activity.

Table 6.1
Number of U.S. Patents Issued to 100 U.S. Academic Institutions with the Highest 1993 R&D Funding, 1974–1994

Year	Number of U.S. Patents
1974	177
1979	196
1984	408
1989	1004
1994	1486

National Science Board, 1996.

III. The Effects of Bayh-Dole on the Content of UC and Stanford Disclosures, Patenting, and Licensing

Bayh-Dole and the Rise of Biomedical Research at UC and Stanford University, 1975–1988

Both the University of California system and Stanford University established offices to promote the patenting and licensing of faculty inventions well before the passage of the Bayh-Dole Act. 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 developed to the Board of Patents."[5] In 1976, responsibility for patent policy was transferred from the General Counsel to the Office of the UC President, and in 1991 the Patent Office was reorganized into the Patent, Trademark, and Copyright Office (PTCO), and renamed the Office of Technology Transfer (OTT).

Stanford University's Office of Technology Licensing was established in 1970, and Stanford was active in patenting and licensing throughout the 1970s. Disclosure by faculty of inventions and their management by Stanford's OTL was optional for most of OTL's first quarter-century, but 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. 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." ("Office of Technology Licensing Guidelines for Software Distribution," 11/17/94).[6] Before and after 1994, the Stanford data contain many more faculty software inventions than do the UC data, reflecting the fact that the mandatory disclosure policy of the University of California did not cover software, deemed at the time to be copyrightable rather than patentable intellectual property.

Since both of these universities were 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, provides a "before and after" test of the Act's effects. The average annual number of invention disclosures at the University of California during 1984–1988, following passage of the Bayh-Dole Act, is almost 237, well above their average level (140 annual disclo-

sures) 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 figure 6.1); but the timing of the increase in annual disclosures suggests that more than the Bayh-Dole Act affected this shift.

Figure 6.2 displays a 3-year moving average for annual invention disclosures by UC research personnel, omitting the first and last years in the 1975–1988 period. Both figures indicate that the increase in the average annual number of invention disclosures 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 single most profitable invention licensed by the UC system and Stanford 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 was issued in 1980).

Since biomedical inventions account for the lion's share of UC patenting and licensing after 1980, our assessment of trends before and after Bayh-Dole focuses on biomedical inventions, patents, and licenses.

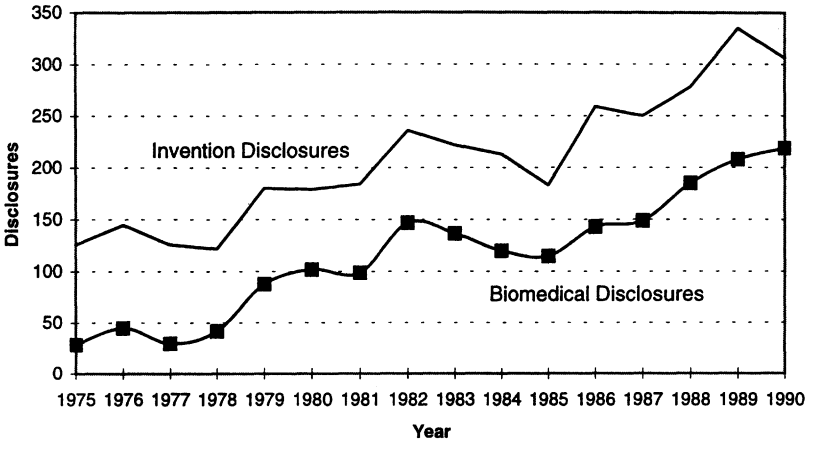

Figure 6.1
UC Invention Disclosures, 1975–1990

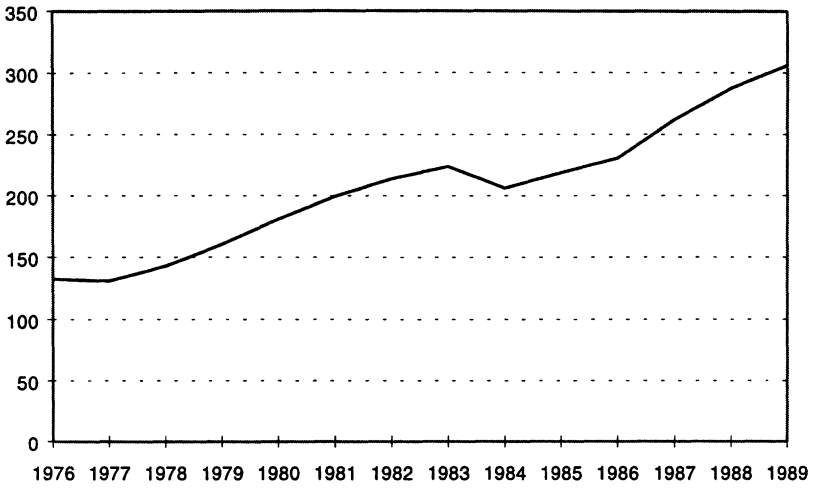

Figure 6.2
UC Invention Disclosures (Three Year Moving Average)

Figure 6.3 reveals that the shares of biomedical inventions within all UC invention disclosures began to grow in the mid-1970s, before the passage of Bayh-Dole. Moreover, these biomedical inventions accounted for a disproportionate share of the patenting and licensing 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 that period.[7] 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.

Data from the Stanford OTL provide similar "before and after" information on the patenting and licensing activities of a major private research university. Like those for 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. Figures 6.4 and 6.5 display trends during 1975–1990 in Stanford invention disclosures. The average annual number of disclosures to Stanford's Office of Technology

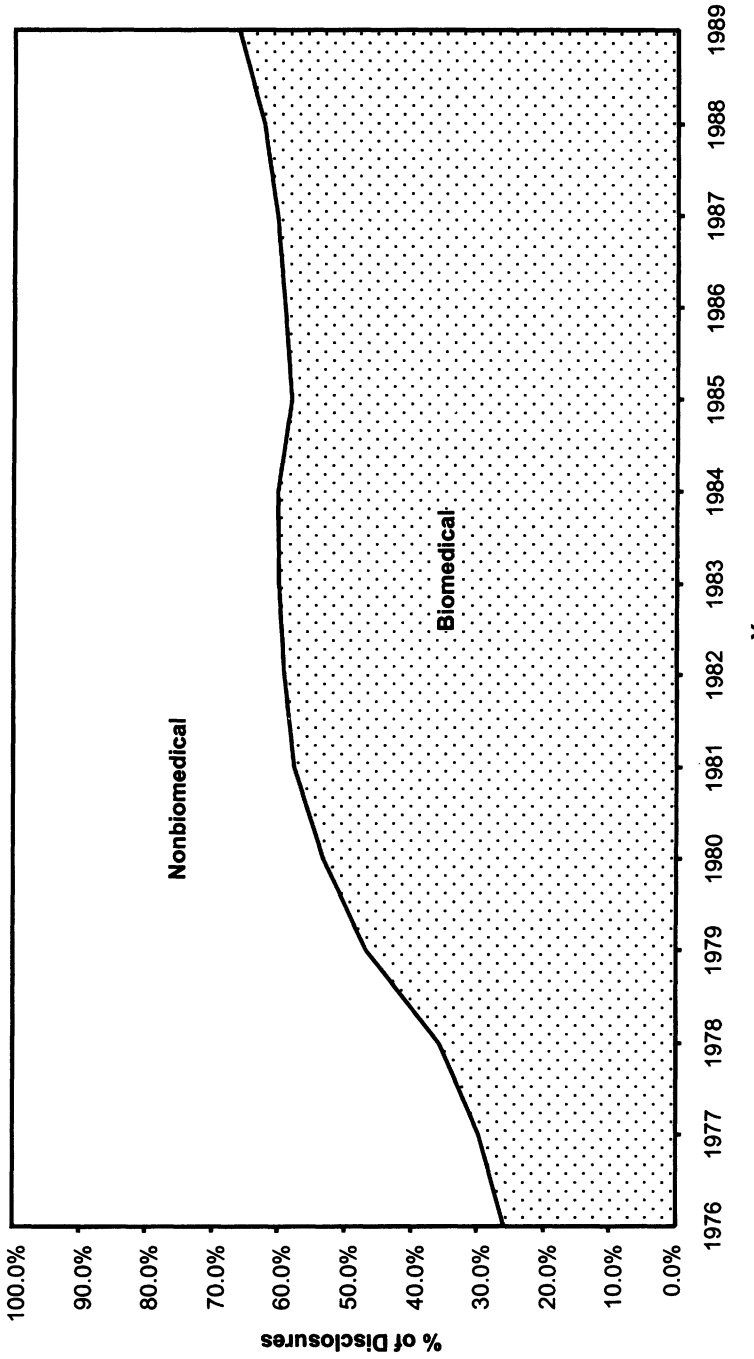

Figure 6.3
UC Biomedical Disclosures as a Percent of Total Disclosures, 1975–1990 (Three Year Moving Average)

Licensing increased from 74 during 1975–1979, prior to Bayh-Dole, to 149 during 1984–1988. The evidence of a "Bayh-Dole effect" on the annual number of disclosures (such as the jump in disclosures between 1979 and 1980 in figure 6.4) is stronger in the Stanford data than in the UC data.

The data in figures 6.4 and 6.6 suggest that the importance of biomedical inventions within Stanford's invention portfolio advances had begun to expand before the passage of Bayh-Dole. Figure 6.4 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 figures 6.4 and 6.6) increased steadily from 1977 to 1980, leveling off after 1980 and declining after 1983. 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. Biomedical inventions also increased their share of Stanford's (nonsoftware) licenses during the 1975–1990 period, although the upward trend is less pronounced and fluctuates more widely than in the UC data.

Additional evidence on the shifting composition of the UC and Stanford technology licensing portfolios is displayed in table 6.2. The UC

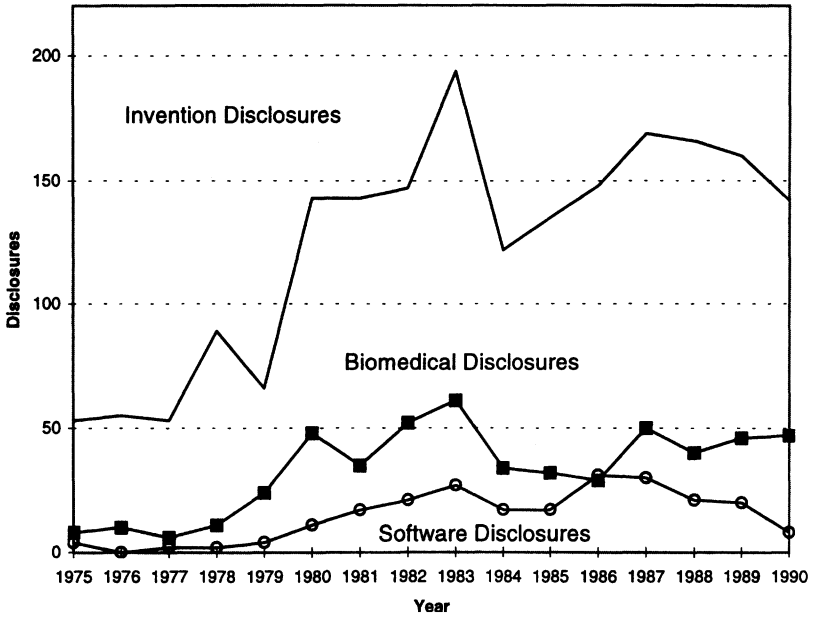

Figure 6.4
Stanford University Invention Disclosure, 1975–1990

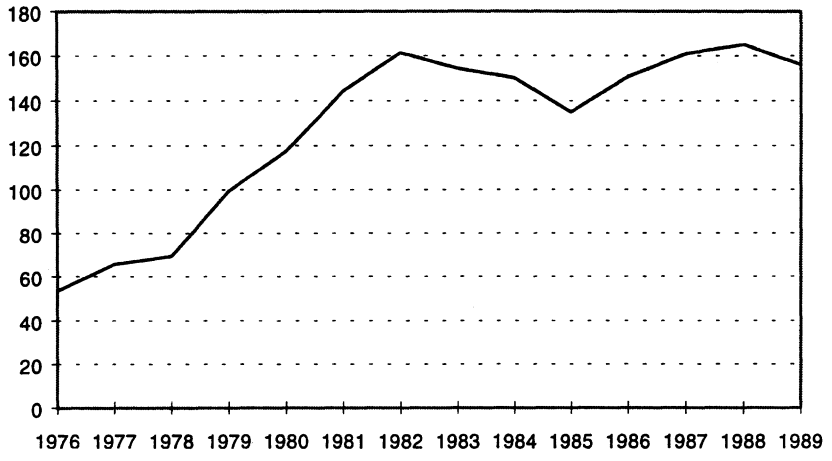

Figure 6.5
Stanford University 1975–1990 Invention Disclosures (Three Year Moving Average)

data in table 6.2 reveal the high concentration of licensing revenues among a small number of inventions throughout the pre-Bayh-Dole period, as well as indicating significant growth (more than 50-fold) in constant-dollar gross revenues during 1970–1995. 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 discussed in detail in this paper, 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 $40 million in revenues (in 1992 dollars), was derived from biomedical inventions, up from 20% in fiscal 1975. Moreover, and consistent with the previous discussion, this share increased before the passage of Bayh-Dole in late 1980: the share of the top 5 licensing revenues associated with biomedical inventions jumped from less than 20% in fiscal 1975 to more than 50% in fiscal 1980.

The data in table 6.2 on Stanford's licensing income display similar trends to those observed at UC. 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 increased to more than

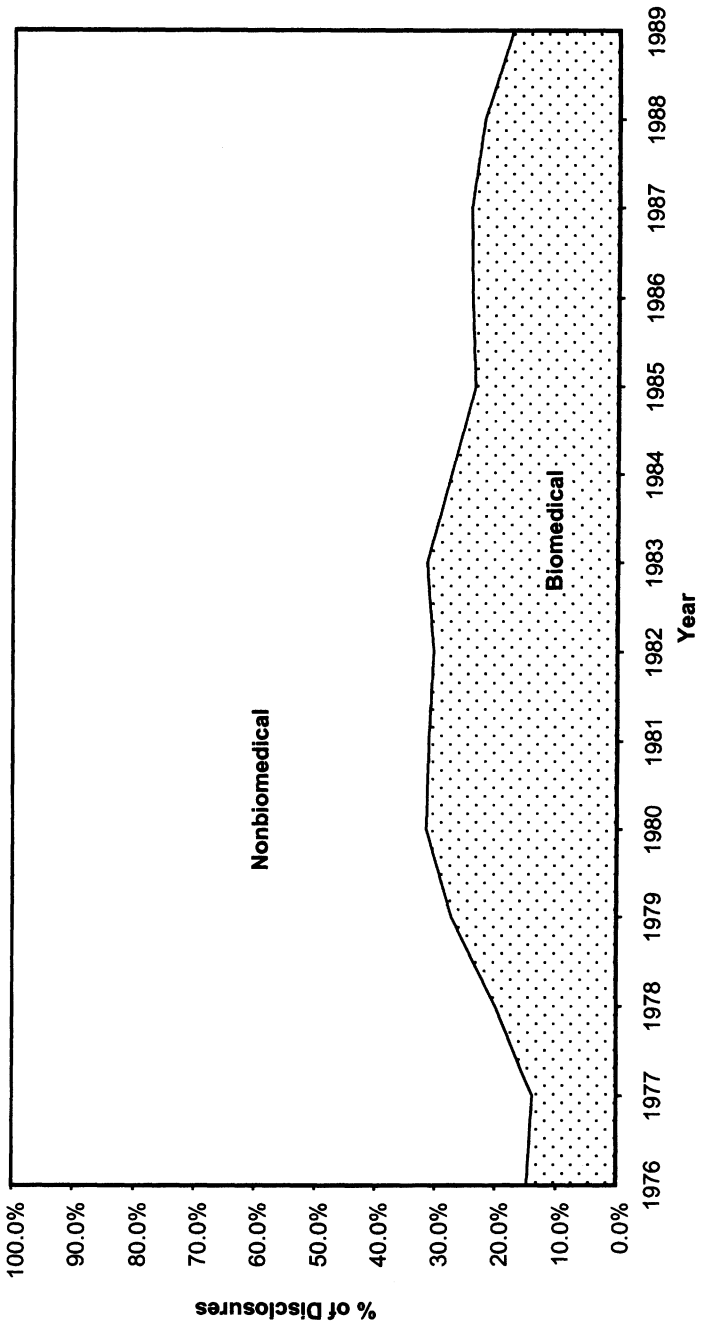

Figure 6.6
Stanford University Biomedical Disclosures as a Percent of Total Disclosures, 1975–1990 (Three Year Moving Average)

Table 6.2
Seclected Data on University of California, Stanford University, and Columbia University Licensing Income, FY1970–1995

UC	FY1970	FY1975	FY1980	FY1985	FY1990	FY1995
Gross income (1992 dollars: 000s)	1,140.4	1,470.7	2,113.9	3,914.3	13,240.4	58,556.0
Gross income from top five earners (1992 dollars: 000s)	899.9	1,074.8	1,083.0	1,855.0	7,229.8	38,665.6
share of gross income from top five earners (%)	79	73	51	47	55	66
share of income of top five earners associated with biomedical inventions (%)	34	19	54	40	91	100
share of income of top five earners associated with agricultural inventions (%)	57	70	46	60	9	0
Stanford		FY76				
Gross income (1992 dollars: 000s)	180.4	842.6	1,084.4	4,890.9	14,757.5	35,833.1
Gross income from top five earners (1992 dollars: 000s)		579.3	937.7	3,360.9	11,202.7	30,285.4
share of gross income from top five earners (%)		69	86	69	76	85
share of income of top five earners associated with biomedical inventions (%)		87	40	64	84	97
Columbia						
Gross income (1992 dollars: 000s)				542.0	6,903.5	31,790.3
Gross income from top five earners (1992 dollars: 000s)				535.6	6,366.7	29,935.8
share of gross income from top five earners (%)				99	92	94
share of income of top five earners associated with biomedical inventions (%)				81	87	91

96% by fiscal 1995. Stanford's licensing revenues grew 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.

Stanford and the UC system thus both experienced a shift in the composition of their invention and licensing portfolio in favor of biomedical inventions prior to Bayh-Dole. This shift in the composition of the invention disclosures at both universities was a result in part of the large increases in federal funding of academic biomedical research, particularly research in molecular biology, that began in the 1960s and received an additional impetus with the Nixon Administration's "War on Cancer" of the early 1970s. The shift in the composition of invention disclosures also reflected the dramatic advances in scientific understanding during the 1970s that laid the foundations for the biotechnology industry. Finally, the ability to obtain patents on and license the results of this research was strengthened by the judicial decisions and other shifts in federal policy that occurred during the late 1970s and early 1980s. The apparent effects of Bayh-Dole on Stanford and UC invention disclosures, patenting, and licensing are confounded with these other influences on academic research and the feasibility of patenting and licensing. Bayh-Dole was an important, but not a determinative, factor in the growth and changing composition of patenting and licensing activity at these institutions. Much of the increase in biomedical patenting and licensing at both Stanford and UC during the late 1970s and 1980s would have occurred in the absence of the Bayh-Dole Act, reflecting these other influences.

The Yield of Patenting and Licensing at UC and Stanford, 1975–1979 and 1984–1988

Although both UC and Stanford generated significant numbers of disclosures, patents, and licenses before the passage of Bayh-Dole, these universities' patents and licenses grew significantly after 1980. What effects did Bayh-Dole have on these universities' technology marketing activities? To examine this issue, we compared data on the yield of the technology marketing activities of UC and Stanford University before and after 1980 (See Mowery and Ziedonis 2000).

The UC and Stanford data do not reveal significant shifts in the character of the inventions disclosed to UC or Stanford administrators for possible patenting after Bayh-Dole's passage, which suggests little change in the character of faculty research disclosures after 1980. The

UC data indicate that university administrators sought patent protection for a broader share of the underlying population of disclosures after 1980—the share of invention disclosures generating patent applications increased from 24% during 1975–1979 to more than 31% during 1984–1988. Interestingly, the share of UC patent applications resulting in patents shrank between these two periods (from more than 62% in 1975–1979 to nearly 44% in 1984–1988), suggesting that this larger set of post-Bayh-Dole patent applications declined somewhat in patentability. The post-Bayh-Dole period of invention disclosures also is associated with more intensive licensing of the patents resulting from these disclosures, as the share of UC patents that were licensed grew from slightly more than 25% during 1975–1979 to more than 35% during 1984–1988. We lack comparable data for Stanford on patent applications, but the share of Stanford patents that were licensed remained almost unchanged, increasing from 62.7% for 1975–1979 to 63.7% for 1984–1988.

The more extensive licensing efforts of the post-1980 period appear to have produced a decline in the yield of these licenses at both UC and Stanford, measured as the share of licenses yielding positive royalties. At UC, the share of licenses yielding positive income declined sharply, from more than 84% during 1975–1979 to 47% during 1984–1988. When Stanford's software licenses are excluded (so as to increase the comparability of the UC and Stanford data), this share declines from 90% during 1975–1979 to 76% in 1984–1988. But these indicators of decline in the yield of the marketing efforts of the UC and Stanford technology licensing offices need not imply inefficient or economically irrational behavior—after all, it is the marginal, rather than the average, returns to licensing activities that are most important in evaluating the returns to these institutions' licensing activities. Moreover, this measure of the yield of these universities' licensing activities does not capture the size of the revenue streams associated with the average or the marginal license before and after Bayh-Dole.[8] Nonetheless, these data provide indirect evidence of intensified technology marketing activities at both universities in the wake of Bayh-Dole.

IV. The Importance and Generality of Academic Patents from Incumbents and Entrants, 1975–1992

The indicators of the yield or productivity of the technology licensing activities at UC and Stanford suggest that in the first decade after the passage of the Act, these incumbent universities' technology transfer

efforts intensified, with a concomitant decline in their yield. But this evidence does not address an important issue raised in the work of Henderson et al. (1998), who suggest that these intensified post-Bayh-Dole efforts to market faculty inventions were associated with the issue to U.S. universities of patents that were less important and less general, based on the patterns of citations to these patents. In order to examine this issue in more detail, we supplemented our data from UC and Stanford with information on the patenting and licensing activities of Columbia University, a leading post-Bayh-Dole entrant.

We included Columbia University patents in our analysis of the post-Bayh-Dole era in order to support a more detailed comparison between the patents issuing to an important post-Bayh-Dole entrant with the post-Bayh-Dole patents of our incumbent university patenters. For much of the pre-1980 period, Columbia University had no formal policy for the patenting or administration of faculty inventions, beyond a statement prohibiting the patenting of medical inventions that was rescinded only in 1975. Columbia's patent policy was significantly altered after the passage of Bayh-Dole. The new policy, which took effect on July 1, 1981 (the effective date of Bayh-Dole), reserved patent rights for Columbia and shared royalties with the inventor and department. In 1984, a new policy statement clarified and codified the rules: the policy mandated that faculty members disclose to the University any potentially patentable inventions developed with university resources. 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 technology transfer office, the Office of Science and Technology Development, which was founded in 1982.

Although we define Columbia as an entrant academic patenter, reflecting the fact that this university developed an active patenting and licensing policy only after 1980, in fact Columbia did accumulate a modest portfolio of fewer than 10 patents during the 1975–1980 period. Interestingly, despite Columbia's later entry into patenting and licensing, the data in table 6.2 on the characteristics of Columbia licensing income indicate that by the end of its first decade of licensing activities, Columbia was reaping considerable gross revenues from licensing, suggesting that this entrant was quite unusual. Despite its status as an entrant into patenting and licensing, by the early 1980s Columbia University was (along with Stanford and the UC system) one of the leading U.S. academic recipients of licensing revenues.[9] The composition of Columbia University's licensing portfolio also was remarkably similar to

those of UC and Stanford. In particular, Columbia's licensing revenues were highly concentrated among a small number of inventions, and this small group of home runs was dominated by biomedical inventions, just as was the case at UC and Stanford.

Comparing UC, Stanford, and Columbia University Patents

Our comparative analysis of the pre- and post-1980 patents from UC, Stanford, and Columbia Universities used patent citations to compute measures of the importance and generality of university patents. Patent citations have been used in numerous empirical analyses as measures of knowledge spillovers and other characteristics of firms' technological capabilities (Griliches 1990 provides an excellent survey of the strengths and weaknesses of patent-based measures). When the U.S. Patent and Trademark Office grants a patent, the granting officer includes a list of all previous patents on which the granted patent is based. This list is made public as part of the publication of the patent at the time it issues. The patent officer is aided in compiling a list of previous patents by the patent applicant, who is legally bound to provide with the application a list of all patents that constitute relevant prior art.[10] Citations of prior patents thus serve as an indicator of the technological lineage of new patents, much as bibliographic citations indicate the intellectual lineage of academic research.

Our before and after analysis of UC and Stanford patents used the year in which the invention was first disclosed as the key datum in categorizing faculty disclosures and any associated patents as falling into the pre-Bayh-Dole (before or during 1980) or post-Bayh-Dole (1981 or later) eras. We focused on forward citations in our analysis of changes in the importance and generality of UC, Stanford, and Columbia patents; that is, the number of citations received by each patent following its issue. Citations to patents typically peak 4–5 years after the date of issue of the cited patent, and data on citations to more recently issued patents therefore are right-truncated; that is, more recent patents are underrepresented in the citations data. In order to address this problem, our dataset included only citations to patents that occurred within 6 years of the year of issue of the patent, and our sample included only patents issued between 1975 and 1992. Our dataset also included a control sample of nonacademic patents for each of these three universities, spanning the same time period and replicating the distribution of the UC, Stanford, and Columbia patents among patent classes.[11] Our patent-citations data for all three universities were sepa-

rated into biomedical and nonbiomedical classes, because of the importance of biomedical patents in the licensing activities of all three universities before and after 1980.

We used the number of citations to a patent during the 6 years following its issue as a measure of the importance of the patent, based on the assumption that citations form an index of sorts of the influence over subsequent inventive activity of the cited patent. Our comparison of citations to this sample of academic and nonacademic patents yielded several interesting findings (see table 6.3 for a descriptive summary of the statistical results). All three universities' academic patents were cited more frequently than our control samples of nonacademic patents throughout the 1975–1992 period, suggesting a higher level of importance for the academic patents. Of greater importance for the issue being analyzed in this section is the lack of evidence of a decline in the relative importance of Stanford and UC patents, relative to nonacademic patents, in the post-Bayh-Dole period. These differences in relative citation rates for academic and nonacademic patents after 1980 were statistically significant overall, although the higher citation rates for Columbia's post-1980 patents were only statistically significant at the 10% level.

The results for these subsamples must be interpreted with considerable caution, since we have a relatively small number of observations for some time periods and technology fields. The relatively infrequent significant differences in importance between the university and control sample biomedical patents' citations is surprising, in view of the importance of biomedical patents within the patenting and licensing activities of Stanford and UC before and after Bayh-Dole. But the data provide no indication of any decline in the importance of these universities' patents, relative to our control samples of nonacademic patents, after the Bayh-Dole Act. If anything, the data suggest that the UC and Stanford patents' relative importance increased, rather than declined, after 1980.

Although these results provide some evidence that the patents applied for during the 1980s by Columbia, a university that did not patent significantly prior to Bayh-Dole, were less important, relative to all nonacademic patents, than those of Stanford and UC during this period, they do not suggest that Columbia's patents were significantly less important than those in its nonacademic control sample. The absence of significantly greater citation rates for Columbia patents could reflect a less selective approach to patenting during the early years of its licensing activities by Columbia University, an institution with little

Table 6.3
Summary of Differences in Mean "Importance" and "Generality" between UC, Stanford, and Columbia University Patents vs. Control Group Patents for Inventions Disclosed and Patented Before and After Bayh-Dole

Importance (*defined as* citations to academic patents–citations to nonacademic patents):

	Overall			Biomedical			Non-Biomedical		
	UC	Stanford	Columbia	UC	Stanford	Columbia	UC	Stanford	Columbia
Inventions Disclosed and Patents Issued 1975–1980	+	+**	NA	+	+	NA	+	+**	NA
Inventions Disclosed and Patents Issued 1981–1992	+**	+**	+*	+**	+**	+	+**	+**	+

Generality (*defined as* generality index for academic patents–generality index for nonacademic patents):

	Overall			Biomedical			Non-Biomedical		
	UC	Stanford	Columbia	UC	Stanford	Columbia	UC	Stanford	Columbia
Inventions Disclosed and Patents Issued 1975–1980	+	+**	NA	+	+**	NA	+	+**	NA
Inventions Disclosed and Patents Issued 1981–1992	+**	+**	+**	+*	+**	+*	+**	+**	+*

Definitions of Symbols:
+: Difference between academic and nonacademic index is positive.
–: Difference between academic and nonacademic index is negative.
** denotes difference in means between university and nonacademic control group patents is significant at 5% level.
* denotes difference in means between university and nonacademic control group patents is significant at 10% level.

experience in patenting, than UC or Stanford.[12] We return to this issue below.

We also tested for changes in the generality of UC, Stanford, and Columbia patents before and after Bayh-Dole. The more widely cited a patent outside of its home patent class, the greater its generality, and arguably, the more significant the advance in knowledge represented by the patent. Following Henderson et al. (1998), we compute generality as follows:

$$GENERAL_i = 1 - \sum_{k=1}^{N_i} \left(\frac{NCITING_{ik}}{NCITING_i} \right)^2$$

where for patent i, k is the index of patent classes and N_i the number of different classes to which the citing patents belong. Higher values of $GENERAL_i$ indicate that a patent is cited in a broader array of technology classes, which we take to indicate greater influence on subsequent inventive effort in diverse fields.

Overall, the mean generality measures for overall UC, Stanford, and Columbia patents were higher than those for their respective control sample patents, excepting only UC patents applied for and issued before 1981 (table 6.3). We found no evidence of a decline in generality (relative to the control sample of nonacademic patents) in the UC and Stanford patents in the post-Bayh-Dole era. Indeed, the differences in mean generality between the overall UC and Stanford patents and their respective control samples were statistically significant (at the 5% level) for the post-1980 period. The mean generality score for the post-1980 Columbia patents also was significantly higher (at the 5% level of significance) than was true of the patents in its control sample.

Overall, the results of this analysis of the importance and generality of Stanford, UC, and Columbia patents yield conclusions that differ somewhat from those of Henderson et al. (1998), who analyzed a larger sample of U.S. university patents. Why do we find little or no evidence of declines in the importance or generality of these universities' patents after the Bayh-Dole Act? First, our sample of university patents is small, although this should tend to favor findings of no statistically significant differences between the university and nonacademic patent samples. Second, these results ignore the effects of entry by other universities (other than Columbia) into patenting and licensing after 1980 on the characteristics of the overall U.S. academic patent portfolio in the post-Bayh-Dole era. Although Henderson et al. (1998) find similar evidence of declining importance in even the patents assigned to the 15

leading academic patenters (based on their 1988 patents) during the 1975–1988 period, this group also may have been affected by the entry of less experienced academic patenters. In the next section, we discuss the results of our analysis of the effects on the importance and generality of U.S. academic patents of entry by inexperienced academic patenters after 1980.

Entry, Importance, and Generality in Overall U.S. Academic Patenting, 1975–1991

We next analyzed a broader sample of all U.S. academic patents from the pre- and post-Bayh-Dole periods, in order to examine the effects on patent importance and generality of entry into patenting by inexperienced universities after 1980. These data allowed us to separate any change in the generality and importance of all U.S. academic patents after 1980 into those associated with incumbent universities' patents and those associated with the patents assigned to entrants, defined here as universities with few or no patent applications during our pre-Bayh-Dole period of 1975–1980.

The results of this analysis are intended to distinguish between two hypothesized effects of Bayh-Dole on academic research and patenting. Some observers have expressed concern that the expanded post-1980 efforts by U.S. universities to promote patenting and licensing of faculty inventions, especially when faculty share in the financial returns to these licenses, have skewed the content and character of university research to favor more applied research activities. Parallel declines in the importance and generality of the post-1980 patents of both incumbent and entrant universities indicate that the Bayh-Dole Act affected the incentives of academic researchers and (importantly) academic administrators to disclose and patent inventions of lower importance and generality throughout U.S. academia.

If these changes in the characteristics of U.S. post-1980 academic patents result from entry by less experienced patenters, however, a different interpretation of the effects of Bayh-Dole is plausible. For example, if new entrants initially patent a broad cross section of faculty discoveries, they may accumulate a patent portfolio of limited importance and generality (some anecdotal evidence supports this characterization). Over time, as they learn the complexities of protecting and marketing intellectual property and become more selective in their patenting, the gaps between the characteristics of their patents and those of the high-intensity incumbents could narrow somewhat, and any decline in

the average generality or importance of overall U.S. academic patents should be attenuated.

The first interpretation of Bayh-Dole's effects emphasizes changed incentives and behavior throughout U.S. universities, while the other views the 1980s as a period of learning and adjustment to a new incentive environment by organizations inexperienced in patenting and licensing. Needless to say, these explanations are not mutually exclusive, and the development of U.S. academic patenting during the 1980s likely reflects both effects. But our empirical analysis should support an assessment of the relative strength of the two effects.

We probed the effects of entry by U.S. universities into patenting on the importance and generality of academic patents by constructing a dataset of all patents assigned to U.S. universities other than Stanford, UC, and Columbia during the 1975–1992 period. Within this dataset, we distinguished among three categories: (1) Universities with at least 10 patents that were applied for after 1970 and issued during 1975–1980; (2) Universities with at least one but fewer than 10 patents applied for after 1970 that were issued during 1975–1980; and (3) Universities with no patents issued during the 1975–1980 period and at least one patent issued during 1981–1992 that was applied for after 1980. Our definitions of entrant and incumbent universities are somewhat arbitrary, but we believe that this tripartite distinction enables us to separate the effects on patent importance and generality of increased patenting after Bayh-Dole by active pre-1980 patenters (a group that includes UC and Stanford) from increased post-1980 patenting by universities historically inactive in this area and increased patenting by universities (such as Columbia) that were minimally involved in patenting before 1980.

Figure 6.7 displays trends in the shares of all academic patents applied for after 1970 that are accounted for by these three groups during the 1975–1992 period. The figure illustrates the declining share of the high-intensity pre-1980 academic patenters after the passage of Bayh-Dole. The high-intensity patenters' share declines from more than 85% during 1975–1980 to less than 65% by 1992. The low-intensity pre-1980 patenters, by contrast, increase their share of all academic patents from 15% in 1981 to almost 30% in 1992. And entrants, institutions that display no patenting activity during 1975–1980, increase their share of overall academic patenting from zero in 1980 to more than 6% by 1992. The post-Bayh-Dole era clearly is characterized by a significant change in the population of academic patenters and a shift toward institutional patenters with less experience in this activity.

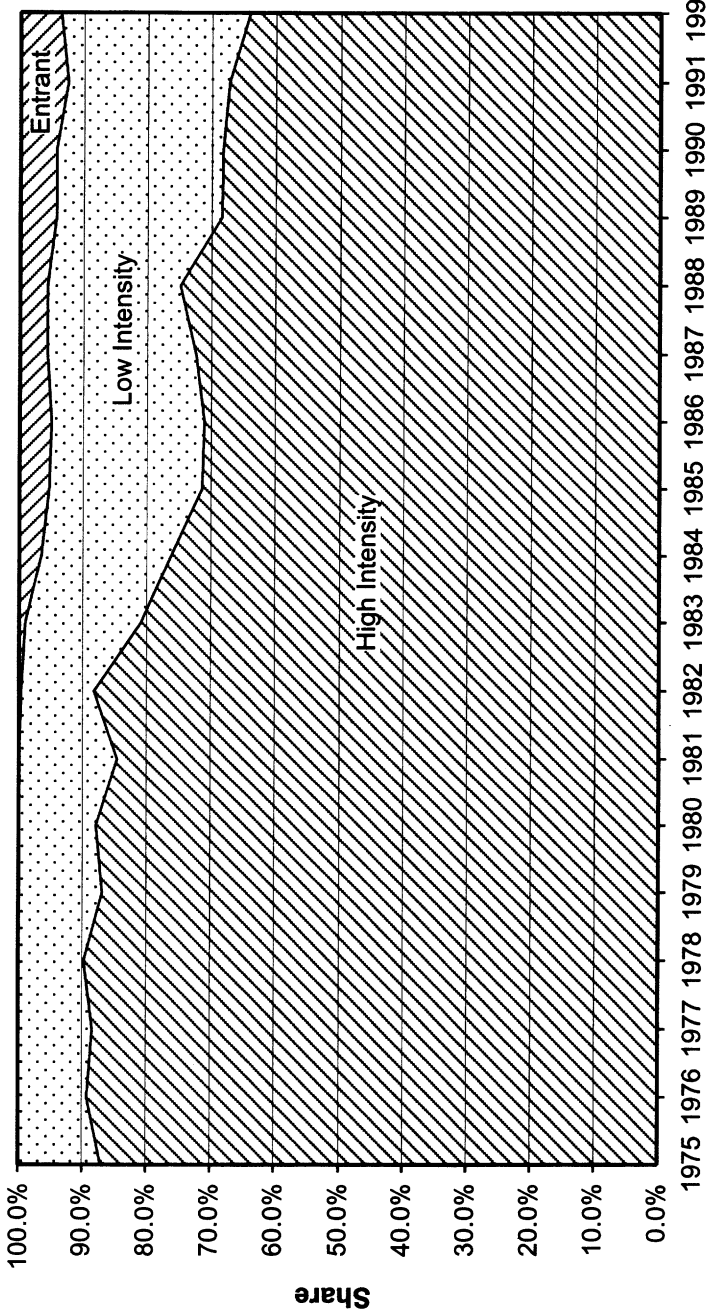

Figure 6.7
Shares of All University Patents by High Intensity, Low Intensity, and Entrant University Patenters, 1975–1992

We once again used patent citations data to analyze the importance and generality for the patents assigned to academic institutions in each of these three categories, covering 1975–1991 for the high- and low-intensity incumbents and 1981–1991 for the entrants.[13] Our statistical analysis covered overall academic patents, and separately examined biomedical and nonbiomedical patents. The results for our analysis of each of these three samples of academic patents display contrasting patterns of importance and generality. The patents assigned to the high-intensity incumbents are consistently more important and more general, relative to nonacademic patents, throughout the 1975–1991 period. Indeed, this group's patents were cited with increasing frequency after Bayh-Dole, relative to nonacademic patents.

The results for the other two groups of academic institutions whose patenting increased substantially after 1980 indicate consistently lower levels of importance and generality for their patents throughout the 1980s, relative to nonacademic patents. These results suggest that the patents of the two groups of U.S. universities that increased their share of overall academic patenting during the 1980s were of lower importance and generality, by comparison with a similar sample of nonacademic patents, than the patents issuing to U.S. universities with longer histories of patenting activity. The findings broadly corroborate our earlier finding of no decline in the importance and generality of post-1980 patents issuing to UC and Stanford University. Taken together, these results indicate that the deterioration in the importance and quality of post-1980 U.S. academic patents may have resulted from the Bayh-Dole-Act's encouragement of entry into patenting by academic institutions with relatively little experience in this activity.

In this view, Bayh-Dole's immediate effects on the content of academic research were modest, by comparison with the Act's encouragement of a new group of universities to expand or begin patenting of faculty inventions. With the passage of time, learning on the part of these entrants may gradually improve their management of patenting and licensing activities, and the apparent differences between their patent portfolios and those of the institutions long active in patenting may decline. We lack a sufficiently lengthy or rich longitudinal time series to test this possibility, although some anecdotal evidence is consistent with this characterization of many entrant academic institutions' patenting activities during the 1980s. But this interpretation of the effects of Bayh-Dole has different, and arguably less worrisome, implications for the future of the U.S. academic research enterprise than the alternative characterization noted above. The causes of any change during the

1980s in the characteristics of U.S. academic patents merit additional study.

V. Conclusions and Policy Implications

Since the passage of the Bayh-Dole Act, many U.S. universities have expanded (or begun) programs to patent and license the results of federally and industrially funded research. Data from the University of California indicate that the Bayh-Dole Act was associated with an increase in the University's propensity to seek patent protection for faculty inventions that was not matched by a comparable increase in the yield of its patenting activities. At both UC and Stanford University, Bayh-Dole resulted in expanded efforts to market licenses to academic inventions. These expanded marketing efforts appear to have been associated with a modest decline in the yield of the invention marketing efforts at both of these institutions. At both universities, Bayh-Dole had modest effects on the content of academic research, since the composition of these institutions' invention portfolio had shifted before 1980 in favor of biomedical inventions that were highly attractive to commercial licensors. Moreover, the pre- and post-Bayh-Dole licensing efforts, and the revenue flows associated with these licensing efforts, tended to be concentrated in the biomedical area.

Nevertheless, the upsurge in patenting and licensing at these and other U.S. research universities after 1980 was affected by other factors in addition to the Bayh-Dole Act, and it is difficult to separate the effects of the Act from those of other factors. In particular, by the mid-1970s biomedical technology, especially biotechnology, had increased significantly in importance as a productive field of university research with research findings that were of great interest to industry. The feasibility of technology licensing in biotechnology was advanced by the *Diamond v. Chakrabarty* Supreme Court decision, which opened the door to patenting the organisms, molecules, and research techniques emerging from biotechnology. This judicial decision, as well as the broader shift in U.S. policy to strengthen intellectual property rights, contributed to the increased post-1980 patenting and licensing activities of U.S. research universities.[14]

This analysis of the effects of Bayh-Dole on the content of academic research and the importance of the patents assigned to these two leading research universities yields conclusions that both corroborate and contradict the findings of Henderson et al. (1998). The data on UC and Stanford invention disclosures before and after Bayh-Dole suggest

some increase in the propensity of both institutions to patent and/or license faculty inventions. But our analysis of the importance of the pre- and post-Bayh-Dole patents assigned to these two universities reveals no systematic decline in importance or generality after Bayh-Dole, in contrast to the findings of Henderson et al. (1998). Nor do we find that the quality of patents accounted for by a major entrant, Columbia University, are significantly less important or general than those within a matched sample of nonacademic patents, although the Columbia patents are not significantly more important than those in the control sample for the post-1980 period.

How do we reconcile a finding that citation-based measures of UC and Stanford patents reveal no decline in importance after Bayh-Dole with our conclusion that both UC and Stanford's technology licensing operations appear to have experienced a decline in yield, that is, a decline in the share of licenses yielding positive revenues? Fundamentally, these two sets of indicators measure different characteristics of the invention and patent portfolios of these universities. Along with other scholars, we interpret patent citations as measures of the importance of the contribution to inventive knowledge of a given patent. But this contribution may or may not be correlated with the attractiveness to industry of a license for this patent. The extent of correlation between licensing revenues and patent citations is an important research question that we plan to examine in future work.

Our analysis of the effects of entry by less experienced academic patenters on the importance and generality of a much broader sample of post-1980 U.S. academic patents indicates that the patents of entrants with little or no previous history of patenting were not significantly more important or general than nonacademic patents. Given the significant expansion in the share of U.S. academic patents accounted for by these entrant institutions, it is plausible that the findings of Henderson et al. (1998) of declining importance and generality during the 1980s in U.S. academic patents reflect the effects of Bayh-Dole on entry, rather than on the incentives of academic researchers and administrators in long-active academic patenters. The evidence from the Columbia post-1980 patent sample, which is no less heavily or broadly cited than those of its nonacademic control sample, suggests that there is considerable heterogeneity within the population of entrant institutions.

The limitations of our analysis are apparent. We have detailed institutional data on patenting and licensing for only three very unusual universities, institutions that were among the leaders in patenting and

licensing of faculty inventions before and after the Act's passage. The empirical results for both our three-university and broader academic samples are sensitive to the composition and construction of the patent control samples. In assessing the effects of Bayh-Dole on university technology transfer, we are analyzing only the formalized technology transfer activities of these universities, and cannot exclude the possibility that activities in invention disclosure, patenting, and licensing may affect the numerous other channels through which university knowledge reaches commercial application. Moreover, the small size of our samples of university patents, especially those covering the pre-Bayh-Dole period, limits the robustness and power of our statistical tests. Finally, this analysis of the post-Bayh-Dole period necessarily covers only the early years of this new regime. As denizens of any university can attest, change within these institutions occurs slowly, and it is possible that the true effects of the Bayh-Dole Act are only now being revealed. Nevertheless, we believe that the results of this analysis underscore the importance of complementing analyses of aggregate data on academic and nonacademic patenting trends with work on individual institutions engaged in these pursuits, be they firms, universities, or public laboratories.

What implications for policy emerge from this analysis? First and perhaps most important is the finding that more than Bayh-Dole alone underpinned the rise of U.S. universities' patenting and licensing activities after 1980. Without the rapid growth in federal biomedical research funding throughout the 1960–1980 period, as well as the other changes in federal policy toward intellectual property rights, the Bayh-Dole Act by itself would have had much less effect on university patenting and licensing. Indeed, this conclusion underscores a point made in the introduction to this paper—the post-1980 surge in patenting and licensing by U.S. universities is only the latest chapter in a long history of close ties between U.S. academic and industrial research.

The unusual institutional structure of the U.S. university system contributed to the strength and long history of such links. The large scale, high levels of institutional autonomy, and diversified source of public and private funding that characterize the U.S. higher education system have long created powerful incentives for faculty and administrators to seek external sources of research support, be these from private firms during the 1920s and 1930s, the Defense Department during the 1950s and 1960s, or industry during the 1980s and 1990s. Among other things, the importance of these other structural factors suggests that

emulation of Bayh-Dole in other industrial economies with systems of higher education that are very differently structured may be counterproductive or unsuccessful.

Another important point from this discussion concerns the dominance of patenting and especially, licensing, by biomedical inventions at the three leading U.S. universities we analyzed in detail. There are several reasons for this dominance—patents in biomedical technologies are strong and very difficult to invent around; the field is characterized by an unusually close link between basic scientific research and commercial applications; and successful commercial applications are extremely profitable. Patenting and licensing thus may serve as reasonably effective channels for the transfer of academic research to commercial application in this technology. But in other fields of research, such as many areas of engineering, the strength of patents and the value of licenses are much lower.

University administrators and policymakers alike must recognize that universities transfer knowledge to commercial applications through a diverse array of channels, including the training of students, publication, faculty consulting, faculty involvement in new business enterprises, and more informal interactions, in addition to the licensing of patents. Moreover, the relative importance of these different channels varies among fields of research. Policies that aspire to uniformity across fields, especially where these policies borrow from the biomedical fields, may actually undercut the effectiveness of knowledge transfer and may reduce university-industry collaboration.

Although we find little evidence of significant change in the content of U.S. academic research in the wake of Bayh-Dole, and believe that many of the post-1980 changes that have occurred in the relationship between U.S. universities and industry would have occurred without Bayh-Dole, this does not mean that there are no reasons for concern over the effects of these new relationships on the academic research and teaching enterprise. There is an abundant supply of anecdotes of faculty conflicts of interest and universities that now include faculty patenting activities in their reviews of research excellence. Formal restrictions on publication or release of research results, or the informal discouragement of collaboration among faculty or students that may result from the growing commercial value of some academic research activities, pose real risks to graduate education in particular. In some fields of research, universities now are competing with industrial firms as much as they are collaborating—research tools, which many universities seek to patent and license to pharmaceutical and other biomedi-

cal firms, is one example. Strategic alliances between universities and individual firms, such as the agreement between UC Berkeley and the Novartis Corporation, are another example. Many of these challenges (such as conflicts of interest or restrictions on publication) are neither new nor attributable in their recent manifestations to the Bayh-Dole Act. They merit close scrutiny nonetheless.

Notes

Authors' names appear in alphabetical order. Earlier versions of this paper were presented at the 1999 AEA meetings and the July 1999 meeting of the NBER's Science and Technology Policy Group, and benefited from comments by participants at both meetings. Portions of this paper draw on an earlier paper coauthored with Richard Nelson and Bhaven Sampat of Columbia University (Mowery et al. 1999), and we have benefited from numerous conversations and comments from them on the issues covered in this paper. The paper also benefited from the comments of Josh Lerner, Adam Jaffe, and Scott Stern. We are indebted to the staff of the technology licensing offices of Stanford University, the University of California, and Columbia University for invaluable assistance with the collection and analysis of these data. Michael Barnes and Lynn Fissell of the University of California assisted in the collection and analysis of the University of California data, and the research on the Stanford data benefited from the assistance of Sandra Bradford. Special thanks to Michael Barnes for the use of his university patenting data and to Adam Jaffe of Brandeis University and the NBER for making his patent data available to us. Support for this research was provided by the California Policy Seminar, the U.C. President's Industry-University Cooperative Research Program, the Alfred P. Sloan Foundation, the Huntsman Center for Global Research of the Wharton School at the University of Pennsylvania, and the Andrew Mellon Foundation.

1. This section draws on Mowery et al. (1999).

2. 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).

3. 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.

4. See Hall and Ziedonis (2000) for an analysis of the effects of the CAFC and related policy shifts on patenting in the U.S. semiconductor industry.

5. The Board was a committee of UC faculty and administrators charged with oversight of the Patent Office. 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 nonacademic." 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.

6. 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 ". . . dissertations, papers, and articles, . . . popular nonfiction, novels, poems, musical compositions, or other works of artistic imagination which are not institutional works" from the policy governing software ("Copyrightable Works and Licensing at Stanford," Stanford University Office of Technology Licensing, Spring, 1994, p. 1).

7. Biomedical inventions accounted for a growing share of UC patenting and licensing during the entire 1975–1990 period.

8. For example, average income per license may have increased in the second period, although the skewed distribution of the licensing income of both the Stanford and UC technology transfer offices means that any such changes are likely to be small.

9. According to a recent report of the Association of University Technology Managers (AUTM) on institutional licensing income, fiscal 1997 gross licensing revenues for the UC system, Stanford University, and Columbia University amounted to $67.3 million, $51.8 million, and $50.3 million respectively. These three institutions ranked as the top three U.S. academic recipients of licensing income (Association of University Technology Managers 1997).

10. In addition to the legal requirement, it is in the applicant's interest to be forthcoming in this list because a more complete description of prior art is likely to reduce the prospects of an interference being declared during processing of a patent application.

11. Although our analysis followed that of Henderson et al. 1998 and Trajtenberg et al. 1997 closely, we employed a slightly different control population of patents, one that excludes academic patents and matches the distribution of our academic patent samples among patent classes.

12. Any such effect was significant during only the early years of Columbia's patenting and licensing activities, since by 1986–1990, the share of disclosures resulting in issued patents and the share of disclosures that result in licenses yielding positive royalty income are fairly similar at Columbia, UC, and Stanford (table 6.2).

13. Our analysis of the relative importance and generality of the patents of these three groups once again compared the patents from each group of universities with a control sample of patents constructed to replicate the distribution of the academic patents across time and among technology classes. Our regression analysis of importance used a negative binomial specification. We used a tobit specification in our regression analyses of generality, since this variable's distribution is truncated at a lower limit of zero and an upper limit of one. Each specification was estimated for a dataset covering the patents of

the relevant academic institutions and those in a matched control sample of nonacademic patents (matched by application year and patent class). We controlled for year effects and interacted a dummy variable denoting academic patents with a dummy variable for the application year.

14. But the influence of Bayh-Dole and broader changes in U.S. intellectual property rights policies, most of which affected patent coverage and enforcement, on academic technology licensing may be overstated. Stanford University was active before and after 1980, and Columbia became active after 1980, in licensing unpatented software inventions. For this technology class, the establishment of a university technology licensing office, rather than Bayh-Dole or other changes in U.S. patent policy, appears to have encouraged the disclosure and licensing of inventions whose intellectual property protection and ease of licensure were not affected by the Bayh-Dole Act.

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