UNIVERSITY-INDUSTRY RESEARCH RELATIONSHIPS IN THE UNITED STATES

George R. Heaton, Jr.
and
Christopher T. Hill
with
Tatsujiro Suzuki

Report to NEDO
(The New Energy and Industrial Technology Development Organization of Japan)

June 22, 1997

CONTENTS

PREFACE

This report presents an overview of the system of university-industry research relationships in the U.S. It was commissioned by NEDO as part of an ongoing series of analyses of various structural features and trends in U.S. science and technology policy. Previous work for NEDO by the same authors has covered funding patterns, changes in the political dynamic, and the climate for international cooperation. Several reports on these subjects have been published since 1995. This work was prepared by the authors as individual consultants. The views expressed herein are those of the authors and not necessarily of any of the institutions with which they are affiliated.

George R. Heaton, Jr.
Newton Centre, MA
grheaton@aol.com

Christopher T. Hill
Washington, DC
chrishll@erols.com

Tatsujiro Suzuki
Tokyo, Japan

INTRODUCTION: SYSTEM CONSENSUS

University-industry research relationships in the U.S. are exceedingly complex. Hundreds of universities have research and technology development connections to industry, tens of thousands of faculty members actively participate as research performers and consultants, and at least as many private firms--domestic and foreign--engage in and benefit from cooperation of this nature. The pattern of university-industry research relationships is best seen as a system that has developed incrementally over time and now serves a diversity of purposes. A few distinct types of actors--firms, faculty, universities and the government--play roles of approximately equal importance and pursue unique institutional needs. But it should be emphasized as well that the motivations and initiatives of individuals are an equally if not more important underlying force that drives the system. Interactions among these components yield a system that is highly dynamic, both internally and in its relationships with other systems.

Though diverse and highly dependent on individual initiative, the U.S. system is also very much the result of deliberate policies--in government, universities and firms--designed to cement university-industry relationships. Within the last two decades, these ties have received considerably more attention than previously. One sees, coming out of this period, a manifest consensus within the relevant communities that such ties are highly beneficial and that there are ways of promoting them effectively. Continuing attention to this task is still very much in the forefront of public policy and private decision-making.

Why has such a consensus developed and what comprises it? Its explanatory factors consist both of new concepts and an accommodation to new realities, and its implementing devices span public and private action. First, the new pattern of U.S. university-industry relationships rests to a significant extent on a transformed mind set about the process of technological innovation and what makes it work. The traditional "linear" paradigm, it is often said, emphasized inputs to an innovation pipeline, where different actors played well-defined, distinct roles. Universities, seen simply in this framework, were the producers of scientific knowledge and competent professionals; government's main role was to fund basic research; and industry's, to commercialize research results. The paradigm more commonly accepted today sees the innovation process differently, as a much more complex system in which the various actors' roles are connected, overlapping, intimate, and dynamic.[1] Perhaps as importantly, the perceived virtues of cooperation--both efficiency and synergy--are increasingly driving

[1]The general acceptance of this view is reflected in a new publication, National Innovation Systems, from the OECD Directorate for Science, Technology and Industry, Paris 1997.

collaborative relationships across competitors, disciplines, sectors, and countries.[2]

Beyond conceptual change, the development of closer university-industry links in the U.S. has been motivated by mutual need. Particularly during the 1980s--and continuing for the foreseeable future--universities saw their traditional research funding base--government grants--cut back. Industrial funding and cooperative relationships provided an important means of filling the funding shortfall. Industrial firms, for their part, were faced with the new realization that their own technical capabilities were often proving inadequate in the face of technologies that were much more complex, much more linked to science, and much faster moving than those in the past. Connections to universities therefore provided an essential means of broadening and deepening industry's technical capabilities at relatively low cost.

Happily, the new research relationship between American universities and industry appears to be yielding significant "pay-offs"--to the nation, to firms and to academe. New technology-based industries have been shown to rely heavily on university research and patented technology.[3] The widely recognized technological dynamism in "spin-off" companies is seen largely as a university-spawned phenomenon.[4] And researchers on both sides of the relationship report satisfaction with university-industry cooperative research as a mutually beneficial means of funding useful work and transferring technology.[5]

U.S. government policy has also played an important--even pathbreaking--role in the development of the university-industry research relationship. By the late 1970s, actions taken by the Congress and government agencies had begun to chart a new public mission: the support of technological innovation in industry. Throughout the ensuing decade, a wide range of legal and institutional changes were undertaken with a view toward supporting cross-sectoral cooperation in general and university-industry research cooperation in particular. These include provisions as diverse as new intellectual property rights, the application of R&D tax credits to cooperative research, and financial assistance to university R&D predicated on matching funding from industry.

Institutional change has been equally apparent in the private sector, both in reaction to these new public policies and as an independently generated strategy. Firms have avidly pursued

---

[2]"Picking Up the Pace: the Challenge to American Innovation," Council on Competitiveness, Washington, D.C. 1988.

[3]Nathan Rosenberg and Richard Nelson, "American Universities and Technical Advance in Industry," Research Policy, 23:3, 1994.

[4]See "The Impact of Innovation," MIT News Office, March, 1997.

[5]See "Chapter 4: Research and Development: Financial Resources and Institutional Linkages," Science & Engineering Indicators - 1993, National Science Foundation, Washington, D.C., 1993.

cooperation with universities as an explicit aspect of technology development and improvement strategy. Most of the large research universities have also deliberately pursued industry connections, through research contracts, liaison offices, faculty consultantships, and other means.

Each of these components has been an essential aspect of the system of U.S. university-industry research relationships, although no one of them is sufficient to explain its extraordinary success. Each is, of course, still in the process of evolution--motivated at least in part by the tensions that still surface as each of the main actors struggles with the continuing redefinition of traditional roles that developing a new system implies. At the moment, however, there is a strong sense that the present consensus in favor of vigorous university-industry interchange on research and technology development is likely to persist for the foreseeable future.

This report begins with an analysis of the fundamental structural features of the American academic and industrial research systems. We then explore the societal expectations for research universities, particularly how they have changed in recently years so as to dovetail with the industrial agenda, as well as the main systemic features that make the university-industry relationship in the U.S. unique. Next, we discuss the mechanisms of public policy and private institutions that affect, cement, and implement university-industry research relationships. Then we examine a few of the continuing issues that arise in the management of university-industry cooperative relationships. The final section offers conclusions about the directions the U.S. system is expected to take in the future.

THE ACADEMIC AND INDUSTRIAL RESEARCH SYSTEMS IN THE UNITED STATES

To provide a context for the more analytical sections to follow, this section describes the essential features of the academic and industrial research systems in the United States. It also provides some descriptive information on the major ways in which the two systems interact.

The American System of Research in Higher Education

The Institutions

Academic research in the U.S. is embedded in a system of higher education that is large, complex, and diverse. More than 3,700 institutions of higher education in the U.S. serve nearly 15 million students.[6] Some 1650 of these institutions are organized as public institutions (nearly all operated by states or municipalities), while 2050 are privately owned and operated. Of the

[6] National Center for Education Statistics, U.S. Department of Education, web site.

latter, nearly all are organized as nonprofit, tax-exempt charitable institutions. Only a handful are owned by the national government and these are almost all dedicated to the training of military officers.

A much smaller number of institutions play significant roles in the conduct of research and the training of advanced graduate students in the sciences, engineering and medical sciences. For example, only 50 institutions account for more than 55 percent of the separately-budgeted[7] R&D conducted in academic institutions, and 100 account for 78 percent. Thus, the conduct of research is highly concentrated in only a few major institutions, typically called "research universities."

Some of the smaller and less prestigious organizations, including some two-year and community colleges, play important roles in the transfer of existing technology to small and medium sized firms and in specialized training of technicians and other staff for industry.

The research universities, in turn, are quite diverse in their organization, specialities, locations, and size. They include both private and public institutions. With a few prominent exceptions, such as Rockefeller University in New York, they offer both undergraduate and graduate education. Most are large compared with other academic institutions--enrolling ten to fifty thousand students or more, although a few remain small and highly selective, such as California Institute of Technology with a student body of less than one thousand.

Financing the Research Universities

University financing is a complex process in the United States. Most institutions are supported by a combination of direct government appropriations, student tuition and fees, endowment income, individual and corporate charitable contributions, gifts from alumni and friends, and grants and contracts for research awarded by government, industry, and charitable foundations. Some also earn substantial income from so-called "unrelated businesses," such as bookstores, rental housing and land, and other profit making subsidiaries, including licensing fees and royalties from patents, other intellectual property, and exploitation of university owned natural resources such as oil and natural gas.[8] Universities with associated teaching hospitals

---

[7]National Science Foundation, Science and Engineering Indicators-1996, page A-29. A large but unknown number of faculty and graduate students conduct research projects without formal, separately budgeted financial support. Typically, these projects are of limited duration and incur few expenses other than the faculty's salary and the uncompensated efforts of the students. They are more likely to occur in the humanities, arts and social sciences than in the natural sciences, engineering or medicine.

[8]Some universities have received grants of land from states or individuals with the expectation that the agricultural production from the land would help finance the institution. In a few cases, subsequent to a grant, a university has discovered economically important mineral

also gain substantial income from the delivery of medical services to individuals and groups.

Higher education can fairly be considered as "big business." Several institutions have annual operating budgets exceeding one billion dollars. A number have endowments in excess of one billion dollars, with a few exceeding ten billion. In 1995, American institutions of higher education spent approximately $21.6 billion for separately budgeted research, an amount equivalent to about 12.6 percent of all R&D performed in the United States. The federal government continues to be the largest single supporter of academic research, although it has slipped from 75 percent of the total support in the mid-1960s, to about 61 percent of the total in recent years. Industry provides about $1.5 billion annually, or about 7 percent of the total research funds for universities.

Total federal spending on research in universities exceeds $13 billion annually.[9] The federal government provides about 61 percent of the funds for academic research in the top 50 institutions, state and local governments and industry each provide about 7 percent, institutions self-fund about 17 percent, and other sources support about 8 percent.[10] The distribution by source of funds for research is very nearly the same for all academic institutions as a group.

From a financial point of view, the distinction between private and public universities is not sharp. For example, some private universities receive not only government research grants and contracts and student assistance funds, but also direct appropriations of funds from state governments[11]. Similarly, the public universities are heavily dependent on private gifts and on research grants and contracts from private sources.

While larger than many private businesses, however, universities differ from businesses in many important respects. Perhaps the most important from a financial perspective is that universities produce a diverse array of products and they do it using a common set of facilities, staff, and operating inputs. That is, universities produce, as outputs, educated graduates,

---

resources such as oil or natural gas under the land surface. The University of Texas system owns an especially rich mineral resource endowment.

[9]NSF, op. cit., page A-166

[10]NSF, op. cit., page A-170

[11]The responsibility for financial support of public primary and secondary education in the United States lies with state and local governments, not with the federal government. Private education--organized by religious bodies and other non-profit institutions--is common at that level as well, but it usually receives little or no direct government financial support. (Bitter battles over whether it is appropriate for governments to help pay for private primary and secondary education are a staple of American state and local politics.) Paradoxically, the federal government funds research at both private and public institutions of higher education, including those supported or owned by religious bodies, almost without notice or debate.

contributions to new knowledge, and services to society in general. Each of these outputs uses a common set of teachers, buildings, laboratories, and libraries. This means that the allocation of costs to each category of activity and output is necessarily somewhat arbitrary. Furthermore, the ratio of fixed to operating costs in universities is relatively high, which further complicates the allocation of costs to specific activities and outputs. In practice, this means that universities in the United States "charge" for doing research an amount that includes both the identified direct costs of the project (salaries of faculty, stipends for students, special facilities, expendable equipment and supplies, travel, etc.) and a substantial additional indirect cost, or "overhead," that seeks to recover a portion of the allocated fixed and shared costs of the project (space, libraries, university administration, utility costs, security, etc.) The determination of the allowable and appropriate direct and indirect costs of research is an arcane and important aspect of research university finance.[12]

An Academic Research System Built for Growth

The United States has made a remarkable investment in institutions of higher education throughout its history. From the founding of Harvard in 1636--only 16 years after the first permanent European settlement in New England, the system has grown to encompass more than 3,700 institutions that spend more than $170 billion annually, or a little more than 2.5 percent of GDP.

The modern system of research universities is largely a product of the latter half of the twentieth century. It is a system that grew at an exceptionally high rate from the mid-1950s to the mid-1970s, spurred in part by growth in federal funding for research; graduate education; facilities construction; and medical education, research, and service provision. As important as this direct funding was the so-called "G.I. Bill," which provided generous financial assistance for advanced education to veterans who returned from service in World War II and the Korean conflict. The rapid growth in the population of young people born between 1946 and 1965 (the so-called "Baby Boom") also contributed to an increased demand for higher education services in the 1960s and 1970s, as did the growing demand for professionally trained people throughout the modern American economy.

Most of the institutions among the top 50 performers of separately budgeted research existed before this growth spurt; however, their size and the scale of their research and graduate

---

[12]With the rapid growth of federal funding of university-based research during the 1940s, the principle of "full cost recovery" was adopted. According to this principle, the government agreed to fund not only the direct costs but also the indirect costs of research it sponsored. The difficulty is that the indirect costs are, in principle, not knowable with precision. The resulting debate over indirect costs between universities, federal research agencies and the federal Office of Management and Budget, which is responsible for determining federal policy on overhead reimbursements, is an enduring feature of science policy in the U.S.

education activities grew dramatically during this period as well. Furthermore, the number of institutions that wished to make a serious commitment to research increased during the growth spurt, because many of the faculty of the new and growing institutions were themselves drawn heavily from the ranks of people who had done their graduate studies at leading research universities and had been socialized to believe that they, too, should carry out research and publish, just as their mentors did.

For example, federal funding of academic research grew from $405 million in 1960, to $1,647 million in 1970,[13] a compound annual rate of growth of approximately 12 percent in real terms. Growth has slowed since that time, but federal funding has reached $13,000 million in 1995, for a compound rate of growth in real terms of about 3 percent from 1970 to 1995.

During the rapid expansion of federally funded research on campuses in the 1960s in such fields as biomedicine, space, defense, and energy, the federal government contributed billions of dollars to the building of research and education facilities at universities. The value of the physical plant of institutions of higher learning nearly tripled between 1950 and 1970, owing in substantial measure to government investments.

The present leadership of higher education experienced the earlier period of rapid growth as students and junior faculty. For them, "normalcy" is rapid growth in federal and state support of higher education. More recently, however, both the effort to control the federal budget deficit and the tougher stand of many state legislatures toward higher education funding has created a much more stringent budget environment for this sector. As a result, universities, including the prestigious research universities, have been seeking to diversify and expand their sources of income.

The American Industrial R&D System

The Firms

Industrial R&D in the United States is conducted by a variety of firms in diverse industries. It is also conducted under contract by a number of specialized contract research firms, both profit making and non-profit. Most of the industrial R&D is conducted by a few hundred large firms, yet thousands of small technology-based firms also play important roles in bringing new products and processes to market. In addition, many other firms make competent use of the latest in process and systems technologies, yet do little or no formally organized R&D on their own. For example, many computer networking and telecommunications firms make important advances in software and technology-based systems but report doing no R&D themselves.

---

[13]NSF, op. cit., page 166.

Research-Intensive Large Firms

Formally organized R&D laboratories have been a feature of large manufacturing firms in the United States for nearly a century. While the favored form of organization of these laboratories has changed over time, most large firms have a central research laboratory that usually focuses on long-range projects of broad use to the company, as well as satellite laboratories collocated with operating divisions. These divisional laboratories are responsible for developing new products and processes as well as for assisting in solving operating problems in the business units.

Separately organized R&D is concentrated in a few hundred laboratories. For example, 200 firms conduct more than 70 percent of the industrial R&D in the United States.[14] A few firms spend a great deal of money on R&D. The top ten firms spend more than $28 billion annually on R&D and together account for nearly one-third of all industrial funds for R&D in the United States.

Small Technology-Based Firms

Compared with most other countries, the U.S. features a large number of small technology-based firms. While many are relatively young, having been established to exploit a new technology based on R&D done in a university, federal laboratory, or large firm, some are well established in narrow niches from which they supply advanced technology products to larger firms, systems integrators, and retail customers.

Statistics on the population of these firms are not easy to obtain. Until recently, they were not systematically sampled by the NSF when it did its surveys of industrial R&D in the U.S. In 1992, NSF began a new survey series using an expanded population of small R&D performers. Such firms are prominent in biotechnology, a field in which new ventures receive a great deal of media attention. They are by no means limited to this domain, however, and are active in fields as diverse as medical instrumentation, space launch vehicles, and high-performance sporting goods. According to NSF, firms with fewer than 500 employees accounted for 13 percent of industry's own funds for R&D in 1993, up from 8 percent in 1990 and 7 percent in 1985.[15]

It is important to emphasize that in the United States, a growing number of small and medium sized firms that are very technology intensive--as measured by their employment of

---

[14]NSF, op. cit., page 4-15.

[15]NSF, op. cit., page A-116. The large increase between 1990 and 1993 is probably an artifact of the change in survey approach in 1992. There is reason to believe that the more recent figure is more accurate.

scientists and engineers or their purchases of high-tech goods--do not do any organized R&D as traditionally defined. Many networked telecommunications firms fit this model. For example, of some 1600 "high-tech" firms in the metropolitan Washington, DC, area, very few do any reported R&D, yet characterize themselves on surveys as "high-tech."

Financing Industrial R&D

In 1993, industry spent a total of about $96 billion of its own money on R&D. In addition, it received about $23 billion in contracts and grants (overwhelmingly in contracts) from the federal government, so that it spent a total of about $118 billion on R&D.[16]

Large firms typically finance their R&D activities from retained earnings; i.e., they can be characterized as financing R&D from profits. As a rule, banks and other lenders will not make loans to help pay for R&D since R&D investments are riskier than most lenders are willing to support.

The federal tax code offers important incentives for industrial R&D spending. The most important is that firms may deduct from income before taxes all the costs of R&D, except fixed structures and permanent equipment, in the year in which they are incurred. (They also have the option of treating such expenditures as depreciable assets, which can be favorable to the firm under unusual circumstances.) In addition, since 1981, an additional tax credit has been available to firms for R&D expenditures in excess of the average of the previous three years' expenditures. While the exact form and timing of the R&D tax credit has changed several times over the period, it, too, is an incentive to growing firms to increase their R&D spending.

Small firms also typically finance R&D from their equity investments, although the precise form of those investments can vary a great deal. Since new firms frequently have no earnings from which to finance R&D, they turn to venture capital, individual wealthy investors, and large-firm partners for R&D funds. There are cases of firms in which R&D spending for a limited period of years substantially exceeds income from sales of products. Investments in such firms obviously are quite risky, with the promise of an occasional spectacular success motivating some investors to take the risk.

The federal government offers important incentives for R&D spending in small firms. For example, since 1982 the Small Business Innovation Research Act has required all federal agencies with substantial R&D programs to set aside a small percentage of their budgets to fund R&D in small firms. Today, this has grown into a program that makes available nearly one billion dollars annually to small firms to support R&D.

[16]NSF, op. cit., page A-117.

University-Industry Interactions

This section offers a brief overview of the nature and amount of university-industry interaction in R&D in the United States. Later sections will detail the institutional modes of such interaction, the incentives and disincentives for it, and the issues that arise in conjunction with such relationships.

Historical Overview

Close interaction between U.S. universities and industry in research and technology development is not new. For example, the academic field of chemical engineering was built in the late 19th and early 20th century by academicians who also maintained active consulting practices, who started their own firms to exploit advances in applied chemistry and electrochemistry, and who moved freely from academia to industry and back. These interactions did face some limits. For example, Arthur D. Little, an MIT chemical engineering professor who pioneered the concept of unit operations in chemical process engineering, was asked by the MIT faculty around early in the 20th century to remove his growing industrial services business from the university's premises, an action that led him to establish the Arthur D. Little Corporation, a consulting firm that continues to thrive.

Most of the early interactions--even up through the 1970s--were carried out under the framework of individual consulting arrangements between faculty members and firms. Faculty consultants were retained by firms to offer advice in solving specific problems in both research and operations and to offer training courses in the state of the art of new fields. These activities were seen as largely separate from the duties of the faculty in teaching and research at their academic institutions. There has long been a tradition that faculty in both private and public institutions could carry on such consulting practices, for pay, within stated limits (typically one day per week). Some institutions require that faculty who consult disclose the identity of their clients and, sometimes, the amount of money they receive, to the university. It has been thought that consulting both enriches the teaching and research of professors in such fields as engineering and applied sciences and helps make up for the fact that salaries are lower in academia than in industry where such faculty might find alternative employment opportunities.

In parallel, a number of major industrial firms provided grants to academic institutions to support education, research, and graduate training. Typically, these grants were offered in the spirit of charitable giving, with unstated expectations that the firm might benefit somehow indirectly by having preferential access to good students or faculty consultants.[17] Even when charitable grants were given to support specific research projects, the usual motivation was to support the general advance of knowledge in an area, not to obtain research results that might be of immediate use to the sponsoring firm.

---

[17]As charitable gifts, these donations also earned federal tax deductions for the donors.

During the 1960s and 1970s, and later at a greatly accelerated pace in the early 1980s, relationships began to evolve from this base in individual consulting and charitable grants, to a more strategic and purposeful set of relationships between individual firms and consortia of firms on the one hand, and academic institutions on the other. Firms began to expect that such arrangements would yield tangible results of significant value, on time and on budget, and universities began to look to firms as an important and sustained source of research support funds in addition to those provided by governments.

Growth of University-Industry Interactions in the 1980s

The number and importance of university-industry research relationships grew enormously in the early 1980s and have continued to grow since. For example, the level of financial support of R&D at universities by industry grew from $236 million to $1.12 billion between 1980 and 1990, which amounted to a tripling of such funds in real terms in just 10 years. It grew further to $1.5 billion by 1995.[18] Whereas these industry funds account for about seven percent of all academic research support, they amount to only slightly more than one percent of industry's total R&D spending.

It is not possible to ascertain what fraction of the industry support for academic research is devoted to activities that are clearly cooperative in nature, as opposed to that which is motivated largely by charitable aims. However, it is reasonable to assume that a considerable portion of the total is devoted to the firms' specific technical needs.

A variety of incentives tend to encourage university-industry cooperative research activities, as detailed in later sections of this report. The question to address here is why they expanded so sharply and became qualitatively more important in the early 1980s. Several reasons can be adduced, although no definitive answer is available. Among them are:

- Federal funding for academic research, after having grown nearly continuously since 1941 (the exception was a reduction in such funds in the late 1960s owing to the cost of the war in Vietnam), had begun to slow and the incoming Reagan administration had threatened to cut it sharply,

- The Reagan administration cut sharply into federal funding for energy R&D in 1981, leaving a whole generation of researchers who were skilled at large scale applied research searching for new sources of support,

- The end of the estrangement of university campuses and industry that was a side effect of the campus-led opposition to the Vietnam conflict and of the environmental movement of

[18]NSF, op. cit., pages 166, 167.

the 1970s,

- A handful of high-profile industry-university cooperative ventures caught the attention of both the academic and industrial communities, including ones between Exxon and MIT's chemical engineering department, Monsanto and Washington University's School of Medicine, and American Hoescht and Massachusetts General Hospital (Harvard),

- A group of leading American industrialists had become convinced that the key to Japan's success in taking high-technology markets from U.S. firms was the practice of the Japanese government in helping to finance industrial cooperative research,

- Early experiments in federal financial support for cooperative research between industry and universities had yielded encouraging results. These included ARPA funding in the mid-1960s of a materials research laboratory managed jointly by Monsanto and Washington University, the NSF Research Applied to National Needs (RANN) Program of the early 1970s, and the NSF program in the late 1970s to provide partial funding for Industry-University Cooperative Research Centers (IUCRCs),

- Passage of the National Cooperative Research Act of 1984, which substantially reduced the threat of antitrust penalties for firms that conducted R&D together, and

- Passage of the Bayh-Dole Act of 1980, which enabled universities, non-profit organizations, and small firms to hold title to inventions made with federal funds.

It should be noted that students of university-industry R&D cooperation differ regarding the causes, proximate or otherwise, that led to the sharp rise in this kind of activity. It is clear, however, that once accepted as legitimate and proper activities for academic institutions, they grew quite rapidly. Furthermore, once they began to show real promise, the federal government then adopted a series of programs intended to foster such relationships, including the highly successful Engineering Research Centers (ERC) program at NSF, begun in 1985.

Government Incentives for Industry-University Cooperative Research

The federal government has committed increasing funds, since the mid-1960s, to support industry-university research cooperation. It has also changed the "rules of the game" governing the incentives for such cooperation and adopted specific financial incentives for it.

The Bayh-Dole Act and the National Cooperative Research Act created new incentives for firms to work together, including with universities. Bayh-Dole also created a financial incentive for universities to patent the useful results of federally funded research and to seek alliances with private firms to exploit those patents in order to earn revenue for the university.

As an indirect incentive, Congress adopted a "basic research" tax credit, which extended to firms an even more favorable tax treatment for R&D expenditures channeled through universities.

There have also been numerous program incentives. Mentioned above were programs at NSF, including RANN, the IUCRC program, and the ERCs. Not mentioned earlier were such programs as the NSF Science and Technology Centers built on the ERC model, a DOD program that gave DOD R&D contractors financial incentives for cooperating with universities in executing those contracts, and various elements of the six-agency Technology Reinvestment Project led by DARPA that encouraged universities to partner with industry in research and technology transfer consortia.

EVOLVING SOCIETAL ROLES OF AMERICAN RESEARCH UNIVERSITIES

The Dual Agendas of American Research Universities

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. In pursuing this agenda, they act as stewards of both fundamental inquiry into the unknown and the preservation of human wisdom, unfettered by society's passing demands. In this pursuit, universities portray themselves as communities of scholars--both faculty and students--dedicated to freedom of inquiry and organized around libraries, laboratories, and classrooms. Such time-honored practices as academic freedom, tenure, rigorous peer evaluation and review of proposed and completed inquiry, and the organization of teaching and learning into sharply delineated disciplines all contribute to the university's distinct role as the major institution in society dedicated to teaching and learning. These practices, in turn, also buffer academia from the demands of society for relevance.

On the other hand, throughout most of U.S. history, its universities have been seen as, and have seen themselves as, instruments through which society seeks to accomplish many of its goals. Since the founding of the first institutions of higher education in America more than three centuries ago, they have often shaped their teaching, learning, and research in directions that contribute to society's immediate needs. Over time, teaching has responded to needs for persons prepared to take up positions as clergy, teachers, lawyers, military officers, agronomists, physicians, scientists, engineers, politicians, social workers, business leaders, and even professional athletes. Similarly, the research and scholarly work at universities has often responded to societal needs by focusing on such topics as theology, pedagogy, law, animal husbandry, military history, public administration, biomedicine, management, sociology, nuclear engineering, ecology, and kinesiology.

Clearly, university service to industry through R&D cooperation is consistent with the long history of university response to national needs. One could even venture to say that the groundwork for university response to industry needs was prepared in substantial measure by the wide-spread response of academic institutions to calls during the social movements of the 1960s and 1970s that they be "relevant" to the needs of society. Only the nature of the needs has changed in the interim.

Managing the balance between these two roles is a fundamental challenge to universities, individually and as a system of institutions. Institutions differ in their degree of adherence to the two roles; for example, the large, well-known technical institutes emphasize meeting national needs, as do many of the smaller state universities and public two-year and community colleges. By contrast, many of the prestigious comprehensive private universities, as well as top ranked state universities, emphasize traditional scholarly objectives. The smaller, top-quality undergraduate private institutions also emphasize traditional objectives. All of these institutions, however, pursue both roles; the differences are matter of degree, not kind.

On the whole, the American system of research universities has evolved in such a way that it has become exquisitely responsive to new needs and new opportunities manifest in the world around it. In some respects, the research universities seek to pursue both major tracks simultaneously--they both sustain scholarly traditions and contribute to the world's needs. The ones that are good at doing both tend to be the most successful over the long term as measured by growth, impact on the world, and judgments of quality by peers.

Determinants of the Responsiveness of the Research Universities

A variety of mechanisms influence the responsiveness of the system of American research universities to the nation's needs. Some encourage responsiveness, others inhibit it.

Dependence on External Funds

The dependence of the universities on external sources of funds to pay for a good portion of their research and graduate training is key to their responsiveness to changing external needs. The roots of this practice go back to the origins of private universities as the beneficiaries of contributions from individuals and private foundations and to federal funding of agricultural research and training beginning in the mid-1860s. However, 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.[19] This action established the concept of the R&D contract and of full-cost reimbursement--including indirect costs--for government contract research.

---

[19]By contrast, during World War I, many scientists and engineers were mobilized to aid in military research by conscripting them into the Army and Navy.

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. These funds may pay for graduate student stipends, full-time research staff salaries, travel, materials and consumable supplies, and equipment. In addition, external funds are frequently the only source of income for faculty during the summer (non-academic year) months, and many institutions make a practice of substituting external funds for some of the institution's own money that would otherwise be used to pay faculty salaries during the academic year.[20]

The Principal Investigator as Faculty Entrepreneur

Closely associated with the concept of dependence on external funds is the notion of the faculty member as the entrepreneurial principal investigator, or "P.I.," on externally-supported grants and contracts. The principal investigator is responsible for conceiving of the research task to be performed, for preparing a formal proposal to external sources that may choose to support the proposed project at the institution, for the management of the funds and of the research should external funds be awarded to the institution, and for reporting and writing about the research when it is completed.

A number of points need to be made about the role of the P.I. First, the P.I. does not receive the external funds personally and directly; instead, the funds are awarded to the institution in the name of the P.I.

Second, the P.I. benefits financially from the external funds under most circumstances only to the extent that they are used to pay for summer salary. The P.I. does benefit in other, non-financial ways, of course, since the external funds frequently make it possible to support more graduate students and to conduct more--and more expensive--research than would otherwise be possible. Furthermore, some institutions explicitly or implicitly reward the

[20]Typically, regular faculty members in American research universities receive a salary for nine months during the academic year, which is to compensate them for teaching, research, service to the institution, and other scholarly activities. External funds, if available, may be used to pay for a portion of the faculty member's salary, in return for which he or she is excused from some teaching or service duties in order to focus more intensively on the research. The institutional funds thus made available may be used to pay for other persons to take over the teaching duties. During the summer, faculty on "nine-month" appointments receive no institutional compensation, and may arrange to work for other organizations, to write articles and books, to travel, to take an extended vacation, or to augment their institutional salaries with external funds from government or industry grants and contracts with the institution.

contributions of P.I.'s to the institution's financial base by paying them higher salaries and giving them other perquisites. And, some institutions further reward P.I.'s by setting up flexible institutional accounts controlled by the P.I. in some proportion to the total overhead or indirect costs on projects for which he or she is responsible. This practice is sometimes known as "overhead return." These accounts can be used by the P.I. to support any legitimate professional purpose, although they cannot be converted to personal salary or other direct personal use.

Third, the P.I. is not a totally "free agent." Faculty are given a great deal of latitude with regard to what research they would seek to do, but they must do so within an administrative framework that is established by the institution, operating under a number of mandates imposed by federal and state authorities.[21] Faculty members are not free to apply for and conduct any arbitrary sort of research that they might like to do under any terms that can be negotiated. The institution--typically including a department head, a dean, and a responsible university official--must approve the proposal before it can be submitted to a potential funder. Similarly, responsible university officials must approve spending funds that have been awarded to support the work of a P.I. and his or her students and other associates, and the university remains legally accountable for that spending and for responding to audits of it when asked.

Fourth, on larger projects involving several faculty, the P.I. may serve as a nominal project manager, but the responsibility for the conduct of the research lies with each of the individual faculty members whose research and graduate students are supported in part or totally by the external funds. In other words, the principle of academic freedom extends down even to the level of the faculty working within a single project.[22]

---

[21]One of the side effects of having accepted large amounts of government funding is that universities must agree to abide by a host of government rules and regulations on research. Among these are rules governing accounting practices, constraints on research on human subjects and on animals, management of hazardous and nuclear materials, and the like; as well as rules not specifically related to the conduct of research but imposed on universities as government contractors, concerning equality of opportunity, maintenance of a drug-free workplace, preferential purchase of certain classes of American-made goods and services (including airplane tickets for overseas travel), and so on. Critics of the dependence on external funding point to these rules as a substantial incursion on the tradition of academic freedom and institutional independence. However, only a tiny fraction of the nation's colleges and universities refuse all government funding in order to avoid government rules--one relatively visible such institution is Grove City College in Pennsylvania, whose president is John Moore, a former deputy director of the National Science Foundation.

[22]A distinction between research grants and contracts can be significant for the roles and responsibilities of P.I.'s, students, and others supported by external funding. Grants are typically viewed as financial assistance to a program of research. While the P.I. is under some general expectation that the research supported by a grant is recognizably connected to that which was promised in the proposal, the P.I. also has very considerable flexibility to use the funds to follow

Competitive Allocation of Grant and Contract Funds

The third key element in the responsiveness of the American research university system to societal needs is that external grants and contracts 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 are awarded to support specific projects, rather than an individual or a long-term program of work.[23]

The mechanics of research funding competitions varies widely, depending on the nature

---

the most promising lines of research in which he is involved at the time the grant is made. Grants also typically involve little or no formal accountability to sponsors at the end of the project for the substance of the work. At the same time, the P.I. and the institution are accountable to sponsors for how the funds are spent, and often have little autonomy in determining the categories of expenditures they support (e.g., salaries, student stipends, travel, equipment, etc.).

Contracts, on the other hand, usually represent an agreement to conduct a particular line of research in pursuit of an agreed explicit objective. The contract instrument usually includes a set of deliverable products (research results, reports, experimental samples, etc) and a set time at which they are to be delivered. Contracts involve frequent oversight of the ongoing work by the sponsor, often with formal interim reports and progress reviews. Under a contract, the P.I. and the others supported by the external funds are under considerable expectation to follow the terms of the contract. To this extent, they agree to compromise on aspects of the notion of academic freedom in return for what is often generous financial support. On the other hand, because results of research can never be guaranteed in advance, academic institutions typically accept contracts only on a "best efforts" basis; that is, the institution agrees to do its best to perform the agreed work with the agreed staff and within the agreed time frame and budget, but it refuses to accept the risk of an agreement that guarantees that it will work on the tasks until results satisfactory to the sponsor are obtained.

The federal government uses both grants and contracts to support academic research, as well as an intermediate instrument known as a cooperative agreement (not to be confused with a cooperative research and development agreement, or "CRADA"). Grants are used when the government seeks to support research of broad value to the nation, whereas contracts are used when the sponsoring agency needs the results for its own mission purposes. The cooperative agreement is used when the government has both motivations. (See the Federal Grant and Cooperative Agreement Act of 1977.)

To further complicate these matters, from a legal point of view, a government research grant is in fact executed via a contract instrument.

[23]During the past two decades, grants and contracts to support groups of researchers as well as centers have become more common. These may support either discipline-focused or interdisciplinary activities.

of the funder and of the fields of research.[24] The paradigm case, although by no means the only one used, is the award of grant funds by such agencies as NSF and NIH in response to competitions open to all qualifying potential P.I.'s and institutions. Typically, agencies inform the public that funds are available to support research in one or more fields of inquiry. Bidders prepare research proposals in response to the notices of opportunity.[25] The proposals are assessed for minimal compliance with administrative requirements and those that comply are reviewed by other active researchers in the field; i.e., by so-called "peers." The funding agencies decide which proposals to support based heavily on the advice of the peers, who are usually drawn from competing universities and other organizations. Reviewers know the identity of the proposed researchers and take account of the team's prior accomplishments in deciding which projects and investigators to recommend for funding. Proposers do not typically know the identity of those who have reviewed their work. The agency supports the top rated proposals, modified as needed to obtain a reasonably balanced portfolio of projects in light of the agency's broad objectives.

As stated above, the conduct of competitions for research can differ widely from the simple case discussed above. Some agencies dispense with formal notices and simply receive proposals on an unsolicited basis. Others issue formal "requests for proposal," especially in connection with contract opportunities, which are quite specific regarding what is wanted by the sponsor. Some agencies, such as ARPA and the Office of Naval Research, dispense with peer review and depend instead on a staff of technical experts in subject matter areas to identify and

---

[24]For a review see "Peer and Merit Review in Allocation of Funds to Academic Research Projects and Performers: Report of a Workshop," Christopher T. Hill and Jonathan C. Tucker, George Mason University, The Institute of Public Policy, forthcoming, August 1997.

[25]Research proposals to the government include technical, administrative, and financial portions. The technical part typically describes the research problem, question, or hypotheses to be investigated, reviews the previous literature on the topic, discusses how the topic will be addressed, and provides insight into why addressing the particular topic would be valuable to the field and/or society at large. The administrative part describes who will lead and participate in the project, where it will be conducted and with what resources (space, equipment, computers, etc), how the project will be organized and managed, the time the project is expected to take, and how the results will be disseminated. The financial part gives a detailed budget including both direct and indirect costs of conducting the project. Finally, the proposal must be signed by the P.I. as well as by cognizant university officials who certify that the applicable rules and regulations will be complied with.

Research proposals to industry and other groups are often much shorter and include much less legal and administrative detail. Since they do not have to operate within the same sort of public accountability framework as public administrators in the United States, officials of companies and foundations do not insist on the same level of detail in proposals as do government officials.

support the most promising people and ideas. Foundations frequently seek out people with good ideas and then work closely with them to shape a proposal which is almost always funded, usually as a grant. Private firms may choose arbitrarily to offer a particular P.I. and institution the funds to work in a particular area, based on the reputation and capabilities of the P.I. rather than on an open competition.

Not all federal funds for research are awarded in open competitions. Two counter examples are instructive. One is the long-established systems of land grant universities and Historically Black Colleges and Universities, which receive federal funds annually on a formula basis to do research in the field of agricultural science. These formulas are set in the political process with a good deal of congressional oversight. The selection of specific projects and investigators is made at the institutional level.

The other counter example is the process by which individual institutions or consortia of institutions and their associated P.I.'s arrange to receive research funds under the specific guidance of a congressional directive in an appropriations act of Congress or of specific language in the congressional report that accompanies such an act. Widely and pejoratively known as "pork-barrel science" after an old tradition in American politics of "bringing home the bacon," this practice has grown substantially in the past decade, despite efforts by some members of Congress, the executive branch, and certain leaders of the research community to bring it to an end. This process usually bypasses the peer and merit review processes used by the agencies, although the agencies often contrive to subject such projects to peer review even if they have been directed by Congress to fund them.

Other Mechanisms that Encourage University Responsiveness

Three other mechanisms deserve brief mention. The first is that graduate study in engineering, natural sciences or medicine is an important means of achieving upward mobility in American society. In some ways, it reflects the meritocratic society at its best--graduate students succeed by their wits, determination, and ability to accomplish complex tasks, not because of who their family is or where they came from. As a result, the upwardly-mobile graduate students find out which fields of science and engineering society is likely to reward with good jobs and high salaries during their careers. The best students are typically drawn to seek degrees in fields with the greatest promise--a practice that further enhances the responsiveness of the academic research system to new national priorities and new opportunities.

Second, research universities have made ever greater use of full-time, non-faculty professional staff (sometimes called "un-faculty") to augment the research efforts of the faculty and graduate students. From a base of laboratory technicians in an earlier era, the un-faculty have grown to encompass fully accomplished senior researchers who focus almost exclusively on research and apprentice training of advanced graduate students. In most institutions, the unfaculty is supported almost exclusively by external funds, not just for summer salary and out-of-pocket research costs, but for base salary.[26] These staff are under considerable pressure to identify external research opportunities and to write or assist in writing proposals that will continue to support their salaries and research. In some institutions, senior members of the unfaculty can serve as full-fledged P.I.'s.

The third key mechanisms that enhances responsiveness is the growing use of interdisciplinary and interdepartmental centers as the organizational element within universities in which large and complex research projects are carried out. Centers usually feature the work of several faculty, staff, and students who share common interests in a topic, problem, or research facility. They serve to provide an internal research community as well as an external image of competence and depth in an area. They are usually supported almost exclusively on external funds, so their continued existence challenges their participants to stay informed about and actively pursue new research opportunities.

All three of these mechanisms--upward mobility, the unfaculty, and research centers--contribute to making the research university system exquisitely responsive to societal needs. It is a system devoted almost singlemindedly to the quality of ideas, people, and results. Faculty and other researchers who do not stay up-to-date or do not do good work cannot get external funding or participate in new opportunities. And, when new problems or opportunities arise and/or new sources of funds are made available, it is generally the top people in the top institutions who respond the quickest.

Internal Incentives and Disincentives for University-Industry Cooperation in R&D

The systems of incentives for participation by both industry and universities in cooperative R&D are very complex. While a number of incentives have already been mentioned, this section focuses briefly on the incentives and disincentives internal to the institutions to further explicate this complex structure.

In Universities

For nearly everyone in universities, research ties to industry can open doors to personal exchanges with influential counterparts in industry. The university president can more easily approach the CEO of the company in search of major corporate contributions to the institution as well as in pursuit of political agendas which the CEO may be able to help with. Deans and department heads can similarly use industry contacts to recruit faculty and students, to raise

---

[26]Un-faculty are usually employees of the institution, but they work under short-term contracts of varying duration which assure them employment only so long as funds from external sources are available to pay them.

funds, or to find consulting opportunities for themselves and their colleagues. Faculty find interaction with industry to be a ready supply of new ideas and new challenges, and they may be able to use their contacts to arrange corporate gifts of research equipment and facilities to the university. Students also find new challenges but also can use joint research with industry to identify job opportunities after they graduate.

On the other hand, while industry often imposes fewer bureaucratic demands on universities, faculty and students than government does, it also tends to seek more frequent personal contact and to supply funds in smaller amounts per project than government does. So, for researchers, it can be more demanding of time and energy per unit of funds to cooperate with industry than to take funds from government. Furthermore, despite the widespread embrace of industry ties at universities, some key university practices, such as tenure, promotion, and award of advanced degrees still tend to follow more traditional academic behavior, with the result that young faculty and graduate students take some risk in working with industry that they will not actually be able to use their time and energies to satisfy the expectations of their peers and the administration when it comes to these critical career decisions.

In Companies

For everyone in industry, the key incentive for research cooperation with universities is access to smart people, new ideas, and young talent. In the short run, universities are only occasionally successful at helping industry solve its immediate problems. In the longer run, however, the new ideas and new understanding from universities can help industry find new technologies to market and can help industry make continual improvements to technologies it is already using. Universities also have a lower cost structure than industry, largely owing to the cadre of graduate students who receive far less compensation than do researchers in industry and to the fact that universities can spread their costs out over non-research tasks such as teaching undergraduates.

Close association with university staff can help advance the personal agendas of industrial researchers, many of whom harbor ambitions to return to universities to teach at some future time in their careers. Cooperation with universities may offer individual industrial researchers opportunities to serve in adjunct capacities as part time teachers and participants in doctoral dissertation committees, thus helping to prepare them to assume academic jobs later on. For business managers and R&D directors, engagement in cooperative R&D with industry can also offer a "window" of insight and awareness into a realm of new research methods and findings that is much wider and more diverse than most firms could hope to support themselves.

On the other hand, the relatively slow pace of progress in academic research, combined with the unwillingness of most universities to sign contracts that commit them to deliver results at any cost, means that universities are not entirely reliable partners with industry in projects for which being on time and on target are imperative.

One result of these incentive structures may be that industry continues to look to leading universities for long-range research projects which it cannot do itself at reasonable cost but for which being on time may be of secondary importance. Similarly, there is some evidence that companies tend to go to universities of lesser rank, which may be more willing to compromise on the nature of the work they do and the terms under which they do it, to help address problems with a more immediate time horizon.

MECHANISMS TO FACILITATE AND ENCOURAGE UNIVERSITY-INDUSTRY RESEARCH COOPERATION

Public Policies

An Innovation Mandate

The traditional post-World War II format of U.S. science and technology policy can be characterized as having two main pillars: strong government support for science and basic research, and the encouragement of technology mostly in the context of well-defined missions such as defense, space and energy.[27] Concern for the development of commercial technology was believed to be the more-or-less exclusive concern of the private sector, and government programs targeted at it were rare and controversial.[28]

The year 1980 can be seen as a watershed in technology policy, when the concept of a government mission to promote civilian technology was first articulated in legislation with the passage of the Stevenson-Wydler Technology Innovation Act. This Act had two main programmatic initiatives: a network of non-profit based research centers for industrial technology and a program to encourage technology transfer from the Federal laboratories. Even though the first of these was never implemented and the second took additional legislation--the

---

[27]For a more thorough historical discussion see George R. Heaton "Commercial Technology Development: A New Paradigm of Public-Private Cooperation," Business in the Contemporary World, Vol 2, No. 1, Autumn 1989.

[28]From a broader perspective, the federal government has invested in development of the leading technologies of the day since the early investments in agricultural research that began in the 1860s. The government also supported major efforts, for their day, in mapping and charting the natural resources of the young nation to support mining, fisheries, forestry, and agriculture in the latter half of the nineteenth century. It also began to support commercial aircraft technology in 1915, and had a great deal to do with commercial radio developments in the 1920s. It is in some sense in contradiction to this history that the modern debates over the federal role have been so contentious.

Federal Technology Transfer Act of 1986--to put into place, Stevenson-Wydler can be seen as putting the country, at least conceptually, on a new course. First, it reasoned that there was need for a "comprehensive" policy to "enhance technological innovation for commercial purposes." Second, it endorsed the cooperative paradigm--industry-industry and government-industry primarily--as a major pathway through which innovation could be promoted.

While the eight years of the Reagan Administration were marked by many specific policy accomplishments in the area of technology policy, the idea expressed in Stevenson-Wydler--a broad innovation mandate--was never accepted. In the Bush Administration, however, it came again to the fore in the White House technology policy statement in 1990.[29] In this important statement, the Administration endorsed a public role in support of "generic technology" that would contribute to the country's economic welfare. Although again, the role of universities was not specifically brought to the fore, they were assumed to be an important implementer of this mandate.

Shortly after the Clinton Administration took office, it made clear its adherence to the developing notion of a public innovation mandate.[30] While not differing in any major respect from the consensus that had been developing over the previous decade, the Clinton-Gore policy was noteworthy for the extent to which it endorsed "partnerships" as the mechanism through which its program objectives would be achieved. Not only did this indicate a full acceptance of the new cooperative paradigm of technology development, but it also implied the integration of universities, industry and government into active cooperation.

The change of Congressional majority in 1994 initially cast much of the Administration's technology policy agenda into extreme doubt, and, indeed, a number of the programs have seen significant modifications or reductions in funding. Beneath the rhetoric, however, commitment to an innovation mandate still enjoyed substantial support, and almost all of the cooperative policy initiatives were able to persist. It is within this broader framework of public policy support for university-industry activities affecting innovation that the specific programs discussed below need to be seen.

Intellectual Property Rights

The results of university-industry cooperation are important to industry primarily because of their potential commercial applications. It is well-recognized that a strong intellectual

---

[29]"U.S. Technology Policy," Executive Office of the President, 1990.

[30]"William J. Clinton and Albert Gore, "Technology for America's Economic Growth: A New Direction to Build Economic Strength," Executive Office of the President, February 22, 1993.

property rights system functions as a powerful underlying systemic incentive that underpins application of nearly all research. In the United States, new appreciation of this connection has led over the last few decades to a number of policy changes designed to encourage technological innovation and the university-industry connection by strengthening intellectual property rights.

Certain R&D-intensive industries made a strong case during the 1980s that the U.S. patent system did not adequately maintain its innovation incentive effect for them. Thus, the Congress extended the length of pharmaceutical patents to compensate for regulatory delay, broadened the remedy for process patent infringement in response to pressure from the biotechnology industry, and enacted a new form of protection for semiconductors.

When viewed by international standards, U.S. intellectual property laws have historically accorded strong protection to inventors. As U.S. industry globalized and came under international competitive threats during the 1980s, U.S. policy-makers began to realize that a similar degree of protection abroad would tend to accrue to American competitive advantage. Thus, the U.S. began to pursue a strategy combining harmonization and confrontation to upgrade and bring other countries' intellectual property rights policies in line with its own. In the trade context, for example, U.S. negotiators took aggressive positions to encourage other countries to adopt stronger protections for intellectual property. Japan has been the target of such pressure. More recently, China has been another target, where the United States insisted on its enactment of acceptable intellectual property laws as a condition of continued favorable trade relations.

While relatively strong, U.S. intellectual property laws have also exhibited a few aberrational features according to international norms (most notably, a 17-year patent life and the practice of granting patents to those "first to invent" rather than "first to file"). Particularly with American entrance into the World Trade Organization, harmonization has become necessary. Thus, for example, new patents now remain in force for 20 years, rather than 17 as was previously the case.

The Bayh-Dole Patent Act

The main intellectual property rights initiative directly affecting universities was the Bayh-Dole Patent Act. Indeed, many in the university and industry communities see Bayh-Dole as the public policy with the single largest impact on the incentives to cooperate in R&D. Adopted in 1980, Bayh-Dole changed the patent relationship between the Federal government and its various contractors and grantees. Whereas prior to the Act the government had owned the intellectual property rights resulting from research it funded, Bayh-Dole allowed small businesses and nonprofit institutions (universities, notably) to take full title to such inventions. In 1984 the Act was amended to grant similar rights to university-operated laboratories. The most important aspect of Bayh-Dole, however, was that it also permits government contractors, such as universities, to enter into exclusive licensing arrangements with private firms to commercialize technology developed under government contracts or grants and it permits the university to retain all resulting licensing fees or royalties.

Besides its obvious economic impact, Bayh-Dole also represented an important conceptual breakthrough. Traditionally, the view had been that government-supported research "belonged to the country," and that therefore the government should own the intellectual property rights. Licensing of these rights on a non-exclusive basis was seen as the best way to protect the national interest. Bayh-Dole's paradigm implies just the reverse: that the best way to promote the national interest in technology is to create an incentive for members of the private sector to exploit that technology for their own commercial gain. While public rights are not entirely given up under the legislation, it does represent a major rethinking of the balance between public and private action.

The Bayh-Dole changes have been so uniformly welcomed that they have been extended through various legislative and administrative mechanisms to other areas of science and technology policy. Under the Advanced Technology Program, for example, for-profit businesses can take title to the intellectual property resulting from government-sponsored research. Since many universities participate in ATP and other federally funded research consortia, such provisions have been an important mechanism for stimulating industry-university research cooperation.[31]

4.1.3 Funding for Cooperative Research

Until the beginning of the 1980s, Federal R&D funding had shown little concern with the relationship between universities and industry, and joint work between the two sectors in Federally funded research was unusual. In 1985, the attitudes that had already begun to change bore fruit in an important breakthrough: National Science Foundation initiation of its program of Engineering Research Centers (ERCs). ERCs represented a flowering of the cooperative paradigm in a number of respects and have profoundly changed the university research community.

The ERCs were intended to focus on interdisciplinary problems, provide a bridge across traditional academic departments, and provide a site (and topical focus) for industry and

---

[31]However, ATP's authorizing legislation stipulates that title to any intellectual property resulting from ATP-supported research must remain in the hands of the U.S. firms that received the ATP funds, whether they do so as single firms or parts of consortia that may or may not include universities. Under this legislation, universities are free to strike bargains with their industrial partners to share in royalties and licensing fees but they may not own the patents or other intellectual property. This has been a controversial issue surrounding ATP. See, for example, Christopher T. Hill, "The Advanced Technology Program: Opportunities for Enhancement," to appear as Chapter 6 in Investing in Innovation, L.M. Branscomb and J. Keller, editors, MIT Press, 1997, forthcoming.

academe to do joint work. Over the last decade, this program has been consistently well-received by the university, industry and governmental communities. It now provides a secure institutional footing for university-industry cooperation across a wide range of emerging technologies.

The success of the university-industry cooperation concept prompted its adoption in the funding patterns of agencies other than the NSF. The Department of Defense, for example, adopted incentives for its industrial contractors to cooperate with universities in the multi agency Technology Reinvestment Program (TRP) coordinated by DARPA. The Advanced Technology Program in the Commerce Department (ATP) is particularly receptive to consortia, frequently involving universities and companies together, as recipients of its R&D funding. And laboratories throughout the Federal government routinely seek to involve industry and universities in a wide range of cooperative relationships. In fact, approximately 75 percent of the university-industry research centers in existence at the beginning of the 1990s were established either wholly or in part with Federal funding.[32]

Legal Changes

Although the cooperative paradigm had begun to take root in a widespread way by the beginning of the 1980s, it was often hard to put into practice, given that a wide variety of laws and regulations seemed to impede it. As these came increasingly to the attention of national policy-makers, a number of legal changes were instituted to remove perceived barriers.

Perhaps the most widely discussed and controversial legal change involved modifying U.S. antitrust laws so as to promote research cooperation among industrial competitors. In late 1984 Congress passed the National Cooperative Research Act (NCRA) which established a procedure under which research joint ventures could register with regulatory authorities and thereby diminish both the likelihood of antitrust actions against them as well as the size of potential damages awards, if they were successfully sued. Since the passage of the Act, an average of around 50 research new joint ventures yearly have been registered.[33] Although these ventures have predominantly industry participants, they provide yet another mechanism in which industry and university researchers can join forces that has been actively supported by public policy.

Another policy initiative focused on Federal laboratories. Here, the motivation was to energize the technical capabilities of the labs and move their storehouse of technological results into private-sector uses. In 1986 and 1989, new legislation was passed (the Technology Transfer Act and the National Competitiveness Technology Transfer Act) to encourage this through a

---

[32]NSF, Science and Engineering Indicators - 1993.

[33]NSF, Science and Engineering Indicators - 1993, p. 122.

variety of means. Perhaps the most significant institutional change that has arisen is the development of "CRADAs" (cooperative research and development agreements) between the labs and outside entities. Although, again, the main intention of these reforms was to engage industry, universities have also found CRADAs a useful mechanism for research funding and increased connections with industry.

Tax Policy

The United States, like most other countries, uses it tax policies to achieve a wide range of social and economic objectives. One of the strongest technology-related motivations expressed in U.S. tax policy is the desire to support small businesses and entrepreneurs. Though tax provisions to encourage R&D and university research have been somewhat less popular, they also have been enacted. A perennially controversial subject, such tax preferences are again under discussion in the context of the new FY98 budget agreement whose details are now being negotiated between the Clinton Administration and the Congress.

Many tax provisions apply directly or indirectly to university-industry research relationships. While a full discussion of this subject is beyond the scope of this report, the major tax preferences of this nature are contained in the following list. While they tend to break down into categories relevant to R&D, to university-industry relations, and to technology-based businesses, they also interact and overlap:

- The ability for firms to choose whether to deduct R&D expenses immediately or to capitalize them over time,
- A tax credit for increases in industrial R&D spending above a rolling average of past spending,
- Extension of the corporate incremental R&D tax credit to include research that firms fund at universities (the "basic research credit"),
- Tax deductions for charitable donations to educational and scientific institutions, and especially generous deductions for donations of appreciated corporate stock,
- A wide variety of venture capital provisions that reduce venture capital risks to investors by allowing them to use losses to offset other income and to reap capital gains at a lower tax rate than that applicable to other types of income,
- Provisions applicable to R&D limited partnerships that encouraged a new financing mechanism for R&D start-ups, and
- Tax provisions pertaining to new small businesses--Subchapter S Corporations--that make it easier for them to raise capital and that effectively tax them at lower rates than large corporations.

Many of the above provisions have been in place for some time. However, U.S. tax policy was modified importantly at two points during the 1980s, both to encourage R&D throughout society and to encourage research cooperation between universities and industry. In 1981, Congress first passed the research and experimentation tax credit, which offered a significant tax reduction to companies that increased the amount of their R&D over time. In 1986, the perceived success of this provision in stimulating R&D led to its extension to basic research and industrial contracts with universities. The 1986 amendments were seen by many as both a desirable and necessary step, since, without them, industry had a financial incentive to keep R&D in house rather than contract it out to universities. The establishment of tax neutrality between these two forms of R&D represented an important addition to the overall policy package that developed during the 1980s to facilitate university-industry cooperation.

At the moment, U.S. tax policy is again under scrutiny and may change in the context of the budget agreement now being implemented by the Administration and the Congress. A substantial benefit would accrue to universities if proposed higher education tax credits were enacted, although this would pertain to the teaching, not the research side of universities. Small business capital gains and inheritance tax provisions are also being considered for change, to allow entrepreneurs to reap and pass on the rewards from their investments. Whether such provisions are equitable or affordable in the context of budget deficit reduction is now a major issue under debate. While the outcome is not clear, both the Administration and Republicans support some form of tax relief along these lines. And, few contest the consensus view that such measures are effective incentives to R&D and innovation.

Private Mechanisms

Grants and Contracts

The most straightforward mechanism by which industry supports university research is direct funding via grants and contracts. The evolution of industrial funding from an early tendency toward grants to today's more-prevalent contracts has been discussed above. Both grants and contracts still exist in the system, but with somewhat different objectives. By and large, grants are much the more permissive mechanism, and often take the form of broad institutional support without an expectation of specific research results. This is not to say, however, that industry makes grants to universities with no hope of benefit; quite the contrary is true. However, the nature of the grant relationship is such that industry's expectations are more open-ended and diverse than in the contractual setting, emphasizing access to people and knowledge rather than concrete results of commercial relevance. Since there is no centralized reporting of such relationships, it is not possible to estimate their overall number or the amount of funds involved.

University Technology Licensing

With few exceptions, the traditional posture taken by research universities toward the technologies their faculty developed was simply to assist faculty in obtaining patents. Thus, most technical schools had university Patent Offices, and little else. Around a decade ago, this began to change. As firms approached universities more frequently, as new industries such as biotechnology emerged that were based largely on university research, and as public sources of research funding were threatened, universities began to consider new mechanisms to profit from their discoveries.

The result of these trends has been the widespread establishment of "technology licensing offices" in research-based universities. Technology licensing offices go considerably beyond the patenting function, although this still plays a role. At the beginning of university-industry cooperation, the licensing offices frequently play a role in establishing the contract between the institutions. At the end, the office would typically conclude and administer licensing arrangements between the parties, and would receive royalties from the company side. Even where no *a priori* research contract is in place, the licensing offices will typically seek licensees for faculty inventions which seem likely to be attractive to industry. These offices thus function as valuable intermediaries--almost a university sales force, making mutually beneficial matches among faculty, the university itself, and industrial exploiters of the technology in question.

Technology licensing offices seem to offer a successful mechanism to cement university-industry relations and make money for the university and its faculty through technology commercialization. Although there are no data available, informal estimates put the revenues of one, the MIT Technology Licensing Office, at between $5 and 10 million yearly. While MIT is probably at the upper end of the scale of returns to universities from intellectual property, to the extent that it is representative, the value of this and other similar offices to the U.S. economy and to higher education is significant.

University-Industry Research Centers

Among the various mechanisms by which university and industrial research connect, campus-based research centers receive by far the largest amount of funding: in 1993, $2.7 billion out of an estimated total of $4.3 billion, or about 63 percent. There are now more than one thousand university-industry research centers in the United States, engaged in a wide variety of activities across virtually the entire spectrum of industrially relevant R&D.[34] There does, however, appear to be a high degree of concentration in their technical focus, with 42 percent of the centers doing work of relevance to chemicals and pharmaceuticals, 35 percent working on computer-related subjects, 29 percent on electronics, 29 percent on petroleum, and 26 percent on

[34] Ibid.

software. Industry seems to look to the research centers for work that is more basic than what it does in house. Centers expend about 43 percent of their effort on basic research, 41 percent on applied research, and 16 percent on development.

Universities report that the main reason they seek industry support is to offset inadequate research funding from government. At the same time, university-industry research centers continue to rely to a significant extent on government funding. Of the total funds for such centers in 1990, approximately 46 percent came from the Federal and state governments, and 72 percent of the centers received such funding. This degree of public support emphasizes again the degree to which public policies in the United States have been an important facilitator of university-industry ties.

Consulting and Informal Relationships

A wide range of less-formal contacts between people in industry and academic researchers cement the university-industry relationship in ways that are hard to measure, but probably of equal importance to any other mechanism. Indeed, participants in university-industry rate such contacts (along with collaborative projects) as the two most effective mechanisms for technology transfer.[35] Informal contacts can range from person-to-person discussions, to dissemination of university publications, to symposia and other outreach programs. In some places, these activities have become institutionalized in "industrial liaison" programs operated by universities for industrial members on a subscription basis.

Consulting arrangements between individual faculty members and industrial firms constitute perhaps the most important of all the informal mechanisms. While data on their numbers and dollar value do not exist, it is safe to say that such relationships are both widespread and highly valuable, both to the firms and the faculty members, for whom consulting fees result in increased income. Many universities actively encourage the formation of consulting relationships through their industrial liaison programs. Virtually all universities facilitate them through policies that permit faculty members to spend a certain percentage of their professional time in consulting work. This time is seen not only as a way for faculty to benefit financially but also as a mechanism through which the value of university work is made clear to industry. The development of such relationships rests on the perception of faculty members as relatively free agents. Nevertheless, universities monitor them and implement policies to ensure that they do not create conflicts of interest with teaching or other university functions and opportunities (see discussion of management issues below).

Spin-Offs

"Spin-offs" are technology-based firms that trace their existence with a high degree of

---

[35]Ibid.

immediacy to knowledge or technology originally developed in a university setting.[36] Spin-offs are frequently started by faculty members who leave university work to start their own companies, but a significant proportion of them involve faculty members who participate on a part-time basis, while retaining university employment.

The spin-off phenomenon is well-recognized in the United States as one of the main sources of technological dynamism. It is permitted--even encouraged--by universities through their personnel and contracting policies. In particular, faculty members and other researchers are routinely engaged in soliciting outside funds to supplement their salaries, support students and fund laboratories. They enjoy a high degree of independence in how they spend their time and in how they set their research agendas, and they rarely assume that they will be employed at the university for their entire career. Spin-offs are also facilitated by public policies, particularly tax laws that make investments in new small businesses potentially lucrative undertakings for both the entrepreneurs and passive investors.

One of the noteworthy features of spin-offs is their apparent concentration in a relatively small number of geographical areas and universities. MIT, one of the best-known generators of spin-offs, has recently published a study of the impact of MIT spin-offs on job creation and other associated results. MIT estimates that about 150 new companies each year are founded by its graduates and faculty. About four thousand MIT-based companies exist today, and their revenues are equivalent to "the 24th largest economy in the world."[37]

The character of spin-off companies appears to differ significantly from typical firms. MIT's spin-offs are preponderantly in areas at the leading edge of high technology. They are, thus, highly important to the future direction of the U.S. economy.

Spin-off firms are, of course, nurtured by many elements of the technical, financial, governmental, and social systems of a country--not only by their university home. Thus, a complete understanding of the spin-off phenomenon goes far beyond this report's focus on university-industry relations.

DISTINGUISHING FEATURES OF THE UNIVERSITY-INDUSTRY RESEARCH SYSTEM

The pattern of university-industry research relationships in the United States is best seen as a system that has developed incrementally over time and now serves a diversity of purposes. A few types of actors -- firms, faculty, universities and the government -- play roles of approximately equal importance, and pursue distinct institutional needs. But it should be

---

[36]Spin-offs can also come from government laboratories or private firms.

[37]MIT News Office Report, p. 1.

emphasized as well that the motivations and initiatives of individuals are an equally if not more important underlying driver. The components of the system are both highly interactive internally and with external systems -- government research, university education and industrial technology development most notably. While prior discussion in this report has examined particular features of the system, this chapter seeks to identify a number of key features of its overall structure that distinguish the U.S. system most clearly from those elsewhere in the world.

Absence of Centralized Control

Unlike most countries, the U.S. system of higher education has never had 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 predominantly comprised of private and state-chartered institutions. This absence of centralized control has bred a system that is highly diverse, dynamic, and relatively unwieldy. This is not to say that public missions have not influenced the direction of university research; in fact, quite the contrary is true. One can even make the case that national research objectives such as agriculture, defense or health have been as successful as they have been precisely because the university sector has responded to them as incentives rather than as directives from a single powerful agency that could plan and allocate research resources.[38] 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.

Faculty Members as Free Agent-Entrepreneurs

The contractual and funding arrangements pertaining to faculty and other researchers in US research universities constitute another of the distinguishing features of the university-industry relationship. Perhaps the most basic reality is the extent to which faculty operate as free agents. While faculty members and researchers are expected to bring funding into the university, the sources of such funds--foundations, industry, or government; domestic or foreign--are of relatively little concern to the institution. Universities do have procedures to guarantee research appropriateness, openness, and the like. But it seems fair to say that these give wide latitude to the arrangements faculty members propose. Going further, flexibility and freedom in the establishment of research formats--individual, cooperative, externally-oriented, etc.--is affirmatively encouraged by universities through institutional structures, such as laboratories and multidisciplinary centers, that bridge and extend the traditional academic departmental framework.

[38]The United States experimented with a single agency to allocate government (and, to some extent, private) R&D funds during World War II when all energies were focused on a single objective, but it was eliminated shortly after the war's end and the attempt to create a National Research Foundation to continue in this role failed.

The practice of university researchers functioning as free agents carries with it the corollary that there is little assured research funding. Faculty positions, although funded as full-time employment, carry with them no expected research stipend, and research positions are typically dependent for their very existence on external funding. In either case, the researcher must thus become an entrepreneur, generating funds for projects from external sources. The ability to do so is often one of the major determinants of academic career success.

The combination of the free agent and entrepreneur mentalities comes together most forcefully in university policies relating to faculty consulting. These are highly permissive, allowing virtual free rein, and a significant amount of time (20 percent is a widely observed norm), provided that they do not create a conflict of interest with university opportunities or impede, through time conflicts, the performance of university duties.

High Mobility of Personnel

While the personal mobility of Americans in all aspects of national life is well-recognized, there are some particular manifestations of this general phenomenon that impart a unique character to the university-industry research system. Faculty employment in American universities has long been premised on career change. Only a fraction of those hired as faculty in any year can expect to receive tenure, so all are faced from the time of first employment with a reasonable probability that they will have to find another position in a few years. Even among established senior faculty, mobility within academe has become quite common, particularly in recent years, as major universities compete for "star" faculty, whose status is often determined by the amount of external research funding they can gather and transport from institution to institution.

Irrespective of employment prospects within universities, many technical researchers opt at some point in their career to leave academe for industry. Often, this is to establish their own technology-based companies--the well-recognized "spin-off" phenomenon. Besides offering such important benefits in the generation of new technology, these spin-offs tend to cement the relationship between universities and industry through personal contacts, employment and continuing research cooperation.

The last notable aspect of personnel mobility is the movement of senior industry personnel into university employment. Noted perhaps first during the 1980s, when universities began to turn many of their programs toward issues affecting the competitiveness of U.S. industry, career patterns in which senior industry executives move into academic posts have now become common.[39] Often, such positions differ from traditional faculty slots, emphasizing

---

[39]In engineering, it has long been the tradition for new doctorates to spend a few years working in industrial R&D, before taking a junior faculty position, to “learn first hand how

teaching, mentoring and external relations more than scholarship. They are typically seen as highly desirable, and offer a uniquely effective way to strengthen ties between firms and universities.

The Sponsored Research Tradition

The development of university research in the United States over time has resulted in the organization of most research into specific projects supported through grants and contractual arrangements that are referred to as "sponsored research." The establishment of standard operating procedures and administrative institutions to facilitate sponsored research has done much to make the system of university-industry relations work smoothly.

Sponsored research in U.S. universities in basically a long-term outgrowth of public policy, in which the government drew on university capabilities to satisfy many national technical needs. Even today, the sponsored research programs in universities are molded significantly by this tradition, irrespective of the source of funding. Four main features of this tradition stand out, each of which contributes to a fruitful climate for industry-university cooperation:

- Research defined and funded as projects rather than as institutional or individual grants,
- Expectations of research outcomes that are reasonably well defined in advance through contracts,
- The belief that each side--the performing institution and the funding source--should reap benefits from the research enterprise, and
- Organizational units within universities adept at processing funding and contractual arrangements to facilitate sponsored research.

Peer Review

Peer review is one of the most fundamental aspects of the U.S. research system. It functions not only as a mechanism for making choices among potential research performers but also as a way of encouraging excellence. The peer review system rests on a widely acknowledged competitive reality--the sum of the demands for funding from competent researchers will exceed the available funds. To foster confidence that the system is making the "right" choices, and to avoid resentment on the part of the inevitable "losers," it is necessary to have a decision process and criteria that all participants can accept. Peer review, by and large,

---

industry works." Until recent years, however, it was the view in academia that researchers would no longer be qualified for teaching positions after a few years of industrial experience.

fulfills this function well in the U.S. context.

Three main characteristics of the system should be highlighted. First, the concept of peer review assumes that funding decisions should be made as much as possible on the basis of technical merit, rather than on less objective criteria such as research "relevance," institutional factors, or personal attributes. Decisions about technical merit are believed to be best made by those most expert in the field of the research; i.e., the "peers" of the proposer. Second, the system is designed to be as open and fair as possible, allowing a wide range of potential researchers into the competitive process and protecting against procedures that would smack of favoritism. Third, the system enlists a wide spectrum of the research community by calling on members of the relevant discipline(s) as reviewers for particular projects.

Peer review, like many other aspects of the U.S. research system, was developed to its current level of sophistication for use in allocating funds for government-sponsored research, and it is widely accepted in the university research community.[40] In industry, on the other hand, where criteria other than technical excellence loom large in deciding which research projects deserve priority, peer review is less widely accepted as a means of making allocation decisions.

It is important to emphasize that peer review is not designed as an egalitarian process, in the sense that it does not lead to an allocation of research resources in a proportional manner. Nor does it promote institutional continuity, since the competition for funding always recurs. It does, however, allow for new entrants into the research system--provided their work is good--and is thus a powerful force for quality and dynamism wherever it is employed. Not least for this reason, its acceptance in the United States remains solid.

ISSUES IN THE MANAGEMENT OF UNIVERSITY-INDUSTRY R&D COOPERATION

R&D Cooperation Is Not Problem Free

The previous sections of this report have painted a picture of R&D cooperation between universities and industry, with government assistance and participation, as a thriving and healthy part of the U.S. scientific and technical infrastructure. This picture is accurate, but it is not complete. R&D partnerships among different institutions, and especially among institutions with such fundamentally different goals as universities, companies, and government agencies challenge all of the participants to pay close attention to the appropriate limitations of such relationships and to the need to manage them carefully lest they bring substantial difficulties to

---

[40]Even for government funding, for which societal concerns, such as the race or gender of the investigators or the region from which they come, need to be addressed, peer review is sometimes criticized for its tendency to reinforce the dominance of existing players

any of the parties.

The emphasis in the open discussion of problems and issues in university-industry cooperation in the United States is on problems that can arise for the university. This is probably a natural outcome of such concerns since universities are the more open of the two types of institutions and serve a more diverse set of social and personal agendas than do most firms. On the other hand, such cooperation can also raise management issues for the firm. In this section, we touch on a few of the more visible and vexing issues that have arisen frequently in the context of university-industry research cooperation. Each of these topics has been the subject of a great deal of discussion and some limited empirical study. We only raise the issues here--we make no attempt at summarizing the extensive literature on each of them.

Issues for Universities

Effects on the University's Roles in Society

Universities play many roles in complex modern societies: they educate students, discover new knowledge, and assist in the application of knowledge. Of equal importance to these key roles, however, universities are places that at their best encourage critical thinking and analysis of all cultures and societies, including the ones of which they are a part. This critical thinking, which serves as a brake on political enthusiasms and ill-formed popular ideas as well as a wellspring of new ideas and concepts, is at greatest risk precisely when universities most closely embrace the goals of established social institutions, whether it be the military, the clergy, professional sports, or technology-based industry.

As faculty and top administrators champion the cause of university-industry R&D cooperation, they also must attend to whether that cooperation undermines the critical analytical role of the institutions. This can happen in the short run as bargains are struck that, for example, permit industrial sponsors a period in which to review publications before they are made public. In the longer run, as university finances and prestige become more entangled with industrial partnerships, subtle pressures may be put on faculty and students not to be overtly critical of the very firms and industries with which the university is engaged.

The rise of the paradigm of cooperative university-industry R&D has occurred during a period in which faculty and students have been relatively quiescent politically. As noted above, it probably could not have emerged in the 1960s and early 1970s when universities were much more visibly serving as cauldrons of societal criticism and discontent with the established order.[41] It is not clear whether universities have become more tranquil because of university-

---

[41]Just three decades ago, U.S. campuses were wracked with vociferous opposition by some students and faculty to the presence of recruiters on campus representing major corporations that were also defense contractors producing materiel for the war in Vietnam. Today, some of those same campuses tout their wide-ranging R&D cooperation with some of

industry cooperation or whether a period of tranquility has facilitated the new paradigm. In any event, at the current time, there is relatively little opposition on campuses and among their supporters to closer ties with industry. That which does occur is typically episodic and driven by concerns over the terms of particular arrangements rather than on broader philosophical grounds.

A related concern is that the promise of monetary reward may divert faculty and students from doing the sort of far-reaching research that offers great social pay-off but offers only limited personal gain. Most theoretical work has this characteristic--it may be very widely useful, but typically it is not patentable, so its authors stand to gain little financially from doing it.

Conflicts of Interest

The first duty of university faculty is toward their students--to ensure that they learn in an atmosphere of both challenge and support and that they obtain the skills necessary to succeed in their chosen life=s work. Their second duty, and one very close to the first, is to the freedom of inquiry and the development of new knowledge and new understanding. One consequence of the way these duties are executed is that faculty tend to have greater allegiance to their disciplines and to the international community of scholars who are their peers than they do to the institutions for which they work. Thus, conflicts of interest are inherent in the structure of academic disciplines and the universities.

---

those same corporations. The same change has occurred on many campuses in the relationships of the university to the Department of Defense. An important difference is that, today, university administrations are much less hospitable to classified R&D projects than they were three decades ago.

Cooperating with industry can raise a multitude of potential new conflicts of interest. For example, the opportunity for personal and institutional profit arising from the Bayh-Dole Act=s assignment of intellectual property to university grantees can lead to withholding of new findings from the larger community pending assurance that patents have been applied for or that trade secrets of partner firms have not been compromised. This can mean that faculty, staff, and students engaged in potentially profitable research may not even be willing to share new ideas and findings with colleagues in the next office or laboratory. Further, it can mean that conflicts are engendered over who, exactly, should benefit from commercially valuable results--should it be the faculty, the students, laboratory technicians, other unfaculty, or university administrators? What obligations does a faculty member have to share his personal rewards as a consultant or a participant in an R&D cooperative activity on campus with his students or his colleagues?

Sustaining Faculty Commitment and Quality

There is a down side to the highly vaunted mobility of university faculty in the United States--those who are successful at cooperation with industry may be drawn into industrial employment by the promise of higher pay and other advantages of industrial careers. There is some concern that the very best faculty may work on relatively trivial, but lucrative, industrial problems at the university or may leave the university for more attractive industrial positions. At the same time, some concern has been expressed that the pressure to make themselves more attractive to industry may lead universities to hire new faculty who are skilled at working with industry but not at fundamental inquiry or at nurturing young, inquiring minds.

University Over-Promising and Overreaching

There is some risk that universities and their faculty may promise more to industry and government than they can actually deliver--the kinds of skills and knowledge that faculty and students have may not be all that valuable or important to addressing real industrial needs. Success in industry involves a great deal more than having knowledge of new technologies, yet some in academia would appear to believe that, if they have developed new knowledge, they are entitled to a very large share of the future profits that can be derived from its exploitation. In the late 1990s, one hears more criticism of universities of this sort from industrial partners, who think that the universities seek to reap overly large licensing fees or royalties from the intellectual property they have created. It is difficult to assess the validity of such claims, however, since, presumably, both the university and the firm(s) involved are free to negotiate such fees, and, if the university seeks too much, the firm can refuse to agree to the terms offered.

Issues for Firms

Fairness of Access to University Research

If universities are to cooperate with industry and to make their valuable talents available in the pursuit of commercializable new technologies, then the question arises as to which firms will have the opportunity to work with which faculty and which institutions on what terms. After all, all U.S. research universities--public and private--are supported to a substantial extent by public funds obtained in part by taxes on corporations. Under the pre-Bayh-Dole paradigm, the results of university research were typically available to all firms on equal terms through publication in the open literature or the issuance of non-exclusive licenses by the government agencies that took title to the intellectual property developed with public funds. Under the new paradigm of cooperative R&D, however, the new knowledge is typically delayed and watered down in publication and is available on favorable terms only to those firms that participated in its development. Firms not party to the agreements can find themselves shut out of the benefits of the new knowledge if exclusive licenses are awarded to another firm.

Closely related to this concern is the fact that the Bayh-Dole Act essentially facilitates the conversion of public funds to private gain via their use to generate new technology in universities that is controlled by intellectual property owned by the university or its industrial partners, not the public.

Beneath the surface of successful university-industry cooperation in research lies a longer-term potential problem--does dependence of industry on new knowledge from external sources, including universities, contribute to a long-term decline in the capabilities of firms to generate and make effective use of new developments in science and technology? Will they become overly dependent on these outside sources, and, thus weakened, become vulnerable to commercial attack by other firms that have eschewed external dependence and maintained internal strengths? Very little has been done to assess what happens to firms that participate heavily in R&D partnerships, and much research remains to be done in this area to ensure that firms do not make long-term strategic mistakes in the name of the apparent efficiency and effectiveness of externalizing sources of new technology.

Commentary on the Issues

The issues discussed above are real, although their severity is in considerable question. A number of studies have found, for example, that the most productive faculty on traditional measures are also those most likely to be engaged in university-industry cooperation. At the same time, studies have found an increasing tendency for universities to permit extended periods of review (say, 90 to 180 days) by industrial partners prior to release of new results for publication. Faculty and students report that colleagues have become more likely to withhold interesting ideas and new results until property rights have been secured.

On the larger screen, the end of the great ideological struggles between market-based democracies and collectivist or authoritarian centralist political-economic systems has seemingly drained the universities of much of the political and ideological controversy in which they were embroiled in the 1960s and 1970s. Perhaps they see themselves today as one of the more successful elements in the triumph of liberal economic ideology in much of the world, so that their partnership and cooperation with industry now seems more like the natural order of things than like an affront to critical analysis as it did in the earlier era.

Nevertheless, continued vigilance is essential to ensure that the traditional roles of the universities and industry are protected and preserved, even as they seek ever richer modes of cooperation in their perceived mutual interests.

CONCLUSIONS: THE NEW EQUILIBRIUM OF UNIVERSITY-INDUSTRY RELATIONSHIP IN THE UNITED STATES

The character of university-industry research relationships in the United States has shifted dramatically over the course of the last two decades. From a relative rarity in the early 1970s, collaborative research and related activities have now become fixtures of both academic and industrial practice, as well as a deliberate objective of public policy. A widespread consensus supports close university-industry relationships, and a great deal of institutional and personal energy is now vested in their continuation. A new equilibrium seems to have been reached in this arena--the U.S. system of university-industry relations will continue along its present course for the foreseeable future.

The practice of university-industry research cooperation has become so deeply ingrained in the American system today that a widely quoted 1996 study by the Council on Competitiveness, The Endless Frontier, recommends R&D cooperation as the most effective approach for managing and addressing a wide range of perceived problems in the U.S. science, technology and economic development systems.

The movement toward this new equilibrium can be seen both as an evolutionary response to changed circumstances and as a result of deliberate choices and strategies on the part of government, universities, and industrial firms. The externally changed circumstances fall into three main categories:

- Conceptual change in how the process of technological innovation has been viewed; particularly, the shift from envisioning innovation as arising from a linear process of independent technical discovery to one in which cooperation, external connections, and feedback loops are essential,

- Weakening Federal support for university research, at a time when the costs of research and demands for research funding have grown; coupled with industry's increased willingness to fund--and academe's alacrity in accepting--university based cooperative research, and

- The passing of an era of confrontation, particularly strong during the 1970s, in which industry and government were often at loggerheads over regulatory issues, and industry and academe often viewed each other warily; replaced for the most part by an ethos that emphasizes the benefits of cooperation across some still-wide institutional divides.

While it is likely that much of the current climate in university-industry relationships would have developed in response to the above factors, it is also true that a few visionary leaders, a few institutions, and a few policy changes have been pivotal in setting and accelerating this new course. Advocacy by Erich Bloch, first as a vice president of IBM and later as director of the National Science Foundation, led to the formation of the Semiconductor Research Corporation (a consortium of semiconductor-related firms that funds university-based research) and to the NSF Engineering Research Centers, both of which set a new tone and context for university-industry cooperation. Bloch is also a central figure in the Council on Competitiveness report cited above. William Norris, chairman and CEO of Control Data Corporation, was an early champion of cooperative research whose efforts were instrumental in formation of the Microelectronics and Computer Technology Corporation (MCC). And, among universities, MIT's Industrial Liaison Program (ILP) is noteworthy for the breadth of its membership across industries and countries as well as the diversity of the university-industry relationships it has facilitated. The point is not that Bloch, Norris, and the MIT ILP alone were responsible for the new paradigm of cooperative research. It is that in the United States strong advocates and powerful and successful examples are central to the maturing and proliferation of policy innovations throughout the system.

Public policy changes have also stimulated closer ties between universities and industry in the United States. These have focused on creating an appropriate climate at many levels. The Stevenson-Wydler Technology Innovation Act of 1980 is the leading example of legislation that sought to establish a federal government mission to promote technological innovation in industry. At the other end of the scale, highly specific changes were made to antitrust, environmental, and intellectual property law. Funding practices and priorities were changed as well, to emphasize cooperative research. A wide range of public policy changes--in operating style as well as in specific programs--was also necessary to reinforce and diffuse the new paradigm of university-industry cooperation.

Although individuals, institutional exemplars, and public policies have all contributed to the establishment of the new paradigm, it must also be attributed in large part to changed practices in many American firms. A keen awareness has developed that today's technological innovations draw on a wide range of technical expertise, that they are often more science-based than in the past, and that, therefore, they are significantly more complex. The "problem-space" of individual innovations is perceived to be considerably enlarged, requiring a "fusion" of expertise, beyond that available to even the largest, most technically sophisticated firms. Faced with this reality, firms have increasingly reached out to acquire the capabilities universities can provide, viewing them as one among many crucial external sources of knowledge. Firms also understand that partnerships with universities can enable them to reduce in-house spending on basic research. Public policies have frequently provided institutional means toward realizing these objectives, through, for example, the NSF ERC's, as well as incentives that make cooperation less costly, through, for example, extending the basic research tax credit to cover industry funding of university-performed research.

Another category of American firms has benefited enormously from the university-industry connection: high-technology start-ups. Three main factors have been critical in encouraging the commercialization of technology in this manner: the public policy climate--tax and fiscal measures mostly--that favor investments in new firms; the personnel and funding practices of universities that engender a climate of mobility and entrepreneurship; and the intellectual property laws--the Bayh-Dole law most notably--that allow universities and their employees to profit from the exploitation of technologies they develop with government funds.

The university community is somewhat more ambivalent toward the new equilibrium. Indeed, prior accepted practice, in which government largess made it easy for university researchers to finance projects, may well have been a more comfortable position for many in academia. On the other hand, the period of easy grant money belongs irrevocably to the past, and many of today's academic researchers find the new climate, in which their research may have immediate relevance in the industrial world, both more stimulating and more profitable.

Looking to the future, the new climate for university-industry R&D cooperation in the United States will undoubtedly encounter obstacles and challenges. Tensions will arise as each side of the triangle--university, industry, government--seeks to further define its appropriate role and enhance the benefits it receives from cooperation. Situations will arise in which the institutional imperatives of one group will come into conflict with the others'--industry's natural desire for secrecy and academe's tradition of open publication provide an ever-present example. But given an underlying consensus that the new equilibrium in U.S. university-industry relationships is fundamentally sound, issues such as these represent micro-level problems that can be managed, more than harbingers of a change of direction. In sum, a stable relationship can be expected for some time to come.