Patterns in U.S. University-Industry Relationships:
Lessons from Current Experience

A Report to JETRO-New York
and NEDO-DC

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Table of Contents

Preface

This report was commissioned by JETRO-New York and NEDO-DC in 2001 to examinie patterns in research and technology development relationships between universities and industry in the U.S. Undertaken by the authors as independent consultants in the firm of Technology Policy International[*], the work and its findings derive in significant part from their experience in government, the private sector and academic life. The opinions herein do not necessarily reflect the views of JETRO-New York, NEDO-DC or the institutions with which the authors are affiliated.

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1. INTRODUCTION

Productive links between academe and industry are a well-recognized pillar of the national "innovation system." In the U.S., this recognition motivated a series of ground-breaking public policy changes during the 1980s -- legal, financial and institutional measures that set university-industry collaboration on a new course. With a framework for a closer relationship thus put in place, the last two decades have seen academic and industrial cooperation blossom. It seems fair to say that these developments have established U.S. policy and practice as a new model in university-industry relationships. No other country has moved so far or so fast to cement this connection in its innovation system.

Many of the financial aspects of U.S. university-industry collaboration have now been reasonably well documented, by quantitative tracking of R&D funding, technology licensing and new ventures, among other measures. A body of qualitative case studies has also been assembled, offering insights into the development of institutional relationships. And a large cadre of professionals -- in government, industry and academe – now manage these relationships. To date, however, policy-relevant analysis has been largely lacking. With some of the most important policies now twenty years old, the urge toward reassessment of their premises and outcomes is emerging from many quarters.

The project from which this report is derived is motivated by this re-evaluative mentality. It focuses on university-industry relationships in the U.S. as they relate to technology development and commercialization[1], seeking to assess current patterns, elucidate how they are viewed by participants, and place

[1] The focus here is on research and technology development relationships, not business assistance. Many universities operate such programs, and the Federal government supports them through its Manufacturing extension Partnership and the Small Business Administration. Most such programs attempt to diffuse

them in a larger public policy perspective. The work synthesizes from an existing knowledge base, without new empirical study, and draws significantly on the authors'experience in this area.

The research effort underlying this document has been funded jointly by JETRO-New York (Japan External Trade Organization) and NEDO-DC (New Energy and Industrial Technology Development Organization). It represents the most recent project in an affiliation begun in the early 1990s between JETRO and NEDO and the current authors.[2] Over time, the research purpose has been to examine selected aspects of U.S. technology policy in terms of historical development, policy rationale and current evaluative issues.[3] Although relevant to emerging policy issues in both the U.S. and Japan, the work deliberately avoids policy prescription.

The report herein is structured into four main parts. In the following section (Chapter 2), an overview of the development of university-industry relationships in the U.S. is offered, focusing particularly on the history of policies affecting the relationship, and the variety of forms this relationship assumes today. Chapter 3 takes a more operational point of view, delineating the major organizational and management issues that face universities and industry in cooperative undertakings. Chapter 4 looks to outcomes, considering the various means by which university technology development and transfer collaborations can be measured, as well as what can be said about the issue of "success" or "failure." Chapter 5 will focus on the policy implications of the foregoing

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current technology and business expertise rather than to develop or commercialize new technology. While they serve an important function, they are not our concern herein.

[2] The authors are all principals of Technology Policy International, an international consulting group specializing in technology policy issues. A description of Technology Policy International and brief biographies of the authors appear at *www.technopoli.net*.

analysis, which come at a unique moment, for both the U.S. and Japan. In Japan, a major reconsideration of the role of the country's universities is underway, with a number of important policy changes already put in place. In the U.S., a reassessment of the policy changes of the 1980s is only beginning.

[3] A list of all publications in this series can be found at *www.technopoli.net*. The 1997 publication on university-industry relations is particularly relevant in looking at the overall context, which this report explores in greater depth.

2. THE DYNAMIC OF UNIVERSITY-INDUSTRY RELATIONSHIPS IN THE U.S.

2.1 Current Quantitative Measures

The most-watched measure of university-industry interaction in the U.S. -- the dollar amount of industrially sponsored research in universities – now amounts to about $2 billion yearly.[4] This figure represents somewhat less than 8% of total university R&D. At the $2 billion level, industry's support for academic research is still dwarfed -- as it has always been historically since World War II -- by government sponsorship, which now totals over $13.5 billion (approximately 59% of university R&D).[5] Industrial spending in universities needs also to be put in context by comparison to its internal R&D, which is now approximately $145 billion. Sponsored research at universities thus amounts to between 1 and 2% of the overall industrial R&D portfolio.

Whatever the absolute amounts, it is the rapid growth in transfers of funds and rights to technology over the last decade or so that casts the university-industry relationship into special relief. Figure 1 below presents data tracking the percentage of university research and development activities that have been funded by industry between the 1950s and 1998. Although today's levels are approximately the same as the mid 1950s, it is important to note that they follow a period – the 1960s and 1970s – in which industry's importance as a source of university R&D funds was relatively low. The significant rise in industry's share that began in the late 1970s, and has continued ever since.

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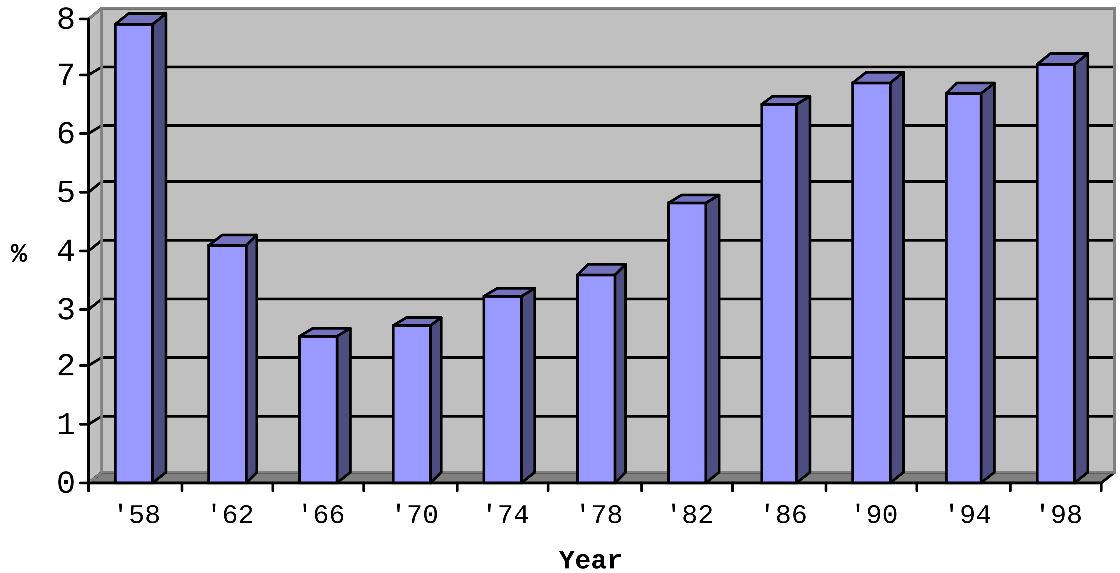
[4] The data in this discussion originate with the American Association of Universities and the National Science Foundation, and have been presented in *Working Together, Creating Knowledge: The University-Industry Research Collaboration Initiative*, by the Business-Higher Education Forum, 2001; and *in Science and Engineering Indicators 2000*, by NSF.

[5] NSF's data show university "institutional" funds as the second largest source of academic R&D – about 19% -- and state and local government funds as slightly less than industry – about 8%.

Figure 1: Industry % of University R&D



Data source: NSF, *Science and Engineering Indicators 2000*, Appendix Table 6-2

The rise in industry's share of university R&D funds is particularly remarkable when placed in a comparative framework with government. In industry's case, one sees that between 1970 and 1997, its funding of universities increased more than seven times in constant dollar terms, while its internal R&D only tripled. As for the federal government, its funding for universities doubled during the same period, with internal R&D staying essentially constant. The corporate sector thus shows a particularly strong movement toward external R&D, with academe as its target.

It is important to note that the transfer of R&D funds and other technology-oriented relationships between universities and industry mostly occur within a relatively small subset (numerically speaking) of American higher educational institutions – the so-called "research universities." While there are approximately 3600 universities in the U.S., many fewer undertake significant research. These are highly concentrated: the top 200 R&D performers account for 95% of all academic research; the top 100, close to 80%; and the top 50, more than half.[6] These are the dominant locus within which the industrial linkage occurs.

Moving to the output side of the ledger – R&D results – there are also a number of available measures that illustrate the trends in university-industry relationship. Most of these data only trace developments since the early 1990s, reflecting the natural lag between research and results, and the fact of the 1990s prominence in solidifying a new relational pattern.

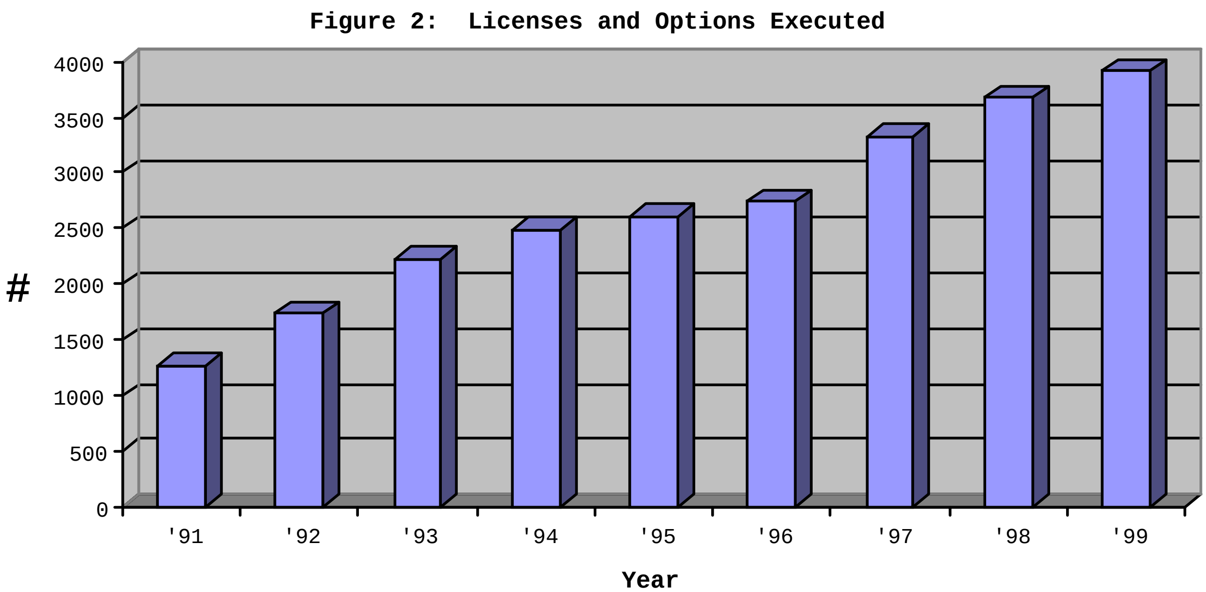
One important measure, "new U.S. patent applications filed," shows a more than three-fold increase between 1991 and 1999 among respondents in a survey by the Association of University Technology Managers (AUTM).[7] This clearly reflects the increased importance of patent portfolios for universities, as well as their ability to develop such portfolios by taking title to the results of Federally sponsored research under the Bayh-Dole Act.[8]

Naturally, many of these patents and other intellectual property are licensed, largely to industry. Figure 2 below tracks the numbers of licenses and options during the 1990s among AUTM Survey respondents. Over this period the yearly total has increased by about 225%.

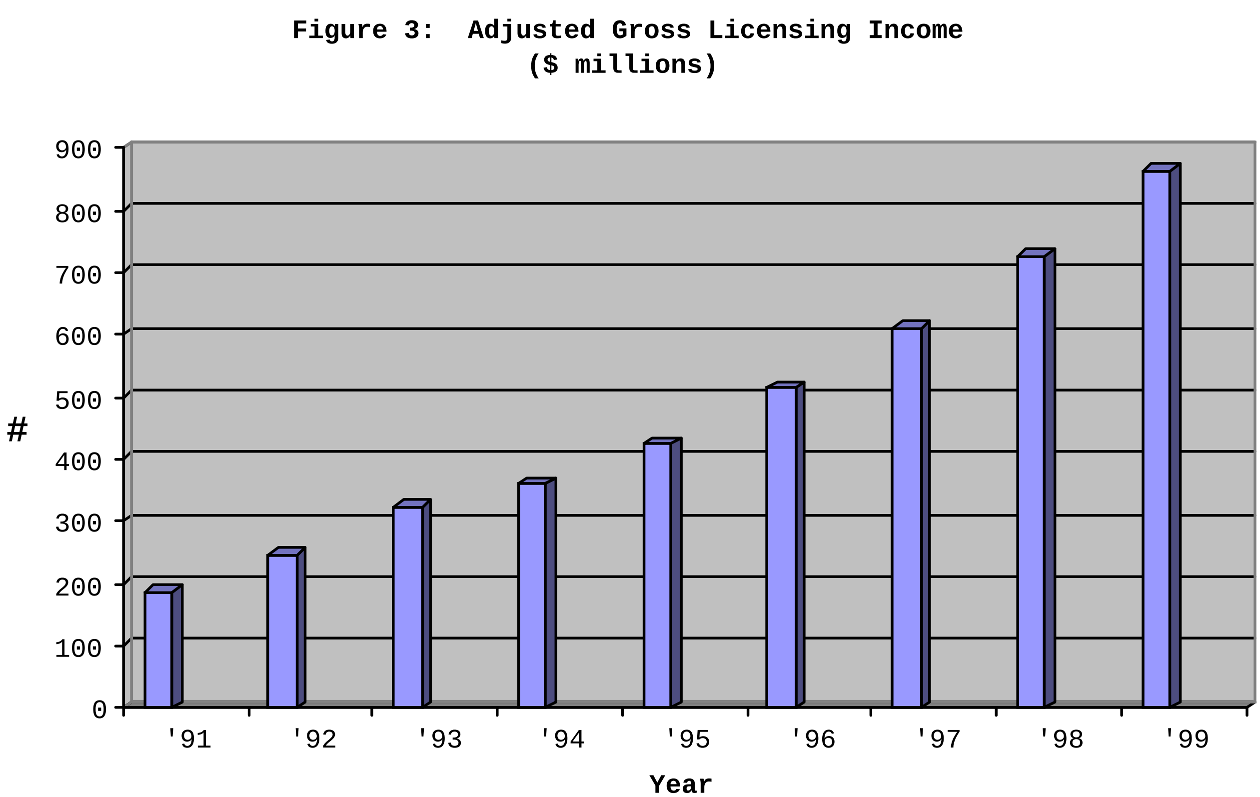
[6] NSF

[7] The data cited are from the Association of University technology Managers (AUTM) survey for FY 1999. The AUTM respondents are universities, hospitals and a small number of other institutions.

[8] Bayh-Dole and other policy changes are discussed below.



Gross licensing income from these arrangements has increased even more sharply: by about 4.5 times. This is shown below in Figure 3.



Just as R&D in the U.S. university system is highly concentrated, so too are licensing revenues. Only a handful of universities have significant licensing income. For example, among the top 15 earners in 1999, only half generated more than $9 million.[9] Some surveys suggest that fewer than 50% even cover the cost of their technology licensing offices.[10] Still. licensing income is far from inconsequential, mounting to an overall total of around $900 million in 1999.[11]A few universities earn very large sums – as much as $80 million. But such amounts, it should be noted, are yielded by a very few licenses, often for medical discoveries.

The creation of new technology-based companies involves universities and industry in a particularly complex form of interaction. Such so-called "spin-offs" appear to have increased significantly during the 1990s: whereas the AUTM respondents reported a formation rate of around 80 such companies per year between 1980 and 1993, by the late 1990s, the numbers had mounted to more than 300 per year. The willingness of universities and industry to collaborate financially in profit-making ventures is further shown by the fact that in 1999 the AUTM respondents reported owning equity shares of 46% of the then-operational start-up companies.

2.2 A Qualitative View: the Entrepreneurial University

The changes that have overtaken university-industry relationships in the U.S. during the last two decades can readily be perceived as swift and remarkable. A closer look, however, suggests that they are in significant part a natural

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[9] AUTM data, reported in *Working Together*.
[10] This figure is attributed to Louis Tornatzky of the Southern Technology Council. It is reported in *Working Together*, cited above.
[11] AUTM, above.

outgrowth of institutional structures that have long characterized the American university system.

America's research universities pursue a dual and somewhat paradoxical agenda. On the one hand, they seek to develop, codify and preserve new knowledge and new understanding about the natural and man-made worlds. On the other hand, throughout most of U.S. history, universities have been seen -- and have seen themselves – as instruments through which societal objectives can be accomplished. Clearly, university service to industry through R&D cooperation is consistent with the long history of university response to national needs – never more so than during the 1980s, when the "competitiveness crisis" of American industry loomed so large.

Four long-standing structural features of U.S. universities distinguish their patterns of activity and governance from the norm in other countries. These include:

- lack of centralized, national control
- reliance on external sources of research funds
- a peer-reviewed contracts and grants system for sponsored research
- entrepreneurial faculty members
- high personal mobility

The overall result is a highly responsive university system, and one that is able to take advantage of new opportunities entrepreneurially.

Perhaps the most singular feature of the U.S. university system is its lack of centralized control. There has never been a national government agency to establish, fund or direct the agendas of its universities. The current Department of Education is a newcomer among the agencies of the national government, and it exercises only modest influence over the university sector, which is almost entirely comprised of private and state-chartered institutions.[12] This absence of centralized control has bred a system that is highly diverse, dynamic, and relatively unwieldy. In spite of considerable movement toward the establishment of national educational standards at pre-college levels, there is no movement at all toward change of this basic structural feature of the university sector.[13]

Consistent with their organization as independent entities, private American universities finance their basic operations to a large extent through tuition charges – often very high – to students. The basic operations of state universities are based on state appropriations as well as tuition. In research activities, however, both private and state schools are largely dependent on external sources of funds. This feature – the tradition of sponsored research – is undoubtedly key to their responsiveness to changing external needs. Its use accelerated dramatically during the build up of federally-supported R&D at the outbreak of World War II, when it was decided that the government would pay for faculty and students to do war-related research on the campuses. Today the research universities accept external funds to support research, graduate education and other activities from an array of sources, including the federal and state governments, industry, private foundations, individuals, and foreign firms and governments.

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[12] More than half of the nation's universities are private, organized typically as independent, non-profit entities. Most of the others are chartered by the states, but are able to behave in many respects like private institutions.

[13] It should be noted that nearly all U.S. colleges and universities are accredited by regional education associations. Thus, there is indeed broad consensus on educational standards and formats, even though it does not originate from centralized authority.

Sponsored research in the U.S. rests on a system of external grants and contracts. These are usually awarded in response to an open competition and for a limited period of time, typically ranging from six months to three years or so. Thus, most external funds support specific projects, rather than a long-term program of work. The mechanics of competitions to choose funding recipients varies widely, depending on the nature of the funder and of the fields of research. However, the paradigm is the award of grant funds by such science-based government agencies as the National Science Foundation (NSF) and National Institutes of Health (NIH) in open competitions. Such competitions, based on rigorous technical review by experts – the peer review system – have conditioned faculty members to compete for and justify their proposed research.

Closely associated with dependence on external research funds is the notion of the faculty member as the entrepreneurial "P.I." (principal investigator). It is expected – often as a determinant of career success -- that faculty members and researchers will bring funding into the university. They are given wide latitude as to the sources of such funds -- be they from foundations, industry, or governments, domestic or foreign. Flexibility in the establishment of research formats is encouraged through laboratories and multidisciplinary centers that bridge and extend the traditional academic departmental framework. The combination of free-agent and entrepreneur mentalities are also evident in university policies relating to faculty consulting, which routinely allow a significant amount of time in the pursuit of off-campus activities.

A last important assumption underlying the entrepreneurial university is high personal mobility. Only a fraction of new faculty hires receive tenure, thus forcing most individuals to search for new positions repeatedly. Senior faculty are often recruited to other schools. Many leave – either permanently or temporarily – to start companies, and increasingly, a reverse flow – industrial migrants to academe – is being seen. Professionals in the university system also assume that their patterns of external collaboration will be highly mobile – determined through their own wide networks of consulting, temporary appointments, and research exchanges.

2.3 The 1980s: Pivot of Policy Change

As indicated above, the willingness of American universities to turn academic capabilities toward the needs of the nation dates from their earliest establishment. But with a few exceptions – the Morrill Act of 1862 most notably[14] – this tendency was more the result of voluntary action than public policy. World War II changed this pattern irrevocably, as the Federal government dramatically increased its funding for research in universities and provided generous financial assistance for veterans' education. Indeed, the belief that "science won the War" clearly undergirds the rationale for Federal support of academic science made in the "Bush Report,"[15] which has played so large a role in American science and technology policy ever since.

Close interaction between U.S. universities and industry in research and technology development is, likewise, not a historically new phenomenon. From the late 19th century at least, certain technical fields in universities – chemical engineering for example – were being built by faculty members who moved freely between academe and industry, and maintained active consulting practices. Consulting to industry, as mentioned above, has long been a constant in American university life, as have "charitable grants" from industrial firms to universities.

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[14] This Act established Federal support for an agricultural extension service, land grant colleges where agricultural R&D was performed, and a program of technology transfer. It is widely seen as the earliest, and undoubtedly among the most successful, Federal programs to support commercial technology via universities.

Direct industrial funding of university R&D exhibits a different historical pattern. As Figure 1 above shows, from a high point in the late 1950s, the industrial share of the university R&D budget declined to its low point in 1966 and remained little changed throughout the 1970s.[16] There are many and complex reasons for this decline, including the large build-up in Federal funding, the Vietnam War, and a period of academic estrangement from industry generally.

The 1980s were an era in which attitudes about university-industry cooperation seemed to execute an about-face. The change was reflected not only in industry's increased interest in academic research, but also in the university community's increased to willingness to accept – even to solicit – industrial funding. While there are many and complex reasons for these changes in attitude, the "competitiveness crisis" of U.S. industry undoubtedly played a part.

The competitiveness crisis also had the effect of motivating the Federal government to enact new public policies focused on technology. An accumulating body of knowledge about the process of technological change clearly suggested that public policies to encourage cooperation across firms, sectors and institutions would be uniquely effective in promoting technology development and commercialization. Strengthening university-industry ties was seen as an essential – though far from the only – element in the package of policy change.

A result of new attitudes, a crisis mentality, and new scholarly understanding, the large number of technology policy changes put into place

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[15] *Science: The Endless Frontier* (1945)

during the 1980s can certainly be characterized as ground-breaking for the U.S. They have been described fully in other documents.[17] What is offered below is a brief recapitulation of the principal discrete policy changes, along with a summary of their impacts on university-industry relationships. It is also worth recognizing that the cumulative impact of these new policies, coupled with pervasive attitudinal change in industry and universities, far exceeds that of any particular new law or program.

- The Bayh-Dole Patent Act of 1980

    This Act allowed the recipients of Federal R&D dollars to elect to take title to patented inventions they created with Federal funding.[18] It reversed the longstanding policy of most Federal agencies in which the government had retained intellectual property rights over Federally-funded inventions, and it made the new policy uniform across most agencies.

    Bayh-Dole has probably had the single largest impact of any of the 1980's policy changes on university-industry relationships. Virtually all research universities now see themselves as managers, or potential mangers, of a significant corpus of intellectual property, and have developed policies, personnel and institutions to execute this function.

- Engineering Research Centers (ERCs)

    The National Science Foundation began funding Engineering Research Centers in universities in 1985. ERCs were novel institutions in two important respects: they focused on technology-related

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[16] In 1957, industry funds accounted for 8.4% of university R&D; in 1966, 2.5%; in 1970 3% and in 1980, 4%. (NSF, 2000)

[17] Among previous reports to JETRO and NEDO by the same authors, note especially *Policy Innovation:The Initiation and Formulation of New Science and Technology Policies in the U.S. During the 1980s.*

[18] It should be noted that Bayh-Dole only applied to small firms and non-profit organizations, including universities. The system set up in the Act was extended to large firms through Executive Order, but the treatment for large and small firms is still not identical, as it depends on other statutes that pertain to particular agencies. Bayh-Dole does not apply to the DOD, for example.

problems that spanned traditional academic disciplines; and they provided a locus at universities to enlist academic and industrial people in joint research.

The ERC program has been a clear success. NSF has expanded its funding to support a few dozen ERCs, Congress and the Administration approve it, and it has provided a funding model for other Federal agencies and among the states. It seems clear that the ERC cooperative model is widely accepted by academic and industrial personnel. However, research is only now beginning to systematically evaluate features of ERCs and link them to outcomes.

- The Technology Transfer Act (TTA)

On three occasions (1980, 1986 and 1989) Congress passed legislation to encourage technology transfer from the Federal government to the private sector.[19] Although this legislation does not refer explicitly to university-industry linkages, its commitment to cooperative technology development has proved an important aspect of the overall policy climate. University personnel are, in fact, frequent participants in technology development and transfer programs with Federal government technical laboratories.

- The National Cooperative Research Act (NCRA)

Prior to the passage of the National Cooperative Research Act in 1984, the U.S. antitrust laws were presumed to inhibit cooperative research ventures among industrial firms, who feared legal actions brought by either the government or their competitors. The NCRA dramatically decreased such fears, through a notification process that minimized legal risk. Since the NCRA's passage, about 50 research consortia per year have made such notifications.

Although the NCRA targeted industrial action, not universities, the research consortia established under its provisions typically include

[19] The Stevenson-Wydler Act of 1980 established a general framework for innovation policy and technology transfer. The Technology Transfer Act of 1986 and the National Competitiveness Technology Transfer Act of 1989 were necessary to focus, fund and expand this general mandate.

academic personnel. And it seems safe to say that the cross-sector teaming which has become a routine aspect of proposals for government research monies would not have flourished without the NCRA.

- Cooperative Research and Development Agreements (CRADAs)

  CRADAs were an institutional innovation in the Federal laboratory system that permitted the public and private sectors, especially industry, to work together in research and technology development projects. They became a mainstay of Federal R&D contracting during the 1980s. University personnel are regular participants in CRADAs, thus strengthening their ties to both industry and government.

- The "Basic Research Tax Credit"

  The Basic Research Tax Credit was a 1986 amendment to a general tax credit for industrial research that had been added to the U.S. tax code in 1981, to stimulate industrial research. By the mid-1980s, as the value of industrial funding of university R&D gained recognition, concern began to voiced that the limited scope of the industrial tax credit actually discouraged industrial R&D out-sourcing in universities. The 1986 "basic research credit"neutralized the disparate tax treatment of internal and external R&D, thus smoothing the way to continued increases in industrial funding for universities.

2.4 A Typology of Industry-University Interaction Today

After two decades of evolution in the context of new public policies, new attitudes, and new institutional arrangements, the relationships between American industry and universities have grown tremendously in number, depth and complexity. They also vary enormously. This is hardly surprising, given that universities and industrial firms craft their own relationships absent any central authority that might prescribe standardized formats, and that these relationships involve hundreds of universities and tens of thousands of faculty members operating largely as independent entrepreneurs. The problem of categorization is further exacerbated by the lack of any formalized tracking system.[20]

Moreover, the fact that there are new patterns in university-industry relationships today does not mean that old formats for interaction have disappeared, or even diminished. On the contrary, the available evidence suggests that the traditional modes of contact – consulting, student placement, service on boards of directors, joint authorship, etc – have only intensified with the rise of such trends as industrially sponsored R&D, interdisciplinary research centers, spin-off firms and technology licensing. Indeed, it is likely that industry gets most of its R&D results from universities via the open literature and recent graduates.

Within the complexity, a few distinct typologies of university-industry cooperation have begun to appear. They pertain to: the sponsorship or origin of academic R&D funding, the locus and format of research projects, and the modes of commercializing research results. A brief description of these typologies appears below.

University research projects of interest to industry generally fall into one of the following three categories of funding sources:

- Government-sponsored research

In this format, long-assumed to be the paradigmatic case, government funding pays the preponderant cost of a university research project[21].

[20] AUTM (Association of University Technology Managers), whose work was referenced earlier, is probably the best source. AUTM is a private professional association, whose activities acquired significant scope only within the last decade.
[21] In fact, government pays direct costs, plus a negotiated portion of indirect costs. (See discussion in Chapter 3)

Given the Bayh-Dole Act, the intellectual property rights resulting from publicly funded research are now most likely to be held by the university. This naturally creates the potential for university patents to be to be licensed to industry for commercialization – the rationale for university Technology Licensing Offices (TLOs).

- Industry-sponsored research

Industrial funds increasingly underwrite research projects (and research programs and institutes) at universities. Industrially sponsored research typically has different objectives and time frames from government-sponsored projects. Logically, the intellectual property rights from such research could belong either to industry of the university. In practice, however, universities generally attempt to assert ownership, and this practice is seen as a norm by the Business Higher Education Forum.[22] Licensing rights tend to become all the more important in this situation.

- Joint research sponsorship

Many research efforts at universities benefit from more than one source of funding. Typically, this would mean both government and industry, but a number of industrial firms could also be involved. Joint sponsorship could pertain to an individual project or a center or research institute, and it could well vary over time, as research activities proceed from the fundamental toward the more commercially oriented. To the extent that Federal government funds are involved, it would be expected that the university would take title to resulting patents, and that licensing would be a prime concern as in other formats.

As the organizational units of universities have become more diverse, now extending well beyond traditional academic departments, the locus of projects with industry has taken on a more complicated pattern, The following three types can be distinguished:

- Individual Faculty "P.I.'s"

[22] Ibid.

Individual faculty members have long sought research grants and contracts funded by sources outside the university, whether government or industry. Although such arrangements commit the university contractually, it is the individual faculty "principal investigator" (P.I.) who is responsible for their performance and supervision. For projects of any size, faculty P.I.'s typically enlist graduate students to perform parts of the work.

- Research Centers

Research centers devoted to a particular topic or technical area, and spanning traditional academic disciplines have become an organizational fixture in research universities. Many faculty members devote part of their time to such centers, which often employ their own, non-faculty research staff, and enlist students as research assistants. It is typically the case that such centers fund themselves largely with externally sponsored projects. The sources of funding are various, often drawing on both government and industry monies. The scope of capabilities that centers can amass allows them to pursue large, often groundbreaking, research, highly tailored to sponsors' interests.

- Consortia

Individual faculty members, professional research staff, centers or other organizational units from universities are frequently involved in projects at research consortia, often organized externally to the university. Industry projects organized under the NCRA or CRADAs involving government labs and industrial researchers are some examples of this format.

As universities – and individual faculty members – become increasingly involved in the process of commercializing the technology they have developed, pioneering organizational arrangements have developed that go far beyond the traditional academic roles of universities. These include:

- Technology Licensing

Although technology licensing has long been a feature of university life, the new public policy framework for cooperative research (above all the Bayh-Dole Act), coupled with increased industry R&D sponsorship has made it ever-more important. Although, as mentioned above, many university Technology Licensing Offices yield only small revenues, they are an almost universal feature of research universities. The rapid growth in membership of the AUTM, mentioned above, attests to the degree of professionalism this function has acquired.

- Spin-off Companies

Although the phenomenon of new companies started from universities is a much-discussed, the exact definition of a "spin-off" presents some difficult issues. A report from the Massachusetts Institute of Technology, for example, has counted about 4000 spin-offs from MIT, which are said to equal "the 24th largest economy in the world."[23]

A more conservative approach would define spin-offs as companies started with the participation of a university as a contributor of technology, funding, personnel or other expertise.

One of the most interesting manifestations of the spin-off phenomenon casts universities in the role of venture capitalists, contributing equity capital to new enterprise with the hope of gains from their growth. Other "deals" – presumably the majority – involve the university accepting equity in lieu of license payments. As mentioned above, some 46% if the AUTM survey respondents reported taking this role, and about 300 such companies are believed to be established among AUTM respondent universities each year.[24]

[23] "The Impact of Innovation," MIT News Office Report, March 1997.
[24] AUTM Survey, cited above.

3. MAKING UNIVERSITY-INDUSTRY RELATIONSHIPS WORK: SOME OPERATIONAL ISSUES

This chapter addresses a set of operational issues that arise in connection with industry support of university research, technology transfer and commercialization, and industrial consulting by university faculty. It includes a discussion of the organizational units that exist in most universities that receive external support for research, including that which comes from industry. Technology transfer units are also described. Administrative practices are reviewed, in the context of federal and state law and regulations as well as university policies and procedures. Specific issues that continually arise in operationalizing university industry cooperation are also reviewed.

The principal focus in this chapter is on the operational issues within the university; somewhat less attention is paid to issues for industry.

3.1 Industrial Support of University Research

3.1.1 *The Context: Financing Separately Budgeted Sponsored Research at Universities*

Financial Administration

The tradition of "separately-budgeted, sponsored research" is a predominant feature of the American research university. While it is an expectation that most or all of the faculty of a university will engage in research, creative pursuits or other forms of scholarly inquiry, most universities spend relatively little of their institutional funds to support such work. Instead, expensive research activity is usually supported through financial support from outside sponsors, such as governments, companies, private foundations or wealthy individuals. When funds are received from these sorts of "sponsors," they are usually budgeted separately from income received from tuition and student fees, alumni gifts, or general government support of higher education.

Many of the terms, procedures, policies and laws governing the system of sponsored research in U.S. universities are a result of a long history of government contracting with universities. Many of these features have been adopted by universities in framing their financial arrangements with industry for sponsored research support. Thus, we begin this section by describing the nature of the arrangements put in place to deal with government support. We then turn to implications of these arrangements for university-industry relations.

As a rule, sponsored research funds are awarded to universities for use by a particular professor or research group of faculty and students in response to a formal proposal to do a particular research project or program. The faculty member who is in charge of the research is called the "principal investigator," or "P.I." The P.I. has a great deal of latitude in spending the funds in pursuit of the project objectives, with the details of that latitude varying depending on the terms under which the funds have been provided. The P.I. also determines the research methods and approach to be used and conducts and/or manages the conduct of the research. The PI., along with other faculty associates, graduate students and professional staff, if any, is responsible for record keeping, reporting and publications of the research results. Perhaps most important, the P.I. is responsible for conceiving of the proposed research and for identifying possible sources of financial support, as well as for writing the technical proposal to potential funding entities.

Appropriate management of sponsored research funds is a fiduciary responsibility of the university as an institution. Hence, each proposal submitted for external funding must follow certain institutional guidelines regarding format, budgeting, and other commitments of personal, space and resources. Universities typically employ a staff of "grants and contracts" specialists who review each proposal prior to submission. Depending on how the university is organized, these specialists may also assist proposed P.I.s in drafting proposals, creating budgets, and submitting proposals.

Often the grants and contracts officials make up what is known, variously, as an Office of Sponsored Research, an Office of Sponsored Programs, a Grants Office, or a Research Office. In larger universities, these offices report to a senior university administrator, typically a vice president for research, vice provost for research, or dean of the graduate school.

Usually, no research proposal can be submitted, and no research grant or contract can be accepted or agreed to by the faculty member, P.I. or academic officer such as a department head or dean. Instead, such official actions can only be taken by duly authorized university research administrators acting under a grant of authority from the university president or other senior officer.

Non-Financial Controls on Sponsored Research

Beyond financial accountability, institutions accepting sponsored research funds are required to comply with a host of rules and regulations governing how research is to be conducted. The federal government, which is the largest single external sponsor of university research, imposes a large number of requirements on recipients of both research grants and research contracts. These requirements address such matters how much can be charged to grants or contracts for specific purposes, how financial records are to be kept and reported to the sponsoring government agency, and how the university does business generally. For example, all recipients of federal funds are required to conduct research on human subjects in such a manner as to minimize the risks to those subjects. The federal government also imposes requirements on the use of laboratory animals in research, on use of hazardous chemical and biological materials, and on the use of recombinant DNA in research. Certain highly controversial types of research may be prohibited altogether, such as research on human fetuses. In addition, research universities must comply with host of other regulations affecting research, regardless of whether they accept federal funds, such as controls on use of radioactive isotopes and X-ray generating devices, on equal employment opportunity, on export controls for sensitive information, and so on. Usually, compliance with all of these regulations is overseen by the Office of Sponsored Research and/or the vice president for research.

Grants, Contracts, Cooperative Agreements and Gifts for Research

While the differences are subtle and often of secondary importance to P.I.s, external funds may be provided to support research at universities via four vehicles: grants, contracts, cooperative agreements, and gifts. These four vehicles incorporate important policy differences in the acceptance of outside funds, especially from industry and other private sources.

Grants are typically provided to universities by governments or foundations to support a defined research project in response to a proposal. The P.I. typically has broad latitude to guide and report on the work, with significant changes in the direction of the work usually acceptable to the funding organization. The goal of the funder who uses a grant mechanism is usually to support the increase of knowledge in a particular domain without regard to using the resulting new knowledge for a particular purpose. If the funder is a goverment agency, however, it usually asks for a detailed accounting of how the funds were spent. Such federal agencies as NSF and NIH usually use the grant vehicle to support research.

Contracts are typically used to support university research when the funder wishes to exert substantial control over what research is done and how. Contracts usually specify that a set of identified "deliverables," such as reports, data bases, or experimental samples, will be produced in the course of the research. Under a contract, the PI has much less latitude than under a grant to design and modify the research program. Such federal agencies as the Department of Defense and Department of Energy make frequent use of the research contract vehicle to support university research when they have a strong interest in ensuring that the project actually yields a desired result. Many industrial funding agreements also take the form of contracts.

The cooperative agreement is a somewhat arcane funding vehicle that is only occasionally used by government agencies and rarely by industry or foundations. It stands somewhere between a grant and a contract. The PI has much the same latitude as under a grant, yet the funder retains certain rights to guide and approve the research program, although not as much as under a contract.[25]

Gifts are usually given to universities to support research out of a charitable motivation on the part of the funder, who is usually referred to as a "donor," rather than a "sponsor." A transfer of funds to a university can be considered a gift only so long as the donor does not expect or get anything of value in return. This characteristic of a research gift has its origin in the income

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[25] It should be noted that, despite the unfortunately similar names, the "cooperative agreement" discussed here is not the same as a "cooperative research and development agreement," or CRADA, under the Federal Technology Transfer Act. The latter is an agreement to cooperate in research, which may or may not include the transfer of money. A cooperative agreement is a research funding vehicle.

tax laws, which allow taxpayers to deduct the value of gifts from income before paying tax on it. If such a transfer were to result in transfer of something of value in return for the gift, the tax authorities would consider the funds to constitute a non-deductible purchase of services. Companies are major donors of gifts to universities in the United States, although most often in support of education rather than research.

Accounting for the Costs of Research

Universities typically follow a set of guidelines established by the U.S. Office of Management and Budget (OMB Circular A-21) in accounting for the costs of separately budgeted sponsored research activities. Circular A-21 has been negotiated over the past several decades as a tool for implementing the broad principle that the federal government will pay the "full costs" of research it sponsors, whether by grant, cooperative agreement or contract. (As noted below, the "full costs" principle is not fully honored at present.)

Under A-21, the costs of research are divided into two groups: direct costs and indirect costs. The direct costs of a project are those costs that are directly attributable to the conduct of a specific project; i.e., if the particular project were not conducted, these costs would not be incurred. For an experimental project, for example, the direct costs would include the salaries of research staff or graduate assistants working on the project, possible summer salary for the faculty (faculty are typically paid by their institutions only for the nine months of the academic year), and the costs of experimental equipment, experimental materials, travel, and unusual computer costs. Direct costs may also be incurred for project consultants, purchased services, or subcontracts.

Indirect costs, on the other hand, are those costs that the institution incurs because it is conducting sponsored research activities, and which it incurs regardless of whether any particular project is funded or conducted. These include the operating costs and depreciation charges for buildings in which research is conducted, the costs of maintaining the administrative systems such as sponsored programs and accounting staffs, libraries and journal subscriptions, and a portion of the time of senior university administrators.

Indirect costs are much more difficult to identify and quantify than are direct costs of research. Many of the activities that generate indirect costs are activities that are shared between research and the other functions of the university such as education and research. As a result, each institution that accepts federal research funds engages in a negotiation with the federal government's audit agencies regarding what its indirect costs are for research. Universities propose to the government that certain costs be included in the indirect cost base, taking into account recent historical experience. Government auditors review those costs, ask for detailed documentation and support, and agree to accept some proportion of the costs as indirect costs. At the same time, government auditors, with the cooperation of the university, account for all of the expenditures of direct costs by the university during the same historical period. The ratio of accepted indirect to measured direct costs, expressed as a percentage, is then set as the negotiated "indirect cost rate" (or "F&A" rate, see below) that will apply to federal grants and contracts in the ensuring years, typically for a three-year period.

Indirect costs are divided by OMB into two broad categories: facilities and administrative costs. In fact, OMB now prefers to use the phrase "facilities and administrative" costs, or "F&A," rather than "indirect" costs, or the older "overhead" costs. At present, the administrative portion of the F&A rate is limited by OMB to 26% for all universities except in certain unusual circumstances. The facilities portion of the F&A rate is more flexible, taking into account the capital and operating costs differences among universities. For public universities in the United States, the F&A rate is typically in the range of 40 to 55%, while for private institutions, which usually have more expensive facilities, it is typically in the range of 50-75%.

Most major research universities argue that, today, the F&A rate fails to reflect the "full costs" of research. First, nearly all universities argue that the 26% cap on the administrative part is too low. For example, since the 26% rate cap was set more than a decade ago, the costs of compliance with various regulations on research has grown considerably. These costs are included in the basis of costs used to arrive at the negotiated administrative portion of the F&A rate. However, since most universities were already at the cap before the regulatory costs grew, in effect none of those costs have been recoverable by universities. It has been estimated that the F&A rates for most universities are perhaps five percent too low, owing to the unrecovered costs of regulatory compliance alone. On the facilities side, federal auditors are said not to account satisfactorily for the full costs of building and operating facilities, including ever-more-expensive information support services, specialized laboratories and other facilities, and the costs of meeting such requirements as those of OSHA and the Americans for Disabilities Act.

A few universities, notably those in the state of Arizona, have estimated their full indirect costs of research and suggest that the negotiated F&A rates may be low by a total of 25 to 50 percentage points.

Finally, it should be noted there that the entire structure of basing the size of grants or contracts at universities on accounted costs, direct and indirect, reflects a system of agreements to provide research services to sponsors at the costs of production. Regardless of the outcome of the budgeting for direct costs and the negotiation of indirect costs, the pricing of university research services to sponsors does not include any provision for a market-based pricing approach based on the *value* of the services to the sponsor or on the *willingness-to-pay* of the sponsor. Put another way, there is no room for making a *profit* on such arrangements, whether such a profit is considered as *normal* or *super-normal* in an economic sense.

3.1.2 *Issues in Industry Support of University Research*

Choice of Financing Vehicle and Resulting Policy Issues

Companies support university research using gifts, grants and contracts.[26] Companies make gifts to universities typically to support a line of research without regard to the specifics of any project and without any expectation of receiving anything of direct economic value in return. In many universities, gifts from companies in support of research are made, not to the university itself, but to a charitable foundation associated with the university for the purpose of supporting the university financially. Such gifts may be given to be used directly for research, while others may be given to form an endowment, the proceeds of which are used annually to support research. The foundation distributes the gift proceeds to the PI to be spent on the research according to an agreement between the university and the foundation. As a rule, gifts do not include funds to pay for indirect costs, as they are conceived of as assisting the university to do what it would do anyway with its own funds. Financial accounting for the gift expenditures may be managed by the foundation itself or under an agreement by

[26] The cooperative agreement is essentially a government support instrument and will not be discussed further here.

the sponsored programs office of the university. Since such gifts are made with no expectation of return, any intellectual property developed in the course of the research belongs to the university and the donor has no expectation of any preferential treatment in access to that property.

Grants are given by companies to universities to support specific research projects in response to a proposal. Typically, the company does not expect a direct return from the grant, but it is usually quite interested in an early look at the research results. Universities usually ask sponsoring companies to pay the federally negotiated F&A rate on the direct costs that are budgeted for the research. Companies sometimes object to paying F&A costs, and universities will often accept F&A payments that are lower than those that would be charged to the federal government. They are at some risk in doing so, however, as they open themselves to the allegation that they are charging a higher price to the government than to other sponsors, which is specifically disallowed under Circular A-21. Such action could result in a roll-back of the federal F&A rate to that charged to private companies, which would be financially ruinous to major research universities. As a rule, companies that make research grants to universities do not expect to own or to have preferential access to any patents or other intellectual property that may result.

Contracts to support university research are used by companies that want to try to ensure that the research done at the university is done on time and that the results will be made available to the company in useful form for the costs that are negotiated in the beginning. Often contracts are used by companies when the university research project has been outsourced to the university as part of a larger, integrated R&D project within the company. In such cases, universities are viewed as "just another supplier" in a technology supply change. Failure on the part of the university to deliver on time can put the entire company project at jeopardy. In this kind of situation the company is likely to view the university as "just another supplier," and to lose sight of the special characteristics of universities that make "doing business" with them different from doing business with another firm. In particular, firms that support university research with contracts often expect to take ownership of any intellectual property that results, while most leading universities seek to retain such title.

Implications of the Source of Funds

Companies may support research at universities using their own funds, or under a subcontract based on a prime contract awarded to the company by a government agency. If the source of funds is a federal agency, the sub-award to the university, as a subcontractor, is generally governed by the same administrative rules, including indirect cost rules, that govern the university as the primary recipient of government funds.

On the other hand, if the source of funds is the company, not the government, then the scope of applicable federal rules is substantially reduced. Federal standards that apply to the university generally, such as rules governing environmental, health and safety issues continue to apply. However, universities have greater latitude in managing funds that flow from a company than those that flow from the government.

That said, the fact that the federal government is typically the largest supporter of research, by far, tends to mean that universities seek to use the same sets of rules and procedures in accepting and managing industrial funds as they do for public funds. For example, universities seek to apply the same F&A rates to industrial contracts and grants as they do for the government. Proposals and contract documents, along with financial management and reporting, are managed in the same way using the same systems and procedures. From an industrial perspective, the application of the federally-inspired rules to private sources of funds can seem arbitrary and contrary to their interests. This divergence can be the source of considerable conflict in negotiating workable R&D support deals between industry and universities.

The fundamental divergence arises from the fact that publicly supported research is generally intended to serve the public at large. This goal is quite consistent with the overall goals of the university to serve society via education, service and generation of new knowledge. On the other hand, privately supported research is generally intended to serve the goals of the company that supports it--which include, ultimately, profits, and, more proximately, establishment of a competitively favored position based in part on control of a unique technological capability. Thus, firms often wish to enter into arrangements with universities that emphasize confidentiality, controlled publication, sponsor ownership of, or at least exclusive license to, any resulting patents, and agreement by the university not to accept sponsorship of research in similar areas from competing companies. Firms often want to have the faculty engaged in the research serve as consultants to the company as well, and sometimes encourage faculty not to disclose inventions to the university or to publish, but instead to disclose inventions confidentially to the sponsor only. Finally, firms often want sole control over not only the results of the research and any inventions that result, but also control over or even ownership of the research data underlying the results. Each of these private objectives runs into conflict with the public goals of the university.

Confidentiality and Publication Control

Universities traditionally thrive on the open exchange of information and new knowledge. Scholarly contributions are inherently public, with their dissemination limited only by the ability of potential readers and users to pay for the journals or books in which they appear. Teaching and learning naturally involve the open exchange of knowledge. Public service often engages the faculty in making their knowledge public to aid in public discourse. Faculty and graduate students must publish — publication is still the route to recognition and advancement for most such academics.

Companies usually want to keep research results closely held as trade secrets, or disseminated in a limited way and only after careful scrutiny to guard against inadvertent disclosure of company confidential information and against premature publication that would jeopardize the ability of inventors to obtain patent protection.

In the present climate, universities typically will agree to let industrial sponsors review papers intended for publication for the specific purposes noted above. Such review is usually time limited — 60 or 90 days is standard, and sponsors are usually barred from requiring changes in publications only to protect the company's reputation. After that, open publication is the norm. Most universities of quality will not agree to any contract that permanently bars or limits publication of research results. The integrity of the university over the long term depends on its willingness to subject all of its research findings to the open scrutiny that follows from peer review and publication. Secrecy is contrary to this deeply held value.

Some sponsored research projects inevitably require that the company share with the university researchers certain technical information that the company considers to be a trade secret. Researchers and administrators may be asked to sign non-disclosure agreements barring further dissemination of such information as well as its return, if in physical form, at the end of a project. Firms commonly sign non-disclosure agreements that are binding on everyone who works for the firm. Universities, on the other hand, have very limited ability to enforce such agreements on all their staff and students, so they often prefer that non-disclosure agreements be signed by, and apply only to, each of the individuals at the university who are associated with the specific project.

Because firms sometimes seek to hold as a trade secret even the fact that they are active in a particular field of research — because such knowledge might help competitors identify the firm's strategy, they on occasion ask universities to keep the very existence of a research contract secret. Private universities may be able to do this, if they choose to, but public universities typically must publish or make available a full list of all their sponsors and projects, so they are unable to provide complete confidentiality in such matters.

Other Issues

Firms often ask universities to indemnify them for losses consequent to a sponsored research project or technology license. Such losses might occur, for example, if the research project led to a product that was later shown to harm customers, or if a licensed patent was challenged in court and determined to infringe on a pre-existing patent owned by a rival firm. However, many universities, especially those owned by the states, are unable to offer such indemnification. Virginia, for example, prohibits its public universities from offering indemnity to any party to a contract. On occasion, firms will choose not to sign a research contract or license agreement unless it contains an indemnity clause, with the result that a successful deal is not reached.without such a clause.

Another issue that can arise is the use of the name of the university by the company sponsor, or vice versa. A firm may wish to advertise widely that its product is based on research done at a particular university in order to benefit from the university's reputation. The reverse can also occur. As a rule, university-industry contracts include provisions that require written approval before the name of the partner institution can be used in advertising or otherwise by the other party.

Support of research at a university by any external party inevitably raises questions about whether such sponsorship might compromise the ability of the university to adopt a neutral, critical stance toward the world around it. If, for example, a large corporation is supporting a very large research contract, it seems likely that those who are responsible for the contract, as well as administrators who may benefit from the additional financial support and prestige, will seek to thwart anyone else in the university community who speaks critically of the sponsor or of the particular arrangement to support research. (See Chapter 4 for a discussion of such cases.) For some faculty, this conflict seems so great that they actively work to limit acceptance of external funds. Other faculty revel in the additional resources. The potential for such institutional inhibitions is yet another reason that quality institutions insist on full disclosure of external sponsors of research.

Even more serious a conflict can arise when the university as an institution develops a conflict of interest arising from its financial investment in a technology spun-off from the university. For example, university faculty may make a pharmaceutical invention that becomes the basis for a start-up company in which the university elects to take an equity position. If, subsequently, the university's medical school carries out clinical studies of the safety or efficacy of the proposed new drug, great pressure may arise to make sure that the studies come to a positive conclusion. In the U.S. at present, discussions are going on about how to manage such "institutional conflicts of interest," especially where human lives and well-being may be at stake.

3.2 Issues in University-Based Technology Transfer and Commercialization

3.2.1 *The Context – University Ownership of Patents*

As discussed elsewhere in this report, university performers of federally funded research are permitted under Bayh-Dole to elect to hold title to inventions made using those funds. Bayh-Dole also requires the university to share the proceeds of any licensing agreement with the inventors. And, it requires faculty inventors to disclose their federally funded inventions to the university, as well as the university to disclose its inventions to the funding agency.

In what follows, it is important to keep in mind that the determination of who qualifies as inventor, and is thus entitled to have his or her name listed on the patent as an inventor, is made pursuant to federal patent law and the courts. Universities have no authority or discretion to make policy decisions about who is listed as an inventor or to agree in research contract agreements to decide who is an inventor, nor do sponsors have any right to affect who is listed as an inventor. Both parties may make policy and enter into contracts regarding the ultimate disposition of the patent and of any income that arises from it, but they may not make contractual agreements about inventorship. In fact, any attempt to influence the identification of the actual inventors of a patented invention may lead the courts to invalidate the patent if it is challenged.

In addition to the federal Bayh-Dole provisions, some public universities operate under state laws that also affect the ownership of intellectual property. In Virginia, for example, public universities own any invention made with "substantial use" of state resources by its employees. Furthermore, in Virginia federal and private funds "become" state resources as soon as they are committed to any state institution, including a public university. This is interpreted to mean that even money given to the university by a private company under a contract becomes state money when spent by the university and, therefore, counts as part of the "substantial use" of state resources under this policy.

Except under certain limited circumstances, Bayh-Dole does not permit universities to assign title to (i.e., to give or sell ownership of) federally-funded inventions to private parties. And, state laws may also not permit such assignment of ownership. In Virginia, for example, public universities may assign title to inventions to private parties only if the state governor personally approves the transfer, and no such approval has ever been given. In certain limited circumstances, Virginia universities may assign such title to non-profit organizations if they are established for the sole benefit of the university.

3.2.2. *Treatment of Patent Ownership Under Industrial R&D Support*

Companies that support research at universities often ask as a matter of course that any intellectual property be assigned to the company in return for the financial support of the research. Even when universities have authority to assign patent ownership to sponsors, however, it is not clear that firms actually need to have such ownership to protect their financial interest in the property or that such ownership transfer is in the best interests of the university or the public. Rather than transferring ownership to the sponsoring company, most universities prefer to enter into a licensing agreement that gives the licensee all the effective powers of ownership without transferring the actual ownership.

Universities maintain this posture because they believe it is in the interests of both the university and the general public to do so. For example, universities need to be able to continue to carry out research in fields for which they have licensed technologies to companies. And, if a licensee decides to withhold the invention from the market, universities typically want to be able to license the technology to another firm that will market it. Furthermore, universities may enhance the utility of an invention by licensing it to different companies for entirely different uses. None of these outcomes are possible unless the university retains the ownership right.

As noted above, if the ultimate source of the research funds is a government contract to an industrial prime contractor which, in turn, subcontracts with a university to conduct some of the research, it is probably the case as a matter of law that the university has a right to own resulting intellectual property. However, since Bayh-Dole does not generally apply to large firms[27], the prime contractor in many cases does not have any right of ownership. Hence, prime contracts often incorporate clauses that give the ownership rights to the federal government, and frequently the prime contractor "flows down" these clauses to its university subcontractor. Universities thus are often left in a position of having to ask the prime contractor to seek removal of the offending

[27] As mentioned previously, Bayh-Dole-like provisions were extended to large firms via Executive Order. But since an Executive Order cannot override existing legislation, and since some agencies had law in place which would not allow large firms to own patents, it is still the case that Bayh-Dole does not pertain to large firms in all cases.

clauses after the prime contract is signed. For this reason, universities ask--but don't often get--an opportunity to be involved in negotiating the terms of the prime contract so as to "protect their Bayh-Dole rights."

When the source of the funds is the firm, negotiation over intellectual property rights can be very challenging. Universities typically seek to offer, in place of ownership, a set of contract provisions that will give the industrial supporter all of the legal tools it needs to protect the intellectual property. This begins with offering the firm the option to sign an exclusive license to commercialize the technology. (If the firm declines that option or the license, the university is then usually free to negotiate with other potential licensees.) Such a license may apply to all uses, or only to a certain "field of use" of the patent. It may or may not include provisions allowing the firm to sublicense the technology, with or without provisions to share sublicense income with the university. If the license is exclusive only in a field of use, the university is usually free to license it to other firms for use in other fields, sometimes with provisions for sharing the income with the original supporter of the research.

3.2.3 *University Management of Technology Transfer and Commercialization*

During the two decades since the passage of Bayh-Dole, most research universities have created offices staffed to manage their intellectual property. Staff train faculty in how to disclose inventions and obtain patent protection, prosecute patents before the U.S. Patent and Trademark Office, find potential licensees, negotiate deals and monitor licensees to ensure compliance with license terms. The position of "technology transfer officer" or "licensing manager" has spread throughout academia. These offices are usually referred to as the Technology Transfer Office, the Patent Office or the IP Office. While such offices draw on legal advice, they are usually staffed primarily by persons skilled at recognizing and marketing inventions and able to work effectively with both industry and faculty.

University inventors typically have an affirmative duty, at least when supported by federal funds, to disclose their inventions to the university technology transfer office. The universities has the option to take ownership of the invention and to seek patent protection for it. If it decides not to pursue patent protection, the university is required under Bayh-Dole to return ownership of the invention to the inventor, who then has the option to pursue a patent. If neither the university nor the inventor seeks patent protection, the government can excercise the right to seek such protection in its name.

In practice, however, invention disclosure depends on the voluntary and affirmative action by faculty, student or staff inventors. University administrators have very limited capability to discover inventions not recognized or disclosed by their personnel.

To provide incentives to make and disclose inventions, universities offer financial incentives in the form of income sharing policies with inventors. For example, inventors may have a right to, say, half of the net income received from a licensed invention, net of the direct costs of patent protection. This income goes directly to the inventor individually, rather than to a university account that the inventor controls, sothe incentive to invent and disclose is very personal. In addition, the inventor's department or school may be entitled to a portion of the university's net income, and part of it may be returned to help support additional research.

3.2.4 *The Question of Start-Ups vs. Licensing to Established Firms*

Traditionally, universities have licensed their inventions to established firms, in return for a package of financial rewards, including assistance with paying patenting expenses, an up-front licensing fee, and running royalties proportional to net sales or some other measure of commercial use of the invention. Some such arrangements also include a commitment by the licensing firm to support more research in the inventor's laboratory. (Note that inventors do not have a right to share in income that comes to the university in the form of a sponsored research support agreement.) It is this form of technology commercialization that is responsible for most of the income reported in Chapter 2.

In recent years, however, as entrepreneurial small firms have become more popular, universities have increasingly turned to licensing their technologies to small firms or even to start-up firms built around the technology. Because such firms are usually undercapitalized and depend heavily on venture capital or angel investor funding, they can't afford to pay up-front fees or large running royalties. However, they offer the promise of earning large returns in the future if their product is a market success, if they are bought out by a larger firm, or if they make a successful initial public offering in the equity market.

Technology licenses to start-ups usually include a small up-front cash payment, along with transfer of some part of the equity interest in the firm to the university. The university then holds that equity for some period of time, depending on the circumstances. If the firm is successful, the university shares in the financial success. If the firm fails, the university gains nothing from its investment.

In a few cases, universities provide not only the technology in return for equity, but also cash in return for additional equity. The source of this cash is usually money earned from endowment income or from prior technology transfer deals.

A critical question for a start-up is to determine the role of the inventor. In some cases, the inventor is the logical choice as the chief executive officer of the company. On the other hand, the inventor may have no interest or experience in leading a company, and investors may elect to bring in an outside management while the inventor serves as a scientific consultant or continues to provide research in return for a sponsored agreement.

Not all university inventions lend themselves to the formation of a new company. Various criteria are relevant to determining whether to license to an established firm or to build a new firm. An important criterion comes from the nature of the technology itself. If the invention can be used directly as the foundation for a new product in a new market, a start up may be the right approach. If, on the other hand, the invention provides a better way to build a complex system such as a telecommunications network, an airplane, or a nuclear submarine, it may better be exploited by being licensed to an existing firm in the business. Similarly, a start up may not be effective if taking the product to market will require substantial investment in non-research activities such as manufacturing and marketing. Deciding which approach to take is essentially a business judgment.

3.2.5 *Other Intellectual Property — Copyrights, Software and Data*

While it is beyond the scope of this paper to comment on copyright management, it is useful to note that software can pose especially difficult intellectual property management challenges to universities and companies, because the same piece of software may be protectable both by patents (for the ideas on which it is built) and by copyright (for the expression of the idea as software code.) At many universities, copyrights are traditionally owned and exploited by the author, while patented inventions are owned and exploited by the university. The same software "property" may, thus, be owned by both the inventor and the university, yet both must agree in order to effect a commercialization deal. Or, the idea may lead to a patent in the name of the inventor-faculty member, while the software code copyright may be owned by students who actually wrote the code. Perhaps the best way to deal with this is to treat the software authorship as a "work for hire" under copyright law, with the ownership devolving to the university, but doing this requires an explicit rewrite of most universities' policies on copyright ownership.

Research data pose new challenges. At the moment, the United States has no statutory law creating a recognized property right in data bases. In fact, the Supreme Court has ruled that the data in data bases may not be copyrighted; only their specific expression can be copyrighted. Thus, the only recourse for both firms and universities is to protect their interests in data by establishing trade secrets around them; in other words, by not letting anyone see them except under the terms of a private contract, or license. Europe has adopted legislation creating intellectual property rights in data, which has not been adopted in the United States. The issue of data ownership has become critical in connection with the huge volumes of data generated in research projects involving gene sequence or protein structure data. There is a market for such data created by pharmaceutical companies who find that it yields valuable clues to drug development.

3.3 Conflicting Critiques of University-Industry Patent and Licensing Agreements

At present, universities are caught between two conflicting critiques of their practices regarding management of intellectual property licenses to industry.

On one side are critics from industry who believe that the university insistence on owing intellectual property that arises from industry or government-supported research is incorrect. Typically, firms argue that they should be given full ownership rights to a licensed invention, either because they paid for the research or they need the rights to fully protect the invention and subsequent commercialization investments. Of course, firms making such arguments assume that the ownership rights in question will belong to them, not to other firms. Left unsaid, usually, is what process universities should use to decide which firm should get the ownership rights. What is clear is that such firms do not believe that university inventions should be put in the public domain for all to use.

At the other extreme are critics who argue that universities should put their inventions in the public domain for free use by any and all. For example, the "open source" software movement is premised on full publication of the source code of software inventions on the grounds that others will make free contributions to the rapid improvement of the software. Some students of the technology transfer process argue that the present system leads to such high frustration on the part of industry that universities would benefit more by giving patents to industry than by asking for royalty payments and fees. Their argument is that firms will, in the long run, make charitable contributions to universities whose technologies they exploit that will far exceed the income that might arise from royalties. These critics suggest that university insistence on patent ownership is a source of real tensions between universities and industry that diminish any inclination of licensees to make contributions to the university.

At present, neither of the critiques has won enough converts to offset university interests in the present system. However, some industrial interests are at this writing circulating proposed changes in the Bayh-Dole Act that would give research funding agencies greater flexibility in assigning patent ownership rights to parties other than the performers of the research. Universities and small businesses are expected to oppose such changes in Bayh-Dole if they are introduced in Congress.

3.4 Issues in Faculty Consulting

Most American universities allow, and many encourage, their faculty members to consult for industry, government or other outside parties. The standard arrangement is that the faculty member may consult for "one day per week." Universities differ greatly in whether they require faculty to disclose such engagements and what to disclose, whether the faculty member needs permission to consult in each case, and what sort of reporting is required.

Most universities have some sort of requirement for disclosure of outside financial interests, including consulting. Such disclosure is usually made confidentially to a supervisor. The identity of the client may be held in confidence, as well. Some universities require disclosure of the amount of consulting income; others do not ask for this information. Requiring prior approval is a bit complicated. Some institutions avoid giving prior approval so as not to be put in the position of having gone in record in support of any particular consulting arrangement.

When consulting is done with a firm that also supports research in the consultant's laboratory or that is based on a license of an invention made by the consultant at the university, conflicts of interest and commitment nearly always arise. Some such conflicts are outright prohibited. Others are permitted but only if they are disclosed to university authorities.

3.5 Concluding Remarks

University-industry relations in research and technology transfer and commercialization are complex and rapidly changing. The reader will have noted the repeated use in this chapter of such words as "typically," "most," "often," and others intended to signal that there is no fixed practice across universities for such relationships. This chapter has tried to capture the mainstream practice, but many divergences exist.

In addition, each specific sponsorship or license agreement poses its own set of facts, challenges, and constraints. Standardized approaches are not typically successful. Every "deal" requires a new negotiation and a new a set of judgments and decisions by both the university and the companies involved. This means that setting up such deals requires a lot of time and involves high transactions costs. So far, no way has been found to obviate the expense or the senior administrative time required to put such arrangements into effect.

The landscape is made even more complex by the fact that different rules apply depending on whether the source of funds is the government or a company, on whether a grant or contract is to be used, and whether a start up or established firm would provide the best pathway toward commercialization.

Complexity is the watchword of university-industry relationships in research and technology transfer.

4. SUCCESSES AND FAILURES IN U.S. UNIVERSITY-INDUSTRY RELATIONSHIPS

This chapter reviews successes and problems in university-industry technology relationships in the United States. It examines three topics:

- How do Americans define "success" in university-industry partnerships, how do they measure that success, and in general have the increasing number of university-industry relationships in recent years been seen as successful?
- What are some major case studies of university-industry relationships – both research partnerships and licenses of university inventions?
- Based on these case studies and other analyses, what "best practices" can universities and companies follow to create successful university-industry relationships and to repair collaborations that have encountered problems? What factors appear to make for success or failure?

4.1 Defining and Measuring "Success" in University-Industry Relationships

In the United States, different organizations and groups may have different definitions and measures of "what constitutes success" in university-industry relations. This is an important point, because it means that no single definition of "success" exists.

As Chapter 2 discussed, university-industry relations within the United States have grown enormously over the past 20 years – including more industry funding of university research ("sponsored research") and more licenses of existing university patents both to established firms and to entrepreneurial companies.

How do different people within the United States view these developments? This section of the report looks at five groups – companies, university administrators, university faculty, state and regional leaders, and national leaders and groups. For each of these five groups we will ask the following three questions:

- What goals do they have for university-industry relations? That is, how do they define "success"? And what metrics do they use to judge whether an individual university-industry project or university-industry relationships in general are meeting these goals?
- What are some of the economic and social circumstances in the United States today that affect whether it is hard or easy to achieve those goals?
- In general, is each group getting what it would like out this new generation of university-industry relationships? That is, are the overall results a success

4.1.1 How Do U.S. Companies Define and Measure Success?

Companies define the success of university-industry partnerships in terms of how much these collaborations contribute to new products, revenues, and profits. But within this general definition, different companies may have different objectives in mind. A 1995 report by the Industrial Research Institute – a U.S. industry association – identified the following motives for industry to pursue cooperative research agreements or licenses with universities:

- To access expertise not available in corporate laboratories.
- To aid in the renewal and expansion of a company's technology.
- To gain access to students as potential employees.
- To use the university as a means of facilitating the expansion of external contacts for the industrial laboratory.
- To expand pre-competitive research, both with universities and other companies.

- To leverage internal research capabilities.[28]

A company will apply metrics for each of the categories above that are relevant to its needs, and it will judge both individual projects with universities and the totality of its university relationships according to those metrics. For example:

- The value of results from collaborative research will be measured in terms of whether the expected research is delivered within the time agreed to.
- The success of efforts to gain access to good students will be measured in terms of the number recent graduates hired by the firm.

Are these objectives realistic, given what American universities can actually deliver and given other economic and social circumstances in the United States? Some key observations include:

- U.S. universities do in fact have many top researchers who can help companies with research problems. The combination of large government R&D funding, high competition among professors for research funding, and an ability to recruit top researchers from all over the world has made U.S. universities very good at research.
- The Bayh-Dole Act of 1980[29] provides a good way for universities to license existing inventions to either established companies or new startups.
- Today, America's university culture favors closer ties with industry. For example, university administrators now seek more money from industry. But top professors have also changed. U.S. professors have long been "entrepreneurial" in the sense that they must take the initiative and compete for federal and private research funding, but for

[28] Industrial Research Institute, *A Report on Enhancing Industry-University Cooperative Research Agreements*, Washington, DC, 1995, page 1. The IRI paper is cited on page 22 of another report: Business-Higher Education Forum, *Working Together, Creating Knowledge: The University-Industry Research Collaboration Initiative*, Washington, DC, 2001. The Forum's report is available at http://www.acenet.edu/bookstore/pdf/working-together.pdf

[29] "Bayh-Dole" is the informal name for this law, named after the two U.S. Senators who sponsored the legislation, Birch Bayh and Bob Dole. The official title of the law is the Patent and Trademark Amendments of 1980, U.S. Public Law 96-517.

many years university scientists and even some engineers preferred to accept government money and did not respect their colleagues who became involved in business. In this so-called "ivory tower" culture, most university professors wanted to be "pure" researchers. However, in recent years the university culture has largely changed. Today, professors who become corporate entrepreneurs or otherwise become involved in the business world are often seen as people to praise and emulate.

- Industry recognizes that the missions and capabilities of companies and universities differ greatly. For example, universities are very good at basic research but rarely at product development; university research proceeds more slowly than most corporate R&D; university departments traditionally have not worked well together on interdisciplinary problems of importance to industry (although this appears to be changing); and universities want open publication while companies want confidentiality.

- Research results and licensed technologies from universities will not be helpful to companies unless those companies develop groups and procedures for placing these new technologies into the company's business units and products.

Chapter 2 shows how the volume of university-industry relationships – sponsored research, technology licenses, etc. – has grown enormously in recent years. But do American companies now believe that the existing magnitude and types of university-industry partnerships meet their needs? Given the social and economic circumstances listed above, are these relationships successful from industry's point of view?

There is no single opinion on this question, because companies and industries differ, and U.S. industrial trade associations have not offered a single "official" statement about the benefits of university-industry relationships. However, industry leaders do often mention several key points:

- Individual projects with universities are of course judged in terms of how well they meet corporate objectives such as delivering valuable new technologies, helping a company recruit good students, and expanding a company's contacts with helpful engineers and scientists.

- Today, many large, established U.S. companies in industries such as information technology and chemicals rely on university research to fill in gaps in their own corporate R&D – gaps that exist either because budget pressures have cut the size of corporate labs or because even large companies now have difficulty keeping up with the full range of technologies that may affect their business. These firms "outsource" much of their R&D – that is, give contracts to universities or other organizations to perform research that might once have been performed within a corporate laboratory. Often, companies will seek to work with a few research professors ("strategic partners") with whom they have long-term relationships.[30]

- Large, established firms may also join multi-company university centers when they are interested in certain general research questions or want to create a group of professors and students who are skilled in the firms' particular industry. Examples include California Institutes for Science and Innovation, four large university-industry consortia established at University of California campuses.[31]

- Companies want to work with major U.S. universities because those universities have professors who are among the world's best researchers. The U.S. Government funds professors according to their research quality, not their seniority, and the richest universities compete to get the best professors. As a result, companies often want to work with professors in major American universities.

- Another group of companies with close ties to academic research are firms started by university professors or graduate students. In some

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[30] We must be careful, however, not to exaggerate the amount of corporate R&D money flowing to U.S. universities. The research that companies fund in academia may be valuable, but even in recent years industry has given very little of its overall R&D funding to universities. Industry's contribution to academia represented an estimated 1.3 percent of all U.S. industry-funded R&D in 1998. The U.S. National Science foundation provides this summary: "Thus, although increasing recently, industrial funding of academic R&D has never been a major component of industry-funded R&D." These data and the quote come from National Science Board, *Science and Engineering Indicators 2000*, Washington, DC: National Science Foundation, 2000, Volume 1, page 6-9. Both volumes of *Indicators 2000* are available at http://www.nsf.gov/sbe/srs/seind00/start.htm

[31] The State of California and a wide range of companies now support four of these institutes, all based at campuses of the University of California (UC): (i) the Institute for Bioengineering, Biotechnology, and Quantitative Biomedical Research (UC San Francisco, UC Berkeley, and UC Santa Cruz); (ii) the California Institute for Telecommunications and Information Technology (UC San Diego, UC Irvine); (iii) the California Nanosystems Institute (UC Los Angeles, UC Santa Barbara); and (iv) the Center for Information Technology Research in the Interest of Society (UC Berkeley, UC Santa Cruz, UC Davis, UC Merced). For additional information, see http://www.ucop.edu/california-institutes/welcome.html

cases, a university will license a technology to the professor who invented that technology, helping the professor to start a company.

- The ability to license university patents is very important to some industries, especially in biotechnology because strong patent protection is needed before a company can persuade investors to fund the 10 or more years it takes to bring a new drug or medical diagnostic tool to market. Of course, Bayh-Dole and licenses of university technology are not, by themselves, enough to create the U.S. biotechnology industry; entrepreneurial professors, venture capital, institutions helpful to entrepreneurs, and market opportunities also play major roles.

- The rise of entrepreneurial companies in biotechnology and information technology (IT) has made the contributions of universities to U.S. industry more complex in some interesting ways. For example, some biotechnology leaders argue that today universities make discoveries, that biotechnology startup firms take the risk of trying to turn those discoveries into successful new drugs and diagnostic tests, and that large pharmaceutical firms benefit primarily not through direct investments in universities (although some direct investments do occur) but by buying or marketing drugs from biotech firms helped by universities. So the principal contribution of universities to large U.S. pharmaceutical companies may be important but indirect. Similarly, some large IT companies such as Cisco Systems now acquire most of their new technology by buying successful startup firms – some of which come out of universities and some of which do not.

- Many U.S. companies also have complaints about universities. Companies outside of biotechnology particularly complain about university technology licensing offices. First, they say, many universities insist on keeping the patent rights even to inventions financed with corporate money. (Bayh-Dole deals only with inventions a university creates with federal funds.) Second, universities often insist that companies not only pay for research but also pay royalties on any new inventions produced during that research. Third, these negotiations over intellectual property can take a long time – something that companies dislike, given their need to introduce new products quickly.

- In particular, information technology companies complain about university technology licensing offices. IT companies sometimes patent their own corporate inventions, but mostly to have patents that they can use in cross-licensing negotiations with other companies. In general, U.S. IT companies consider most university patents of little value: by the time the U.S. Patent and Trademark Office issues a patent, the technology has already changed. These companies argue that university technology licensing offices delay projects and drive up costs by insisting that research be patented and royalties be paid.

- Many entrepreneurs and venture capitalists in fields outside of biotechnology and other biomedical fields also complain that universities have unrealistic expectations about how much royalty money university licenses should produce. A university invention and the academic researchers behind it are very important in many new companies, but by the time those companies sell products many other people and organizations have made major contributions of money and talent. The university inventions are vital but small pieces of the overall companies, and these firms see university demands for large royalties as wrong.

- Companies and universities sometimes fight over two other issues that are more complex, and both sides have reasonable positions. One issue is so-called "indirect costs," the money a company pays in addition to research funding to help pay for the universities buildings, utility costs, and other infrastructure expenses. Companies want to pay little, but universities argue that they need some payments to cover their infrastructure costs.

- Second, companies that want patent licenses also frequently want licenses to "background" intellectual property – other inventions the university has produced that may be necessary in order to make new products. Companies feel they need access to these background patents, but universities frequently object to the cost of investigating what patents are necessary.

- American-based multinational corporations increasingly say that they will sponsor research at the most "friendly" universities around the world. In short, if American universities demand too much royalty money or cause other problems, then the U.S. companies will go to universities in other countries. This is particularly true in industries where universities in other countries have high competence, such as the chemical industry.[32]

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[32] For a discussion of the chemical industry, see Chemical Sciences Roundtable, *Research Teams and Partnerships: Trends in the Chemical Sciences*, Washington, DC: National Academy Press, 1999. See in particular the comments of John C. Tao of Air Products and Chemicals, Inc. and William Wakeman, Imperial College of Science, Technology, and Medicine, London.

- Christopher Hill (one of the authors of this report) and his team of policy researchers at George Mason University have recently investigated the types of university engineering research that U.S. companies are and are not willing to fund. He and his team have focused on company funding for the engineering research centers that the U.S. National Science Foundation and industry jointly finance. His group finds that companies are most willing to fund work that will likely help them soon with products they already make. Companies are less likely to fund research that is more long-term and in areas less related to current products. This result suggests that government funding continues to be very important for new research in important new technologies whose benefits are longer term and more unpredictable.[33]

4.1.2 *How Do U.S. University Administrators Define and Measure Success?*

In the words of the Business-Higher Education Forum report cited earlier, "For universities, working with companies allows them to gain access to external sources of expertise and funding." The report then goes on to quote the 1995 Industrial Research Institute report, also previously cited. The IRI document identifies these motives for why university administrators enter into cooperative research agreements with companies:

- To obtain financial support for the university's educational and research mission.
- To fulfill the university's service mission.
- To broaden the experience of students and faculty.
- To identify significant, interesting, and relevant problems.
- To enhance regional economic development.

[33] Christopher T. Hill, Jonathan Tucker, Franco Furger, and Christina Pommerening, "Factors Influencing Industry Support of Cooperative Research at Universities," School of Public Policy, George Mason University, a report to the National Science Foundation, forthcoming.

- To increase employment opportunities for students.[34]

However, American universities vary in how they pursue these objectives. One major reason is that the universities themselves vary greatly in size, funding, missions, and political and industrial constituencies. This is one of the key social and economic circumstances affecting U.S. schools. As a result, they define and measure success in university-industry relations in different ways. For example:

- Many of the top research universities in the United States are private institutions. Private universities such as M.I.T. and Stanford do receive large amounts of federal research funding and thus respond to federal incentives. But they do not have the same responsibilities and political pressures to help local industries as do universities supported by American state governments. They are free to work with whatever companies they want to work with.

- Many other top research universities are public institutions, and almost all public universities in the United States receive funding and instructions from state governments.[35] Examples include the large state universities in California, Wisconsin, Michigan, Massachusetts, Virginia, and many other states. The U.S. Government helped establish state universities, through laws passed in 1862 and 1895. But since then state governments have played a large role in controlling these universities. These state governments expect that their universities will help local industry through research, by educating workers, and through service activities such as agricultural extension and manufacturing extension.

- Not all universities in the United States have large federally-funded research programs. The United States has 3,600 institutions of higher education, but in 1997 200 of these institutions – the major research universities – accounted for about 95 of total U.S. academic R&D expenditures.[36] Many U.S. colleges and universities measure their success more in terms of education than research.

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[34] Business-Higher Education Forum, *Working Together, Creating Knowledge: The University-Industry Research Collaboration Initiative*, page 22.
[35] The only universities operated by the U.S. federal government are the U.S. Army, Navy, Air Force, Coast Guard, and Merchant Marine academies.
[36] National Science Board, *Science and Engineering Indicators 2000*, Volume 1, page 6-9.

- Some U.S. research universities have a reputation for being very friendly to industry. Industry sees others, including some of the best-known schools, as having top researchers but also being very difficult to work with (demanding high royalties, taking long amounts of time to negotiate agreements, etc.).

However, America's major research universities – whether private or public – also have some important characteristics in common. These characteristics include:

- These universities have high-quality researchers. The United States as a country has groups of high-quality professors – people who have succeeded in the highly competitive business of winning federal research grants and publishing in top journals – and major universities work hard to recruit and retain such people. Labor mobility is high, meaning that professors are free to take jobs at other universities and universities are free to try to hire the best people they can find. No university has world-class researchers in all fields of science and engineering, but each major research university has at least a few departments in which its people are very good. As a result, these universities have researchers that companies want to work with.

- Major research universities want to work with industry for several reasons. First, universities like the research money that companies provide and the royalty money companies sometimes pay for university licenses. Second, universities now find that many of the best professors and graduate students want to work at schools that have close ties to industry and the opportunity to help start new companies. And, third, state and regional leaders now expect public research universities to help existing industries and help create new industries. [37]

In this environment, high-tech companies often want to work with professors in the top schools – professors who are leaders in their fields and who often have federal funding that enables them to conduct very good research. And many universities want to work with industry – both by accepting corporate funds for campus research and by licensing university inventions to either large existing companies or new startup firms.

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[37] Please see section 4.2.4 of this chapter for a further discussion of what state and regional leaders now expect from public universities.

Do U.S. universities consider current university-industry relations to be successful? The general answer appears to be "yes", although some problems do exist for universities. The following points focus on two aspects of university-industry relationships – corporate funding for research within university and corporate payments for licenses of university inventions.

- Universities have succeeded in attracting increasing amounts of industrial R&D money. In 1998, industry provided an estimated seven percent of academic R&D funding – up from 2.5 percent in 1966. Seven percent is still low, but the percentage has been increasing.[38]

- Separate from corporate research funding in universities, American universities also have received amounts of royalty income from technology licenses to industry (licenses primarily but not solely given to American companies). The Association of University Technology Managers (AUTM) reports that in U.S. fiscal year 1999 190 universities belonging to AUTM reported adjusted gross licensing income of $655 million – a significant figure.[39]

- Most royalty income received by U.S. universities comes from biomedical inventions developed by a few top universities. This reflects the value of patents to the biotechnology industry. But one should note that universities without medical schools or other major biological research departments rarely make large amounts of money from technology licenses. (M.I.T. is an exception.) In fact, some universities without major biomedical research actually lose money: they receive less royalty income than their technology licensing offices cost.

- However, some universities do *not* consider the size of their royalties to be the most important measure of how the value of their collaborations with industry. For example, Caltech and some public universities would rather license a new technology either to the

[38] National Science Board, *Science and Engineering Indicators 2000*, Volume 1, page 6-9. The seven percent of total U.S. university R&D in 1998 amounted to an estimated $1.682 billion, a figure provided in Volume 2, Table 2-4 of *Science and Engineering Indicators 2000*.

[39] Association of University Technology Managers, *AUTM Licensing Survey: FY 1999, Survey Summary*, page 15. This AUTM Survey Summary is available at http://www.autm.net/surveys/99/survey99A.pdf. However, the adjusted gross license income figure quoted by AUTM does include the large costs associated with operating university technology licensing offices. The AUTM document does not provide figures on *net* licensing income – that is, the income remaining after deducting licensing expenses.

inventor or to a local company rather than receive larger royalties from a big company somewhere else in the country. These schools deliberately accept lower royalties in return for helping their faculty or the local economy. Similarly, deans and professors in some top engineering schools believe that attempts to get large royalties only alienate important companies, and that the goodwill generated by not being greedy today will lead to good relations and perhaps major financial donations in later years.

- Concern can arise when professors have financial ties to particular companies. Is their research objective and fair? This is a particular concern in the biomedical area.[40] In short, closer ties with industry – both existing firms and startups – can bring challenges as well as benefits to American universities.

- In general, university administrators welcome the money and other benefits that come from closer ties with industry. They particularly appreciate industrial money because federal research support in the physical sciences and engineering has actually declined in recent years, even as federal biomedical research funds have risen. Moreover, many state governments have reduced their support for public universities, leading administrators at these public schools to seek even closer ties to industry.

- However, the new emphasis on working with industry and encouraging faculty to start companies has created both changes and tensions within universities – tensions that are discussed in the next section of this chapter.

4.1.3 How Do University Faculty Define and Measure Success?

University administrators generally like closer ties with industry. However, the faculty – the professors – at U.S. research universities are

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[40] One particular incident illustrates this concern. In September 1999, a young man who was not terminally ill participated in a clinical trial at the University of Pennsylvania for a new gene therapy developed by a biotechnology company. The young man, Jesse Gelsinger, died during that clinical trial. Shortly after his death, newspapers reported that the professor who headed the research institute – although not the doctor running this particular clinical trial – had a financial stake in the biotechnology company. The appearance that a University of Pennsylvania official may have rushed tests of the drug because of personal financial interest led to great concern. That concern, and additional concern that a young man had died, led the National Institutes of Health to suspend all gene therapy experiments at the university until new procedures were instituted.

sometimes divided among themselves. Some favor closer ties with industry; others often criticize them. The divisions are sometimes very complicated:

- Many science and engineering faculty like opportunities to work with companies or to start their own firms. Research professors in the United States have long been "entrepreneurial" in the sense that they compete for federal research money.[41] In recent years, however, professors at many universities have also become "entrepreneurial" in seeking corporate money or even starting their own companies. Professors at a few schools such as Stanford and M.I.T. began this trend, but today even professors who once sought only government funding now compete for industrial money or start their own companies.

- However, even the professors who like to work with industry may object to some of the policies pursued by university administrators. For example, in the U.S. some computer scientists agree with information technology companies that university administrators and technology licensing offices should stop pushing aggressive patent and licensing policies that are designed to force the companies to pay high licensing fees. Such efforts simply delay agreement on projects and alienate important corporate partners.

- Other faculty critics argue that closer ties with industry cause additional harm. Companies may push professors to delay publications and restrict data, limiting the free flow of new knowledge, and exclusive licenses of university licenses may mean that only a few companies benefit from publicly-funded research. Unless precautions are taken, students working on industry-funded projects may find the companies blocking their right to publish their Ph.D. theses. And when some departments on a campus become wealthy from ties with industry, resentment can build in other departments and reduce the collegiality needed to run a successful university.

- Some professors in public universities also worry that close ties with particular companies can threaten the reputation of the university for

[41] As mentioned earlier, an very important feature of the U.S. university system is that professors must compete for federal research funding; no one is guaranteed government research funding. A research grant does *not* add much to a professor's salary; at most, it provides for a small summer salary. But a research grant enables a professor to buy equipment, hire graduate students, and perform the research that brings promotion , prestige, personal satisfaction, and sometimes business opportunities.

objectivity and fairness. (A large collaboration between the University of California at Berkeley and Novartis led to such concerns.[42])

4.1.4 How Do State Governments and Regions Define and Measure Success?

Since at least the 1980s, political leaders in state and local governments have seen research universities as important contributors to industry and regional economic growth.

In some states with older industries, such as Ohio and Pennsylvania, state governments have funded new university research programs to help those industries. California, as mentioned earlier, has now created four large university-industry research institutes to support research and training in several of that state's key high-tech industries.

But many state and regional officials and civic leaders now focus on what research universities can do to help create *new* industries and *new* regional economic clusters. They have seen how Stanford and M.I.T. helped create Silicon Valley and Boston's Route 128, and they would like their universities to play a similar role in their states and regions. These leaders measure the value of university collaboration with industry in terms of the numbers of new companies created or helped, the number of new jobs created, the size of new industrial clusters tied to universities, and the vitality of their regional and state economies.

Several features of universities and the U.S. economy are important here, and they show the good universities are helpful but, by themselves, are not enough to generate significant high-tech economic growth.

- Stanford and some other universities have indeed contributed to significant economic growth in their regions. San Diego is an example of a newer U.S. high-tech region with industries that initially spun out of the University of California campus there and other federally-funded research organizations; its new clusters are wireless

[42] The Berkeley-Novartis collaboration is discussed in greater detail later in this chapter.

telecommunications (particularly Qualcomm) and over 100 new biotechnology companies.

- Not all new industries – or old industries – are research-driven and therefore greatly affected by research universities. In industries such as automobiles and aircraft, systems engineering competence in companies is more important than the latest developments in universities. University research can help existing systems companies improve their technology, but we are unlikely to see new automobile companies or aerospace companies started by university professors.

- In fields where university professors do play a major role in starting new companies – fields such as biotechnology and electronic and optical components – the regions most likely to develop important new companies and clusters are those whose universities have the very best researchers. For example, social science research by Lynn Zucker and Michael Darby of UCLA shows that many early U.S. biotechnology companies grew up around universities that had "star scientists" – world-class biomedical researchers who understood and could apply the latest knowledge. These scientists helped start companies in their own cities.[43] Not surprisingly, the U.S. biotechnology industry is particularly strong in regions with very good biomedical researchers – San Francisco, Boston, San Diego, and Washington, DC.

- Stanford and M.I.T. have long combined world-class researchers with a strong interest in entrepreneurship and local industries. However, one irony is that other top universities that historically had little interest in either business or the local economies around them have became major sources of regional economic growth. These "ivory tower" institutions attracted world-class researchers, a few of whom become entrepreneurs in the 1970s or 1980s and helped create new industries. The University of California, San Diego is a notable example, and more recently so is Yale University. If even a few world-class researchers in top universities become entrepreneurs, they can help create important new companies

- The contribution of federal R&D funding has been enormous. Defense money, particularly by the Defense Advanced Research Projects

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[43] Lynne G. Zucker and Michael R. Darby, "Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry," in Ariel Pakes and Kenneth L. Sokoloff, editors, "National Academy of Sciences Colloquium: Science, Technology, and the Economy," an issue of *Proceedings of the National Academy of Sciences of the United States of America*, Volume 93, November 1996, pages 12709-12716.

Agency (DARPA), both funded cutting-edge technology research at top universities in information technology, materials science, and other fields, and also trained entire generations of top American researchers. In the biomedical field, the National Institutes of Health (NIH) has similarly funded cutting-edge research and trained American experts.

- In addition, government purchases of new high-tech products have also helped new entrepreneurial companies and the regions that host them. One notable example was government purchases in the 1960s and 1970s of early integrated circuits, an action that played a major role in the growth of Silicon Valley's semiconductor industry.

- However, having good universities is not enough by itself to guarantee that regions will create successful new companies and industries. One also needs entrepreneurial faculty, venture capital, supporting services such as lawyers and accountants who can help entrepreneurs, and favorable economic and industrial conditions.[44]

- Communities that have good universities but lack local venture capital and other supporting services can establish organizations that will help create these supporting services and thus help new academic entrepreneurs. Two notable examples in the United States are CONNECT in San Diego and the Kansas Technology Enterprise Corporation.[45]

- While universities can make major contributions to their regional economies, measurement of these contributions can be difficult. Many universities do not keep reliable records of the number of true spin-off companies – that is, companies truly started by university professors and graduate students or with licensed technologies. Moreover, it is difficult to measure how much new companies are the result of university technology and people as compared with the role of other factors, such as professional managers.

- New high-tech clusters assisted by universities are important in regional economies but are not necessarily large employers. Again, San Diego is an example. While the region has many new high-tech companies, many of them employ relatively small numbers of people. This is particularly true with San Diego's biotechnology companies. Few of those companies will grow into large pharmaceutical

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[44] For an important and valuable summary of these points, see Michael Porter and others, *Clusters of Innovation: Regional Foundations of U.S. Competitiveness*, Washington, DC: Council on Competitiveness, 2001. The report is available at http://www.compete.org/innovate/innovate_index.html

[45] For information on these two organizations, see http://www.connect.org and http://www.ktec.com/

manufacturers; most will provide R&D and new drugs that will be manufactured and sold by large pharmaceutical companies based in other cities and other countries.

In this economic and social environment, how successful have universities been at helping their local economies? In particular, how much have they met the metrics that state and regional leaders apply: keeping older industries technologically competitive, helping to create new companies and new industrial clusters, and helping to create new high-paying jobs?

- Some regions have been notably successful at building on university expertise, although largely because of favorable economic conditions and over a very long period of growth. Silicon Valley and Boston are two early examples. As mentioned, San Diego is a more recent example.

- Other regions have been less successful. One problem for some regions is that either the entrepreneurs themselves or the venture capitalists who support them decide to move a new company to another city within the state or even to an entirely different state. Some regions are not seen as attractive or practical places to build new companies.

- Regions that lack world-class universities and researchers may provide significant help to existing industries – a very important economic contribution. But they are unlikely to create competitive companies in new research-based industries such as biotechnology.

4.1.5 How Do the Federal Government and the Nation Define and Measure Success?

Finally, how do U.S. Government leaders and others concerned about the nation define and measure success in university-industry relations? Three objectives seem particularly important:

- Are university-industry relationships and the government policies that help shape them (such as Bayh-Dole) helping U.S. national economic growth and vitality?

- Are these relationships helping to speed the development of new products and services that Americans want, ranging for new medicines to improved communications to new defense technologies?

- Are the current relationships and the federal policies associated with them also good for the long-term prosperity and welfare of the nation? That is, is the current pattern something we want to continue in the future?

These are very large questions, and this chapter cannot comment on every aspect of them. But a few observations may be helpful:

- By any measure, university research has helped create major new high-tech industries in the United States and continues to help important older industries, such as the chemical sector. America's leadership in information technology and biotechnology, for example, stems in large part from federally-funded inventions and discoveries from American universities and from the ability of U.S. universities to train generations of top researchers. The economic benefits to the United States of leadership in these research-driven industries have been enormous, despite the recent recession: many new jobs, additional tax revenues, an improved balance-of-payments in world trade, and, not least, information technologies that have contributed to significant improvements in the productivity of the entire U.S. economy.

- The benefits of past federal investments in university research (as well as important federal R&D investments in innovative companies) have led officials in Washington to fund major new programs in information technology, biomedicine, and, most recently, nanotechnology. Leaders in Congress and the White House believe that federal R&D investments – including investments in university research – will lead to major economic benefits. The fact that universities now work closely with industry – both established companies and startups – makes leaders in Washington more confident that funds for university research will lead to real economic benefits.

- The social benefits are also huge. The Internet and other information technologies have improved communications. Biotechnology companies are beginning to make major contributions to American health.

- At the same time, concern exists among some national experts about a possible imbalance between help for companies versus the free flow of government-funded knowledge. Some suggest that the rush to "privatize" publicly-funded university research has reduced the free flow of knowledge and thus may actually limit, not help, long-term economic and social benefits.[46]

- A large problem from a U.S. national point of view is that universities in general are not attracting and training large numbers of American-born Ph.D. engineers and scientists. This problem does not exist because U.S. universities now have closer ties to industry, but current university-industry relations in the United States have done little to help the situation.[47] American companies have expressed increasing concern about this problem, but some believe that they have not done much to increase the supply of American-born scientists and engineers. However, U.S. universities continue to attract many students from other countries, some of whom remain in America and work for American companies.

4.2 Brief Case Studies of Successful University-Industry Relationships

The recent report by the U.S. Business-Higher Education Forum presents very useful analyses of four important, and generally successful, university-industry projects.[48] The four are:

4.2.1. *Washington University-Monsanto*

The Forum's report summarizes this relationship:

> One of the oldest and most successful university-industry collaborations is the 20-year pact between Monsanto Corporation … and Washington University in St. Louis. Since 1981, this agreement has

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[46] See, for example, David C. Mowery, Richard R. Nelson, Bhaven N. Sampat, and Arvids A. Ziedonis, "The Effects of the Bayh-Dole Act on U.S. University Research and Technology Transfer," in Lewis M. Branscomb, Fumio Kodama, and Richard Florida, editors, *Industrializing Knowledge: University-Industry Linkages in Japan and the United States*, Cambridge, Massachusetts: The MIT Press, 1999, especially pages 299-301.

[47] There are some are some cases in which an industry will invest in universities largely for the purpose of training more engineers and scientists, including native-born as well as foreign-born students. The Semiconductor Research Corporation (SRC), which funds research and training in U.S. universities, is an example.

[48] *Working Together, Creating Knowledge: The University-Industry Research Collaboration Initiative*, cited earlier in this report. For additional information on these four cases, please see the Forum's report.

> provided the Washington University Medical School with more than $100 million in research funding, produced 180 to 190 patents, and even fostered some personnel trades [between the university and Monsanto].[49]

According to the Forum, several factors helped make this collaboration a success: close communication between leaders of Monsanto and Washington University, efforts to involve both academic researchers and company researchers in the design and agenda for the collaboration, openness about the purpose and nature of the agreement, a decision by the Medical School that no single corporation should fund more than five percent of the school's research budget (which reduces concerns that the university is too close to Monsanto), a competitive process to select which researchers get funding from the project, and outside scientists who review the quality of the research.

Both sides also receive tangible benefits. The university gets funding and insight into important industry research problems. The company gets several benefits that do not compromise the university culture, such at the right of first refusal to license and develop any discovery, seminars to exchange information, and an agreement not to release information until it is published or patented. Clearly discussing goals is vital; since companies and universities have different goals, they must communicate with each other and find benefits acceptable to each side.

4.2.2 Biolex, Inc. and Ribozyme Pharmaceuticals

The Forum's report cites these cases as successful examples of university professors and licenses helping to establish new biotechnology companies.[50]

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[49] *Working Together, Creating Knowledge: The University-Industry Research Collaboration Initiative*, page 32.

[50] *Working Together, Creating Knowledge: The University-Industry Research Collaboration Initiative*, pages 68-69 and 93-94.

Biolex was started by North Carolina State University plant molecular biologist Anne-Marie Stomp. It became that university's first biotechnology spin-off company. In 1995, Dr. Stomp invented a process to genetically engineer a plant that could help clean wastewater. The university patented the process and then gave Biolex, Dr. Stomp's startup company, an exclusive license. After licensing the technology, Dr. Stomp did several things that helped make her new company a success: she spent a year developing her business plan and applying for venture capital funding, she and her investors negotiated an agreement by which Biolex would contract with her own university laboratory to develop the technology further, and she had the sense to become vice president for R&D and hire professional business managers to run the company.

In the second case, the head of a new company, Ribozyme Pharmaceuticals, offered a $500,000 grant to the University of Colorado in return for an exclusive option to license any ribozyme-related invention made at the university – whether or not that company's funding was involved. The investment was an intelligent one, given that the University of Colorado had a Nobel Prize-winning ribozyme researcher, Tom Cech. The company licensed key inventions and also developed friendly ties with university researchers. The resulting collaborations helped the company succeed.

4.2.3 Berkeley-Novartis

In November 1998, Novartis (later Syngenta) agreed to a very large research and licensing collaboration with the Department of Plant and Microbial Biology at the University of California, Berkeley.[51] The fact that a major department at a public university had signed a large agreement with a single company ignited great opposition on the Berkeley campus. Ultimately, some

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[51] The following summary of this case study draws upon both *Working Together, Creating Knowledge: The University-Industry Research Collaboration Initiative*, pages 44-45, and the personal knowledge of the Technology Policy International's principals.

timely efforts to improve the deal led to its approval by the campus' Academic Senate.

The plant department actually initiated discussions with industry. It lacked the money to build new laboratories and take other steps necessary to remain world-class. Novartis offered the proposal that the department liked best. Novartis would offer $25 million over five years, and in return would get an option for an exclusive license on about 30 percent of the department's entire research discoveries – including those funded by U.S. taxpayers.

Two aspects of the proposed deal led to major controversy on the Berkeley campus. First, as the Forum report says, "Even some advocates of university-industry scientific collaborations were uneasy about buying access to the research output of a whole college department." This became particularly sensitive since Berkeley is a public university, not a private one, and since the University of California has major responsibilities to help the state's agricultural industry – a group whose economic interests might conflict with those of Novartis. Second, the process that led to the proposed deal was secretive, and many professors outside the department felt that both advocates and the campus administration did a poor job of dealing with concerns about the project.

The Berkeley-Novartis deal quickly became an example of a proposed collaboration in trouble. In some other collaborations, trouble stems from problems in the research itself, a problem best remedied by both sides focusing on exactly what they expect to accomplish and what steps are needed. In the Berkeley case, however, the difficulty stemmed from criticisms raised by people outside of the proposed research collaboration itself. It stemmed from others in the university who felt this type of very large, almost exclusive agreement had no place in a public university.

In the end, the Berkeley Academic Senate – the campus' governing body – did approve the proposed collaboration. University administration offered to make the collaboration an "experiment," and members of the Academic Senate countered with a proposal to require a large, high-quality outside evaluation of this "experiment." The administration agreed, and the collaboration went forward.

The Berkeley-Novartis case suggests that the people designing university-industry partnerships pay attention to important campus groups and obtain their support.

4.3 Best Practices for Creating and Operating Successful University-Industry Relationships

Three steps appear necessary in order to create, operate, and utilize successful university-industry partnerships:

- The university must have effective internal policies for negotiating and operating collaborations with industry. Chapter 3 discussed the major issues that arise, including how to manage conflicts of interest and commitment, the need to find a balance between a university's desire for openness and a company's desire for confidentiality, the need to protect students, and the need to coordinate the various offices in the university that deal with companies. Nothing more on this subject will be said in this chapter.

- For a collaboration to bring real value to a company, not only must the collaboration be a good one. In addition, the company must establish internal processes for using the technology or people obtained through the partnership. This is a matter of company policy, not university-industry relations, and will not be discussed in detail in this chapter.

- However, the third step is to ensure that the university-industry project itself is a successful one – whether it be a research collaboration or a technology license. The case studies cited above and other analyses do suggest important guidelines – suggested "best practices" – for the design and operation of university-industry relationships.

4.3.1 Best Practices for Collaborative Research within Universities

In a 1999 presentation, John Tao of Air Products and Chemicals, Inc. provided a concise list of major factors that lead to a good university-industry research collaboration. He cited the following factors:

- A good historical relationship between people in the company and people in the university.
- Complementary and overlapping strengths in core technologies.
- Clear goals and roles.
- Good teamwork.
- Good communication.
- Good science (and a mutual commitment to good research).
- Mutually beneficial (each side shares success and failure and has an incentive to work for success).
- Intellectual property ownership is agreed to.[52]

The Business-Higher Education Forum's recent report also offers some valuable insights about what leads to successful university-industry research projects. The following comments are quotes from the report:

> Most university and industry research coordinators share an understanding of what type of research is mutually beneficial. It should be ethical, publishable, basic or slightly applied, and it should pair the expertise of the university with the interests of the company. (page 84)
>
> Smaller companies tend to view somewhat applied research as appropriate for university collaborations…. Large, technology-driven

[52] John C. Tao, "Building Industry-University Research Partnerships: Corporate Perspective," in Chemical Sciences Roundtable, *Research Teams and Partnerships: Trends in the Chemical Sciences*, Washington, DC: National Academy Press, 1999, page 62.

companies often find it cost-effective to work with universities for long-term (three to five years) complementary research projects. Short-term research needs of large companies generally do not match university goals or timeframes. (page 84)

To ensure success, a university-industry collaboration needs an "end-user champion" – someone within the sponsoring company [who] is dedicated to making the partnership work. (page 86)

Because the company collaboration manager is such a key part of the collaboration team, his or her departure can present difficult challenges. Experienced university and company officials say that frequent turnover of company project managers is the most disruptive personnel change that affects collaborative teams. (page 88)

The first and most important issue is establishing a research agenda that the company wants to support and the faculty member wants to carry out. Ideally, the project will explore a research pathway that the company perceives as an important new direction for its R&D and that the university researcher believes is a promising route for advancing a given science or technology. (page 87)

Managing a partnership requires scientists in both the university and the company to draw heavily on their team-management skills and places a premium on clear communication, openness, and forthrightness. It relies heavily on the strength of personal relationships. (page 87)

Tying university research to company schedules is essential to successful collaborations. The company, the university, and the researcher should pay close attention to any timelines before agreeing to a project. (page 88)

4.3.2 Best Practices for Licensing Existing University Technologies

Chapter 3 discussed the licensing issue, but here we can make a few additional observations:

- Exclusive licenses are particularly important in biotechnology, in order to persuade company investors that a firm will be able to make money after many years of work. However, universities may want to license biotechnology research tools on a non-exclusive basis.

- A frequent arrangement in biotechnology is for a professor's new company to license an invention developed by that very professor. In addition, the company may then want to sponsor additional research in the professor's university laboratory. Such arrangements are complex and require clear policies.

- New startup firms rarely have large amounts of cash to pay for licensing rights, and royalties are hard to negotiate when one is not even clear what the company's products will be or what other technology may go into them. As a result, some universities will take equity in the new company in exchange for an exclusive license. This kind of arrangement can be mutually beneficial but requires careful planning and prudence on the part of the university

4.4 Some Additional Observations

We conclude with a few final observations about designing, and operating, and using university-industry relationships in ways that succeed by meeting the goals of key groups.

- Different groups in society want different things from university-industry relations, and they therefore define and measure "success" in different ways. There is no single definition or set of metrics for success.

- Without high-quality research universities and world-class researchers, research collaborations between universities and companies are not likely to produce major benefits for either side. Quality is more than just a matter of funding levels. In the case of the United States, intense competition among professors for those research funds and the ability of top researchers to move from one university to another in order to find the best laboratories and resources are equally important.

- Research collaborations between large companies and universities are more likely to succeed if the conditions listed in section 4.4.1 of this chapter are met. Clear, mutually-acceptable research goals and regular personal communication appear to be particularly important. Partners in these collaborations may also need to work with other interested or concerned groups, including other groups of faculty within the university.

- In order for a university to contribute effectively to the creation of new high-tech companies and to regional economic growth, several factors must usually be present: the university must have world-class researchers in one or more technical areas, professors must want either to start or to assist new companies, the university must be flexible enough to allow professors to do that, and other conditions must be present in the region. These other conditions include: a source of financing for the new companies (in the U.S. case, this is often venture capital); supporting service industries (law firms, accountants, and others) that can help university entrepreneurs establish their firms; a local source of managers for the new companies; and some initial customers, either corporate or from the government. Good universities, alone and by themselves, cannot create new companies, new industries, and new economic growth.

5. CONCLUSIONS AND POLICY IMPLICATIONS

5.1 Observations About U.S. University-Industry Relationships

This review of patterns and lessons learned from U.S. university-industry relationships suggests the following observations about the premises on which the U.S. system functions.

Successful university-industry partnerships must satisfy diverse interests.

Successful U.S. university-industry partnerships must satisfy the industrial partners (who seek students, ideas, and intellectual property); faculty (who seek funding and research opportunities with minimal restrictions); university administrators (who seek the overall health of their educational and research institution), as well as state and federal funding agencies. If any of these parties are unsatisfied, it could lead to the failure of the university-industry relationship.

The open and competitive U.S. system encourages all parties to find solutions that accommodate the different interests.

Faculty, students, and Federal and company research funds are all mobile -- over time they can move to or away from universities based on the environment established by the university. In essence, there are markets in which:

- Companies compete with each other to get access to new ideas and students from universities.
- Universities compete with each other to attract company and government research funds, top faculty, and top students.

- Professors and researchers compete with each other for faculty positions and funding from companies, federal agencies, and foundations.

This competition guides and constrains university - industry relationships. A university whose policies with respect to industry partnerships do not compare favorably with other universities will be less able to attract industry funding. On the other hand, a university that provides too favorable terms to industry might find itself less able to attract top faculty, students, or Federal funding. This has led to a set of practices that are not uniform, but are fairly consistent across the U.S. university system.

<u>A similar set of policies, and practices have evolved at many U.S. universities to manage research partnerships with industry.</u>

These include general practices to deal with:

- conflict of interests and conflicts of commitment (disclosure of potential conflicts is key);
- indirect costs (the standard policy is to allow charging of Federally approved indirect cost rates);
- confidentiality and restrictions on publication (some delays of publication are commonly permitted); and
- ownership of inventions (universities generally own the inventions but provide preferential licensing to industry partners).

<u>Many of the details of university-industry collaboration are decided on a case-by-case basis.</u>

Although there are general practices for dealing with many of the issues in university-industry collaboration, the diversity and complexity university-industry interaction leads to many of the issues being decided on a case-by-case basis. Flexibility is important because of differences among universities, companies, technologies and industrial sectors. The details of agreements depend on many factors, including the nature of the research or technology and what each partner brings to the collaboration. For example, universities with outstanding technology and famous professors can take a tougher negotiating position with respect to industry than universities that have less to offer or are trying to build a relationship with a particular industry. Patents appear to have much greater value in the biotechnology and medical technologies than in most other areas of technology, and universities and companies need to be able to negotiate agreements that reflect this. Similarly, start-up companies have different assets and needs than established companies, making different kinds of deals appropriate.

Many universities have developed similar institutional arrangements for managing research partnerships with industry.

These typically include an office of sponsored research that negotiates research contracts, an office of "technology transfer" or technology licensing that negotiates intellectual property, and an office of "development" that seeks out new funding opportunities. Because so many agreements need to be negotiated on a case-by-case basis, these offices play an important role in determining the overall success of university-industry partnerships.

The success of U.S. university-industry partnerships depends on more than just the policies and procedures directly related to those partnerships.

Success in the university-industry system depends on high quality university research that is attractive to industry and entrepreneurial faculty members. This, in turn, has depended on the competitive grants processes, competitive hiring practices, and the peer review system in the U.S. university system. Success in spin-off companies has depended on having a well-established infrastructure for start-up companies, including venture capital funding and supporting services.

University-industry partnerships depend on -- and help build -- technical excellence in universities.

Industry interest in partnerships with U.S. universities depends on their reputation for high quality that was built up over many decades. At the same time, partnerships with industry now help build and maintain technical excellence in universities. They provide opportunities for top faculty to gain extra income, to gain access to expertise and equipment that may only exist in industry, and to work on challenging and relevant problems.

A variety of government policies have supported U.S. university-industry partnerships.

These policies include not only legislative changes such as the Bayh-Dole Act, but also R&D programs that began in the 1980s, including NSF's Engineering Research Centers and Industry-University Cooperative Research Centers. These programs created strong incentives for university to develop partnerships with industry. In addition, Federal

R&D funding for universities emphasized many areas of high industrial interest, such as computing, biotechnology, and advanced materials.

There are continuing tensions in U.S. university-industry partnerships, especially over intellectual property.

Industry, in general, seeks more control of university-developed intellectual property while others argue that intellectual property concerns are now restricting the free flow of information upon which science thrives. This is an area of continuing debate and concern.

5.2 Policy Implications

The U.S. experience suggests that while legislative and policy changes, such as the Bayh-Dole Act and the National Cooperative Research Act were important stimuli to industry-university collaboration, they are only part of the broader system needed for vigorous university-industry partnerships. When these legislative changes took place in the 1980s U.S. universities were already recognized for their technical excellence, industry had been supporting university research for decades, many university professors consulted for companies, and venture capital firms were already providing support for technology-based start-ups. The Bayh-Dole Act greatly facilitated expanded collaboration, but these collaborations were based on a history and culture that supported university-industry interactions.

To successfully promote university-industry collaboration and university-based start-up companies, public policies may need to address this larger context. One focus could be policies to promote a culture that rewards entrepreneurial activity and risk taking by university faculty members. Entrepreneurial activity in this context includes both starting new university-based research programs (with government or corporate funds) as well as starting new companies with university-developed technology. Universities can assist the start-up of new companies by allowing professors to take a leave of absence to pursue developing a new company, while preserving their option to come back to their university job if the new venture fails. Universities can also aid entrepreneurship by training students to be entrepreneurs and manage start-up companies, and by establishing linkage with sources of financing for new technology-based companies.

The U.S. experience suggests that because university-industry interactions are diverse and unpredictable, it is important to develop a system that is flexible, responsive, and able to adapt to unforeseen circumstances. Attempts to develop a set of uniform prescriptive regulations are likely to fail. It is more important that the system set the principles and parameters for behavior in a few key areas, such as intellectual property and conflict of interest, and let the details be adapted to fit the circumstances of the particular partnerships. It is important for universities to develop organizations that gain expertise in working out the details of these partnerships.

It is also important to encourage experimentation in the forms and procedures of university-industry relationships, and then to share what is learned from the experiments. In the United States, organizations such as the Association of University Technology Managers, the Business Higher Education Forum, and National Academy of Sciences' Government-University-Industry Research Roundtable have played an important function in sharing information on university-industry practices.

A final policy implication is that metrics of the university contribution to economic performance need to consider the multiple ways that universities add economic value. As discussed in chapter 3, universities can provide value to industry in many ways -- through graduating students, through publications, through new ideas, through intellectual property, or through new companies. It is important to consider the value provided through all of the pathways. Counting start-ups is a particularly difficult metric because of the difficulty in defining what a university-based start-up is, and because of the weak link between the number of start-ups and economic value. [53]

- Due to the complexity and diversity of university-industry relationships, it is important not to look for a single policy change or administrative action that can address or solve all problems. Instead, it is important to establish some general principles to guide partnerships, and to put in place a system that can adapt and solve problems as they come along.

[53] As an example, most universities allow their professors to consult, and many professors create a small consulting business through which they conduct their consulting. These may technically be new small businesses, but counting each of them as a university based spin-off company would result in a large number of new companies formed, but relatively little economic value.