25 The Changing Role of Universities in the 21st Century U.S. R&D System

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Introduction

Universities have long played a central role in the U.S. research and development (R&D) system.[1] The historic involvement of U.S. publicly funded universities with agricultural research (much of which was applied in character) and the involvement of these universities with the users of this research are well-known aspects of U.S. economic history. But 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 U.S. universities and industry were common before and after World War II (Rosenberg and Nelson, 1994). It is a fallacy to think of U.S. university research as traditionally "basic" and conducted without attention to practical objectives. Many academic researchers have pursued applied research agendas, and much industry-university collaboration historically has focused on the engineering and applied sciences.

Links between R&D in U.S. industry and research in U.S. universities have a long history. But recent developments in this relationship, especially the growth in university patenting and licensing of technolo-

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gies to private firms, have attracted considerable attention. In particular, the growth of patenting and licensing by U.S. universities since 1980 (the year the Bayh-Dole Act was passed) is portrayed as a novel development. But set against the much longer, parallel histories of research in U.S. universities and industry (see Mowery and Rosenberg, 1998), many of the past two decades' developments represent a revival of an earlier and often close relationship between U.S. universities and industrial research.

Although the relationship between U.S. university research and industrial innovation is a long-established one, the role of U.S. universities within this nation's R&D system is changing as a result of shifts in sources of academic R&D funding, the growth of university patenting and licensing, and related trends. This chapter briefly summarizes recent trends in three areas:

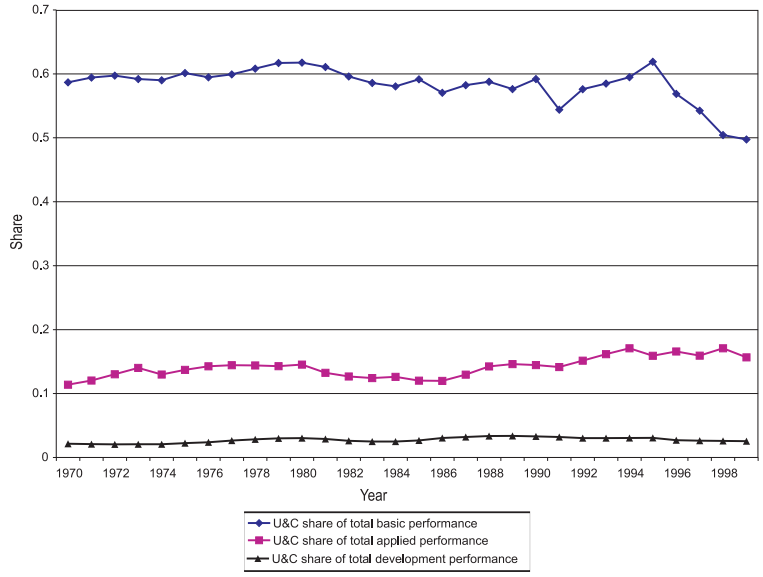
- the changing role of U.S. universities as R&D performers;
- changes in the sources of financial support for U.S. university R&D; and
- changes in the role of U.S. universities as sources of patents and licensors.

One issue not addressed in this chapter concerns the extent to which shifts in the sources of financial support for university R&D or in the role of U.S. universities as R&D performers (especially the shifts observed during the 1990s) are likely to be long-lived or instead reflect cyclical factors. To cite one example, private industry now accounts for roughly two-thirds of national R&D investment in the United States, which means that trends in national R&D investment are likely to be more sensitive to the overall business cycle. Any tendency for national R&D spending to fluctuate more cyclically may well affect the role of U.S. universities as R&D performers and the sources of funding for university R&D.

The Changing Role of U.S. Universities as R&D Performers, 1970–99

The trends in Figure 1, which depicts the shares of basic, applied, and development work performed by universities and colleges ("U&C") during the 1970–99 period, indicate a striking decline in the role of U.S. universities as performers of basic research during the 1990s. U.S. universities' share of national basic research performance declined from nearly 62 percent in 1995 to slightly less than 50 percent in 1999.[2]

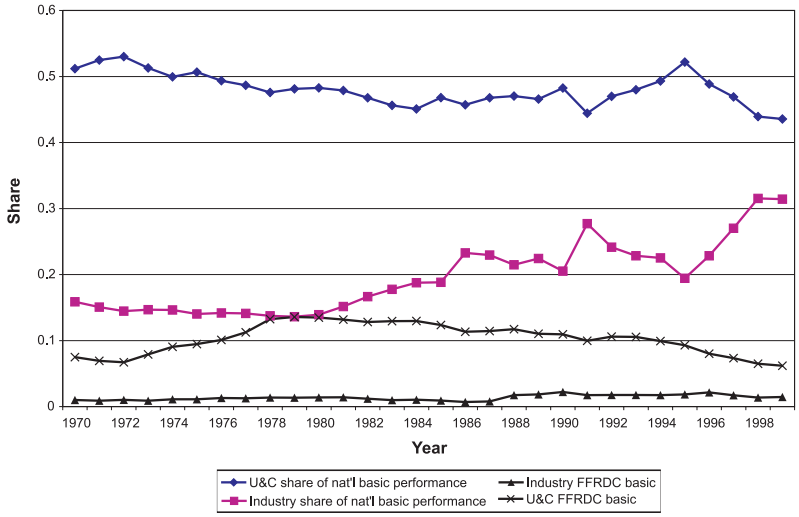
Figure 1
U&C Shares of Basic, Applied, Development Performance, 1970–1999 (inc. FFRDCs)



As Figure 2 shows, the decline in the university share of national basic research performance reflects growth in the share of basic research performed by U.S. industry from 19.5 percent in 1995 to 31.4 percent in 1999. Interestingly, universities' share of applied R&D performance increases during the 1970–99 period from 11.4 percent in 1970 to 15.7 percent in 1999, although most of the growth in this share occurs during the 1970s and 1980s (universities' share of applied R&D performance stands at 14.4 percent in 1990).[3] The university share of development activity remains essentially constant during the period at 2.1–2.5 percent.

The data in Figure 1 include Federally Funded R&D Centers (FFRDCs) operated by universities. In Figure 2, spending on FFRDCs operated by both universities and industry is depicted separately. The declines in university-performed basic research appear to reflect declines in the share of basic research at universities and colleges (U&Cs) supported by federal funds, both directly and within FFRDCs operated by universities. When FFRDC funding is added to federally funded basic research performed at universities, the "U&C" share declines from 62.5 percent in 1995 to 49.7 percent in 1999.

Figure 2
U&C and Industry Shares of National Basic Research Performance, 1970–1999



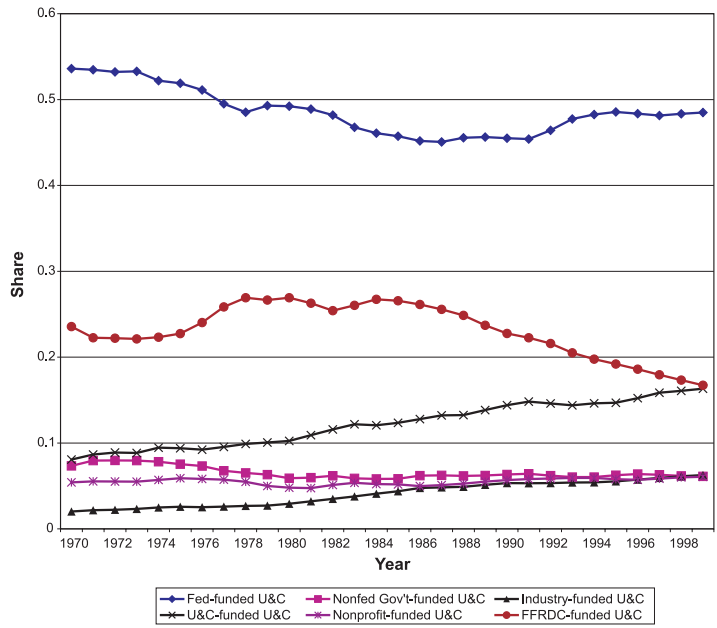
Growth in the industry-performed share of national basic research reflects increased industry spending on basic research during the 1990s. (The share of basic research performance accounted for by industry-operated FFRDCs is essentially constant at roughly 1.5–2 percent throughout the decade.) Basic research funded by industry grew from 79 percent of industry-performed basic research in 1990 to more than 91 percent in 1999, increasing from $6.9 billion to nearly $14 billion in constant dollars during this period. Growth in industry-funded basic research during the 1990s was much more rapid during the second half of the decade, and presumably was linked to the U.S. economic boom of this period. Growth in industry-funded basic research spending during the next several years is unlikely to match the pace set during the late 1990s, and as a result, the sharp decline during the 1995–99 period in the share of basic research performed by U.S. universities should slow.

Changing Sources of Financial Support for U.S. University R&D, 1970–99

The decline during the 1990s in the share of basic research performed within U.S. universities paralleled change in the sources of financial support for R&D performed within universities. At least three significant trends, some of which predate the 1990s, are apparent.

First, as Figure 3 shows, the share of university-performed R&D supported by federal funds shrank from 54 percent to 48 percent during 1970–99 (when funding for university-operated FFRDCs is included, the share drops from 77.1 percent in 1970 to 65.2 percent in 1999). Although the 1999 federal share represents an increase from its low point during this period of 45 percent in 1985, the long-term trend during 1970–99 is one of decline. The industry-financed share of R&D at U.S. universities scarcely grew during the 1990s, increasing from 5.3 percent in 1990 to 6.3 percent in 1999.

Figure 3
Sources of Funding for U&C R&D, 1970–1999



Similar trends are apparent in Figure 4, which depicts changes in the sources of financial support for university-performed basic research. The federal share of support for university-performed basic research declined through most of the 1970–99 period, from 62.5 percent in 1970 to 54.7 percent in 1999 (when university-operated FFRDCs are included, the share drops from 75.2 percent in 1970 to 67.1 percent in 1999), although the 1999 share represents a slight increase from the low point of 50 percent that was reached in 1991. Industry's share of funding for university-performed basic research was virtually flat during the 1990s, increasing from 5.2 percent to 5.9 percent. But the 1990 share represents a significant increase from the industry share of 2.0 percent reported for 1970.

A second important trend, during the 1970–99 period in the sources of support for university R&D that has been noted by Irving Feller (1999) and a few other scholars, is the steady increase in university-performed R&D that is supported from institutional sources, i.e. increased self-funding by U.S. universities of R&D. The data in Figure 3 show that this "self-financed" share of university R&D grew from 8.1 percent in 1970 to 10.2 percent in 1980 and 16.3 percent in 1999. Similar trends in self-financing by universities of basic research are apparent in

Figure 4
Sources of U&C Basic Research Funding, 1970–1999 (w/FFRDCs)

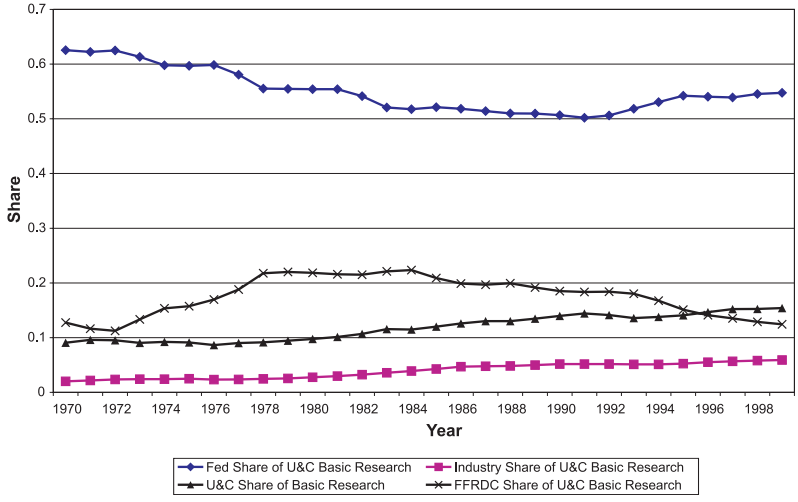


Figure 4, which indicates that internal sources supported 9.1 percent of university-performed basic research in 1970, 9.8 percent in 1980, and 15.4 percent in 1999. During the "post-Bayh-Dole" period beginning in 1980, a period characterized by increased university patenting and licensing (see below), growth in the share of university-performed R&D and basic research funded from internal sources thus appears to have accelerated.

This trend toward increased self-financing of university-performed basic research and overall R&D has interesting implications that have received minimal attention. Further research is needed to determine which universities are among the leaders in the growth of self-financed R&D and basic research. Such an analysis might enable one to distinguish among at least three potential causes of this increase: (1) growth in the market value of the endowments of U.S. research universities during the 1990s, which increased internal support for research; (2) increased demands from federal and other sources of research support for matching contributions from universities; and (3) the growth of licensing income, which is unevenly distributed among U.S. research universities.

It seems likely that all three factors have influenced this trend, and it is equally plausible that the older, better-endowed private and public research universities are among the leaders in increased self-financing of their research activities. Should this trend continue, the decline in the concentration of research funding among U.S. research universities that has characterized the postwar period, a trend that has been encouraged by the allocation of federal research grants in biomedical and other research fields (Geiger and Feller, 1995), could be reversed. The growing pressures on less well-endowed universities to match the efforts of others in self-financing research may also contribute to increased demands from political actors and academic administrators for congressional earmarking of federal research grants.

The third trend affecting the sources of funding for U.S. university research is the remarkable growth in federal funding for biomedical research that has been widely discussed in other studies (e.g., National Academy of Sciences, 1999). The budget released by the Bush Administration continues a long-standing trend of significant increases in funding for the National Institutes of Health (NIH). Were President Bush's budget requests for NIH and other federal science agencies to be enacted without modifications by Congress (something that is very unlikely), nearly 67 percent of federal funding of academic research would flow from a single agency, the National Institutes of Health. This dominance

of academic R&D funding by a single mission-oriented agency obviously reflects the decline in defense-related funding for academic R&D in the wake of the end of the Cold War. But it also reflects the remarkable political success of the National Institutes of Health in gaining significant annual funding increases from Congress. University biomedical research also is an area in which private philanthropic support is substantial, which means that the biomedical area may account for an even greater share of overall extramurally funded academic research

Taken together, these three trends—declines in the federal share of university R&D funding, the growth of "self-financed" university R&D, and the rise of biomedical research to a position of dominance in federal (and private) sources of academic research funding—are transforming the role of universities in the U.S. research system. A single-mission agency now dominates academic research funding to a greater extent than the Department of Defense did at the height of the Cold War. Increased institutional self-financing of academic research may produce greater concentration of research funding and activity among established, wealthier universities and almost certainly will intensify redistribution struggles over the allocation of federal research funds. Finally, the declining role of federal funding in academic R&D, the modest increases in industrial support, and the associated financial pressures on U.S. universities arguably provide additional motives for many universities to seek income by patenting and licensing research advances.

U.S. Universities as Patenters and Licensors

The third change in the role of U.S. universities within the R&D system is their growing role in patenting and licensing inventions, particularly those resulting from federally funded research. It is important to point out that U.S. universities have long been active as patenters, although they have not always assumed a direct role in managing their patents. Professor Frederick Cottrell, of the University of California at Berkeley, amassed a significant patent portfolio in anti-pollution technologies in the early decades of the 20th century and established the Research Corporation to provide patent management expertise to U.S. universities. The Wisconsin Alumni Research Foundation (WARF) was established in the 1920s to manage Harry Steenbock's patents that made possible the introduction of vitamin D into food products through irradiation. The Massachusetts Institute of Technology (MIT) signed an "Invention Administration Agreement" in 1937 with the Research Cor-

poration to manage the licensing of patents associated with MIT faculty inventions.[4] Nevertheless, for much of the pre-1970 period, many U.S. universities avoided direct involvement in managing patents associated with faculty inventions.[5] Some universities discouraged faculty patenting, particularly in biomedical technologies.

Public universities were more heavily represented in patenting than private universities during the 1925–45 period, both within the top research universities and more generally. A number of these public universities established affiliated but legally separate research foundations, similar to WARF, in the late 1920s and early 1930s. This dominance of overall academic patenting by state universities persisted through much of the postwar era. But private universities increased their share of academic patenting from 14 percent in 1960 to 39 percent in 1970 and 45 percent in 1980.[6] This growth in the share of private-university patents is particularly noteworthy, inasmuch as it occurred during a period of growth in overall U.S. university patenting. The era of increased federal funding for academic research was associated with an expansion of the role of private universities in directly managing the patents received by their faculty on publicly and privately funded research.

The 1970s represented the most dramatic period of change in U.S. university patenting during the 1945–80 period and arguably during the entire 1925–80 period. Overall university patenting grew significantly and became less concentrated among a small group of elite research universities. The Research Corporation's role diminished sharply, as universities chose to manage their patents themselves (Mowery and Sampat, 2001a). And biomedical inventions increased in importance within university patenting and licensing. The dynamics of federal support spurred both growth in the number of university patents and change in the characteristics of universities that were active patenters. Increased federal funding of academic R&D was a necessary condition for the growth of university patenting. But the increased inter-institutional dispersion of federal research funds, during the 1960s and 1970s, also affected academic patenting and promoted entry into this activity by public and private universities with little previous experience in managing patenting and licensing (Mowery and Sampat, 2001b).

Figure 5 displays trends in university patenting as a share of all U.S. patents assigned to domestic inventors during the 1963–99 period.[7] Universities account for 0.2 percent of U.S. domestically assigned patents in 1963, 0.3 percent in 1970, and 3.6 percent in 1999, a 12-fold increase in share. These data indicate that university patenting grew significantly after 1980, the year the Bayh-Dole Act was passed.

Figure 5
U.S. Research University Patents Percent of All Domestic-Assignee U.S. Patents, 1963–1999

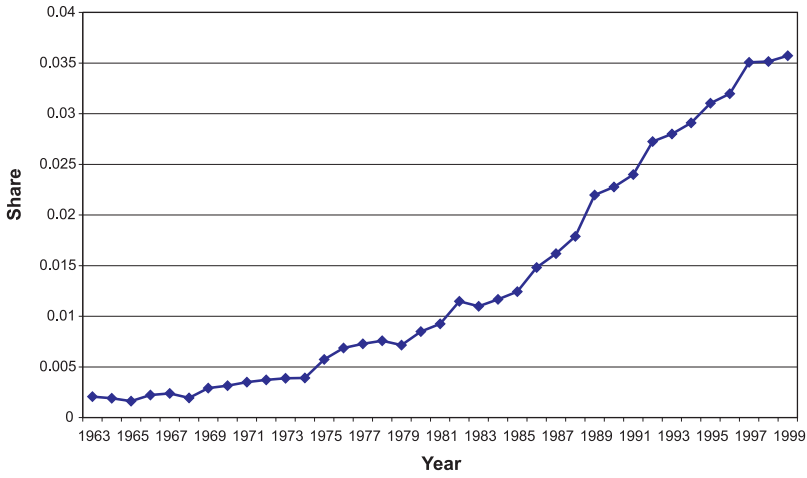
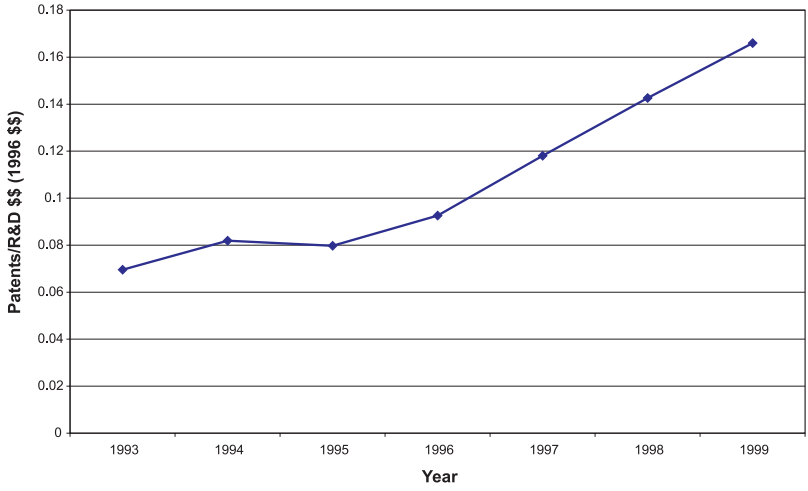


Figure 6, taken from the 2000 survey of member universities published by the Association of University Technology Managers (AUTM, 2000), shows a considerable increase in patents per academic R&D dollar during the 1990s.

Figure 6
Patents/R&D Expenditures, All AUTM Respondents, FY 1993–1999



But patenting by U.S. universities had begun to grow significantly well before 1980, and U.S. universities (especially private universities) had expanded their direct involvement in managing these patents before 1980. Increased U.S. university patenting and licensing after 1980 thus represented an expansion in a trend that was well-established before that date. This characterization also applies to the technologies in which U.S. universities' patenting was concentrated. As Figure 7 shows, biomedical technologies' share of U.S. university patenting increased from 11 percent in 1970 to nearly 50 percent by 1999.[8] Moreover, this expansion in university biomedical patenting considerably outstripped the growth in NIH funding of U.S. university research (Figure 8). Indeed, the profitability and legal strength of biomedical patents and the licensing agreements associated with them is one likely factor in explaining the entry into direct management of their patenting and licensing activities by many U.S. universities, especially private universities, during the 1970s. The decade of the 1970s, after all, was one of dramatic progress in molecular biology and ultimately, biotechnology.

Nevertheless, the reasons for the entry by U.S. universities into direct management of their patenting and licensing activities during the 1970s and 1980s remain unclear, especially in view of their historic reluctance to adopt such a role. There are strong economic arguments for managing patenting and licensing through an organization specializing in these activities, such as the Research Corporation. Such a centralized model seemingly offers great possibilities for cost savings and efficiency gains by spreading the cost savings from learning to manage these activities across a large number of licensing transactions in diverse technologies. The demise of the Research Corporation model, however (see Mowery and Sampat, 2001a), reflected the need for close contact and the cultivation of relationships among faculty inventors, university licensing specialists, and prospective licensees, in addition to the perceived returns to universities from the direct management of these relationships. The experience of "centralized" models of patent management in such institutions as the University of California, where at least five campus-level offices for technology licensing now supplement a system-wide organization, appears to provide additional corroboration for these observations.

How important is the Bayh-Dole Act in the growth of U.S. university patenting and licensing after 1980? As was noted above, these activities have increased significantly since 1980 in response to the Act's simplification and legitimization of universities' management of patenting

Figure 7
Technology Field of Carnegie University Patents, 1960–1999

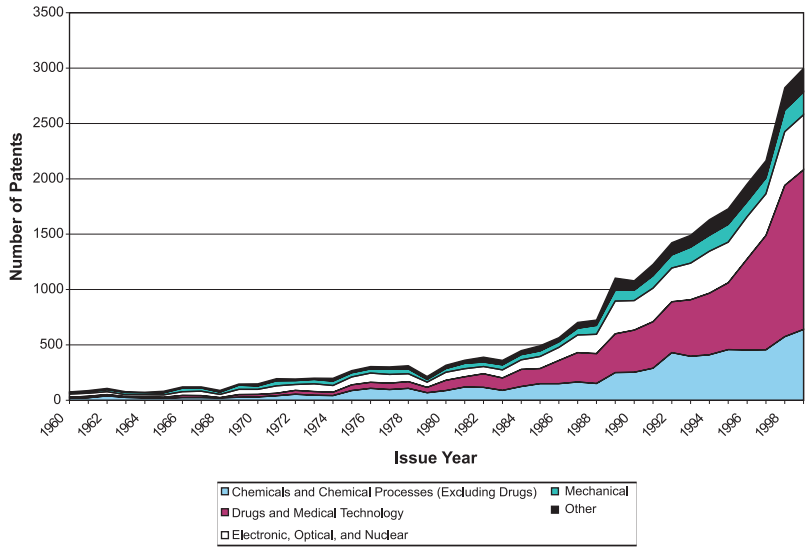
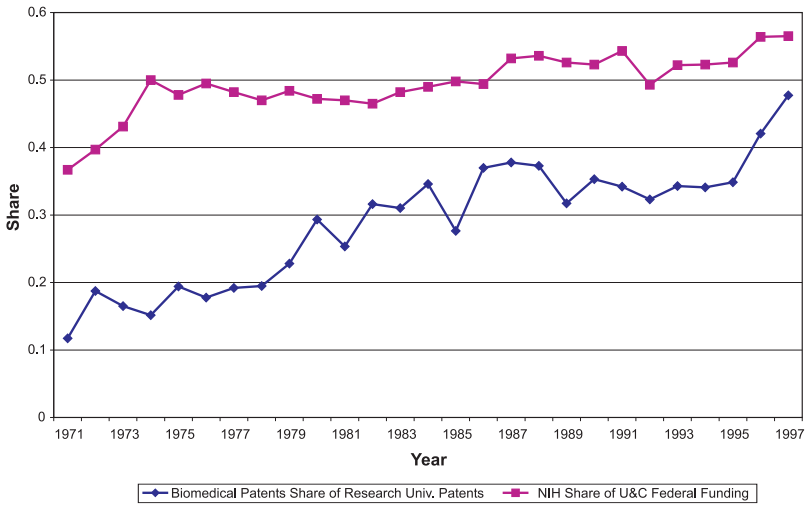


Figure 8
Biomedical Patents and NIH Funding, 1971–1997



and licensing of inventions resulting from federally funded research. Nevertheless, the Bayh-Dole Act did not legalize anything that previously was illegal, and growth in academic patenting, in the level of academic biomedical patenting, and in the share of biomedical patents within overall academic patenting all had begun to grow before 1980. The Act appears to have increased patenting and licensing somewhat at universities with long patenting histories, but the Act also led inexperienced universities to enter into this activity. The share of total academic patents accounted for by experienced academic patenters (institutions with more than ten patents issued during 1975–80) declined from more than 85 percent during 1975–80 to less than 65 percent by 1992, while the share of all academic patents accounted for by institutions receiving no patents during the 1975–80 period increased from zero in 1980 to more than six percent by 1992 (see Mowery and Ziedonis, 2001b). The development of patenting and licensing strategies by these entrants required considerable time and learning, reflecting the complexities of technology licensing, the need for detailed knowledge of the relevant technologies and their markets, and the scarcity of talent in this field (see Mowery, Sampat, and Ziedonis, 2001).

Nonetheless, much more than the Bayh-Dole Act was responsible for the growth in university patenting and licensing during the 1980s, as well as the dominance of this growth by biomedical technologies. Among the key contributing factors are the long-term growth in NIH funding of academic research and the scientific advances in biomedical research that resulted from this funding stream. Another contributing factor was the strengthening of U.S. intellectual property rights, during the 1980s, that resulted from a combination of judicial decisions, including the U.S. Supreme Court's *Diamond v. Chakrabarty* decision that made life forms patentable (see Mowery, Nelson, Sampat, and Ziedonis, 2001).

The data in Figure 9, which compare licensing income trends during the 1970–95 period at Stanford University, the nine-campus University of California system (which continues to report system-wide licensing revenues), and Columbia University (which established a university technology licensing office only in 1981, so data are available for Columbia for only the 1985–95 period), reveal several interesting characteristics of the licensing revenues of these universities, which typically rank among the leading academic recipients of such income. First, the magnitude of the growth in gross licensing revenues at all three universities is remarkable, ranging as it does (in constant dollars) from over 50-fold at the University of California to nearly 200-fold at Stanford University and

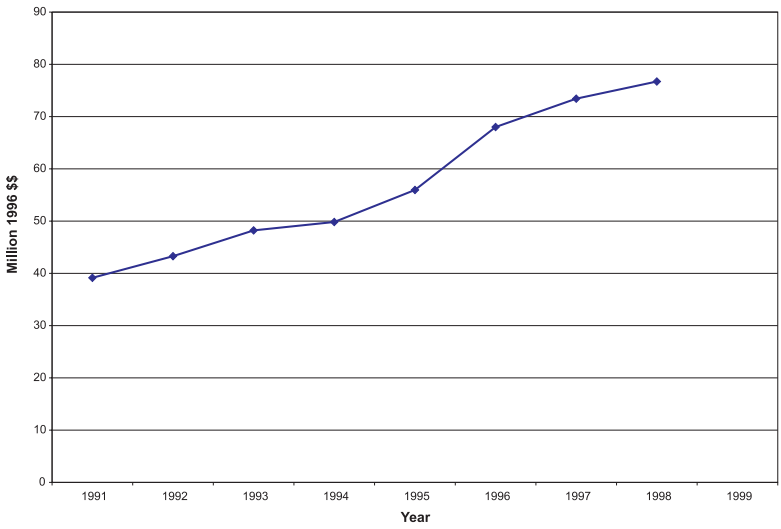
Figure 9
Selected Data on University of California, Stanford University, and Columbia University Licensing Income, FY1970–1995

UC	**FY70**	**FY75**	**FY80**	**FY85**	**FY90**	**FY95**
Gross income (1992 dollars: 000s)	1140.4	1470.7	2113.9	3914.3	13240.4	58556.0
Gross income from top 5 earners (1992 dollars: 000s)	899.9	1074.8	1083.0	1855.0	7229.8	38665.6
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
Stanford		**FY76**				
Gross income (1992 dollars: 000s)	180.4	842.6	1084.4	4890.9	14757.5	35833.1
Gross income from top 5 earners (1992 dollars: 000s)		579.3	937.7	3360.9	11202.7	30285.4
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
Columbia						
Gross income (1992 dollars: 000s)				542.0	6903.5	31790.3
Gross income from top 5 earners (1992 dollars: 000s)				535.6	6366.7	29935.8
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

nearly 60-fold at Columbia University (1985–1995). Second, these revenues are highly concentrated among a relatively small number of inventions—the "top five" inventions account for 66 percent, 85 percent, and 94 percent, respectively, of the gross licensing revenues of the University of California, Stanford University, and Columbia University by 1995. Third, these "top five" inventions are dominated by biomedical technologies, which account for 100 percent, 97 percent, and 91 percent, respectively, of the revenue stream of the five leading licensed inventions for the University of California, Stanford University, and Columbia University by 1995.

These data support two broad conclusions. First, "home runs," i.e. successful or lucrative inventions, utterly dominate the income flows from academic licensing. This observation is hardly surprising and describes a common characteristic of most invention or patent portfolios—the distribution of inventions or patents by importance and/or potential profitability is very skewed. Second, biomedical inventions appear to be among the most consistently profitable inventions in licensing transactions. Universities without strong medical or biological research centers may wish to pursue objectives other than income from licensing and technology transfer programs. Moreover, the costs of patenting and licensing are considerable. As Figure 10 shows, the (constant-dollar) patent-related litigation expenses of AUTM member universities nearly doubled during the 1990s.

Figure 10
Gross Legal Fees, FY1990–1998, AUTM "Recurrent Respondents" (n=73)



Conclusion

This brief survey of the changing role of universities within the U.S. research system highlights a number of significant changes in the role and funding of U.S. university R&D, along with expansion in the role of U.S. universities as sources of patented and licensed technologies. As was noted above, many of these shifts reflect the restructuring of the overall U.S. R&D system in the wake of the end of the Cold War. This characterization applies particularly to the declines in federal funding as a share of academic R&D and university basic research, as well as the dramatic growth in the role of biomedical research within federally funded academic research. But other trends, such as the U.S. economic boom of the 1990s, also have affected the role of U.S. universities, reducing their role in the performance of basic research.

It is unlikely that the rapid growth in industrially funded R&D and basic research that characterized the late 1990s will be sustained in the first years of this century. The level and sustainability of national R&D

spending in a system that now is dominated by industrially funded R&D remain uncertain.

The discussion of university patenting and licensing raises a number of unresolved issues, such as the motives for U.S. universities' expanded role during the 1970s as managers of their patent and licensing portfolios. Recent events (summarized in a recent editorial in *Science*)[9] suggest that the concerns expressed by Vannevar Bush's committee in 1931 or Frederick Cottrell in 1932 over the political consequences of universities' direct and visible role in the management of patents and licenses merit close attention from policymakers and university administrators.

References

American Association for the Advancement of Science. *Congressional Action on Research and Development in the FY 2001 Budget*. Washington, DC: AAAS, 2001.

American Association for the Advancement of Science. *Research and Development in the FY 2002 Budget*. Washington, DC: AAAS, 2001.

Association of University Technology Managers. *The AUTM Licensing Survey: Executive Summary and Selected Data, Fiscal Year 1999*. Norwalk, CT: Association of University Technology Managers, 2000: http://www.autm.net/surveys/99/survey99A.pdf.

Cottrell, F. "Patent Experience of the Research Corporation." *Transactions of the American Institute of Chemical Engineers*, 1932.

Feller, I. "The American University System as a Performer of Basic and Applied Research," in L.M. Branscomb, F. Kodama, and R. Florida, eds., *Industrializing Knowledge*. Cambridge, MA: MIT Press, 1999.

Fishman, E. A. MIT Patent Policy, 1932–1946: Historical Precedents in University-Industry Technology Transfer. Unpublished Ph.D. thesis, University of Pennsylvania, 1996.

Geiger, R., and I. Feller. "The Dispersion of Academic Research in the 1980s." *Journal of Higher Education* 66, 1995, 336-360.

Mowery, D. C., R. R. Nelson, B. Sampat, and A. A. Ziedonis. "The Growth of Patenting and Licensing by U.S. Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980." *Research Policy* 30, 2001, 99-119.

Mowery, D. C., and N. Rosenberg. *Paths of Innovation: Technological Change in 20th Century America*. New York: Cambridge University Press, 1998.

Mowery, D. C., and B. Sampat. "Patenting and Licensing University Inventions: Lessons from the History of the Research Corporation." *Industrial and Corporate Change*, 2001a.

Mowery, D. C., and B. Sampat. "University Patents and Patent Policy Debates in the United States, 1925-1980." *Industrial and Corporate Change*, forthcoming, 2001b.

Mowery, D. C., B. Sampat, and A. A. Ziedonis. "Learning to Patent: Institutional Experience, Learning, and the Characteristics of U.S. University Patents After the Bayh-Dole Act, 1981-1992." *Management Science*, forthcoming, 2001.

Mowery, D. C., and A. A. Ziedonis. "Academic Patent Quality and Quantity Before and After the Bayh-Dole Act in the United States." *Research Policy*, forthcoming, 2001b.

Mowery, D. C., and A. A. Ziedonis. "Numbers, Quality, and Entry: How has the Bayh-Dole Act Affected U.S. University Patenting and Licensing?" forthcoming in A. Jaffe, J. Lerner, and S. Stern, eds., *Innovation Policy and the Economy*. Cambridge, MA: MIT Press, 2001a.

National Academy of Sciences, Board on Science, Technology, and Economic Policy. *Securing America's Industry Strength*. Washington, DC: National Academies Press, 1999.

National Science Foundation. *National Patterns of R&D Resources: 1998*. Washington, DC: National Science Foundation, 1999.

National Science Foundation. *National Patterns of R&D Resources: 2000 Data Update*. (http://www.nsf.gov/sbe/srs/nsf01309/start.htm).

Rosenberg, N., and R. R. Nelson. "American Universities and Technical Advance in Industry." *Research Policy* 23, 1994. 323-348.

Endnotes

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2. Here and elsewhere, all figures are taken from the National Science Foundation's *National Patterns of R&D Resources* (National Science Foundation, 1999, 2000). The figures exclude NSF "estimates" and "projections" of R&D spending, and therefore do not extend through 2000.
3. As a result of these varied trends in universities' share of basic, applied, and development activity, the university share of overall national R&D performance increases from 11.8 percent in 1970 to 14 percent in 1999.
4. The MIT Faculty Committee on Patent Policy, chaired by Vannevar Bush, included among its "principles" for patent policy in its 1931 report the following goals: "To provide in contracts as far as possible to relieve the Institute of all responsibility in connection with the exploitation of inventions while providing for a reasonable proportionate return to the Institute in all cases in which profit shall ensue. To provide in all contracts as far as possible for the exploitation of inventions for the ultimate benefit of the public. To safeguard the name of the Institute against improper use." "A Plan by which the Institute might proceed to Safeguard and Develop its Rights to Invention," December 8, 1931; quoted in Fishman (1996), p. 40.

5. Cottrell warned against direct university involvement in managing patenting and licensing, arguing that "A danger was involved, especially should the experiment prove highly profitable to the university and lead to a general emulation of the plan. University trustees are continually seeking for funds and in direct proportion to the success of our experiment its repetition might be expected elsewhere … the danger this suggested was the possibility of growing commercialism and competition between institutions and an accompanying tendency for secrecy in scientific work." (Cottrell, 1932, p. 222).
6. These calculations exclude Research Corporation patents.
7. Domestic-assignee patents rather than all U.S. patents are used as the denominator for this measure in order to control for the increasing fraction of U.S. patents issuing during this period that are assigned to foreign inventors.
8. The Figure displays trends in patenting for the "Carnegie Universities," based on the 1973 report of the Carnegie Commission on Higher Education. The Commission classified the nation's 173 doctorate-granting institutions as Research Universities and Doctoral Universities. Institutions that awarded at least 50 doctorates in 1969-1970 and were among the 50 leading recipients of federal financial support in at least two of the three years 1968–1969, 1969–1970, 1970–1971 were classified as "Research University I" (RU1). Institutions that awarded at least 50 doctorates in 1969–1970 and ranked in between 50th and 100th in federal financial support in two of the three years were classified as "Research University 2" (RU2). The Commission's "Doctoral Universities" category includes all other institutions that granted more than ten doctorates in the 1969–1970 period. Figure 7 displays data for all Research and Doctoral Universities.
9. See "Drug Prices: Real Problem, Wrong Solution," *Science*, 6/8/01.