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STRENGTHENING UNIVERSITY-INDUSTRY INTERACTIONS,(U)
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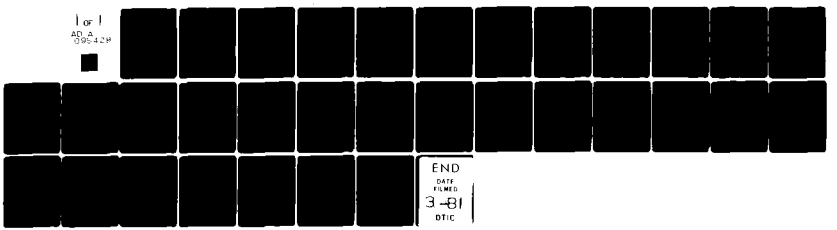

STRENGTHENING UNIVERSITY-INDUSTRY INTERACTIONS

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SUMMARY

While there is general agreement that stronger university-industry interactions are desirable and in the public interest, these interactions are in fact only means for achieving other ends. The promotion of industrial innovation is the goal of most immediate interest to government, but closer links can also support regional economic development, improve R&D results for government programs, and enhance national research efforts, as well as provide direct gains to universities and firms. Clarity of objectives is the first step toward designing sensible policies or programs.

Three broad approaches to strengthening university-industry interactions to promote industrial innovation are direct corporate funding of university research, cooperative (cost shared) research, and measures to enhance knowledge transfer and the exchange of people. Government actions that could encourage more direct corporate support of university research include clarifying antitrust guidelines for industrial consortia and providing tax credits or federal matching grants. Tax credits or matching grants usefully stimulate the industrial demand for R&D rather than the university supply, but there are no good estimates of their likely effects on total R&D spending or on the federal budget. Means to encourage industrial gifts or sharing arrangements that will upgrade university research equipment deserve particular attention.

The Innovation Initiatives recently announced by the White House would create "generic" technology centers to conduct applied research on commercially relevant technologies. The centers would be modelled largely after the successful Polymer Processing Program at MIT. Industrial cost sharing and a planned phase-down of federal support after five years would appropriately link these university-based centers to the private sector. How many such centers could emulate the MIT program's success remains to be determined, however. Other (not mutually exclusive) cooperative research options include establishing

university-based regional technology centers and expanding industrial participation in national research facilities and programs.

Strong university-industry links depend on the free flow of information, ideas, and people between the two sectors. Government actions may help these flows, but they also may hinder efforts to work out bilateral, mutually advantageous relationships. In many cases, the best government policy may be to step out of the way and let universities and firms negotiate their own arrangements.

Although we have scant knowledge about how university-industry interactions affect industrial innovation, enough seems to be known to support some modest additional efforts by the federal government. Both universities and industrial firms appear ready to welcome such efforts. Modesty, however, is not the hallmark of new political initiatives; consequently, one must beware the danger of overselling university-industry collaboration as an innovation "breakthrough." Direct measures to increase the economic returns from innovation would probably bring more substantial results than programs to strengthen university-industry links.

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INTRODUCTION

This paper explores potential government roles and policies for strengthening university-industry interactions in the United States in support of industrial innovation and other national goals.* It extends the author's earlier analysis of university-industry relationships written for the National Science Foundation-sponsored study, *The State of Academic Science* (Baer, 1978).

The paper discusses policy issues relating to university-industry interactions, the current state of knowledge regarding these issues, and government policy options for dealing with them. While the intent is to provide a neutral view, based on the author's own research and review of the recent literature, at least two recurring themes (or, perhaps, prejudices) are worth noting in this Introduction. First, the basic objectives, management styles, and reward structures of universities and industrial firms differ, and consequently present real barriers to closer interactions. These differences lie at the heart of our pluralistic and still relatively successful system of research and innovation. Proposals to develop closer relationships by making universities more like industrial firms, or vice versa, seem neither conceptually sound nor practically likely to succeed. Rather, efforts to strengthen the links between the two sectors must take into account, and be consistent with, their differing incentive structures.

Second, although the federal government plays an increasingly pervasive role in all research sectors--as evidenced by new regulations governing laboratory safety, employment and promotion practices, and fiscal accountability--strong university-industry links depend principally on the free flow of information, ideas, and people between the two sectors. Government actions may help these flows, but they also may hinder efforts to work out bilateral, mutually advantageous relationships. In many cases, the best government policy may be to step out of the way and let universities and firms negotiate their own arrangements.

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POLICY ISSUES

This section discusses issues surrounding the *objectives* of government policies toward university-industry interactions, *means* of strengthening these interactions, appropriate federal government *roles*, and specific policy issues surrounding government efforts to promote industrial innovation.

Policy Objectives

A first issue is to define clearly the goals of strengthening university-industry interactions. While nearly everyone agrees that closer relationships are desirable and in the public interest, these relationships are in fact only means for achieving other ends. A short list of such objectives includes:

1. Promoting industrial innovation. Concern about lagging U.S. innovation seems the principal factor driving the increased government attention to university-industry relationships. The President's Domestic Policy Review (DPR) of industrial innovation, as well as the proposed Innovation Acts introduced in Congress in 1979 (S.1250 and H.R.4672), reflect this emphasis on improving U.S. industrial productivity, employment opportunities, and economic competitiveness in general. Although causal relationships are difficult to establish, the conventional wisdom believes that strengthening university-industry interactions will lead to increased innovation.
2. Supporting local and regional development. While often conjoined with the innovation objective, considerable local, state and Congressional interest in strengthening university-industry links seems directed toward promoting local employment and industrial development. Congress seems particularly eager to support university programs for aiding public services and small businesses in the local area or region.

3. Obtaining R&D results for government programs. Strengthening university-industry interactions may bring about improved or more rapid R&D results for defense or other programs in which government is the user as well as the sponsor of the R&D.
4. Supporting an appropriate national research base. The now familiar public goods argument for government support of non-appropriable, basic research also makes the federal government responsible for determining the appropriate level of research. Although universities perform the bulk of the nation's basic research, industrial firms are important contributors in many fields. Consequently, strong university-industry links, including industrial support of research at universities, can help assure that the total level of research is inadequate for society's needs.
5. Providing support to universities. Stronger links to industry, represented by increased industrial funds for academic research and education, may become increasingly important to universities. Although firms provide only about 3 percent of university budgets today, industrial payments for continuing education and training could be a significant source of direct university support in the 1980s. Moreover, industrial support of academic research can help buffer universities against fluctuations in federal and state research funds.
6. Improving university training. Inadequate coupling of university education in science and engineering to industrial needs has been a recurrent complaint of industrial research managers. Although universities seek to offer students more than just training for industrial careers, closer university-industry interactions can both increase the relevance of academic education and lead to more realistic expectations within each sector.
7. Upgrading industrial R&D. Since much industrial R&D is proprietary and not subject to outside review or criticism, quality control is a persistent problem. Closer links to

universities give industrial scientists and research managers better opportunities for constructive peer review and "yardstick" measures of performance. Interactions also enable firms to compete more effectively for top-flight university graduates.

Government reasons for seeking stronger university-industry interactions may differ from those used to develop the links in the first place. How to make government policies consonant with university and industrial interests and incentives represents an important policy issue. Explicit recognition of the policy objectives served is the first step toward developing sound strategies for government intervention.

Means to Strengthen University-Industry Interactions

A closely related issue is which means of strengthening university-industry links best support the various policy objectives. A large number of collaborative mechanisms has been tried or proposed. Table 1 attempts to relate these means to their policy goals. Of course, particular programs such as cooperative research can support several objectives simultaneously. The table is not intended to provide an exhaustive or definitive taxonomy, but rather to permit comparisons among programs with similar objectives, and to serve as the basis for further discussion below.

Appropriate Roles for Government

When should government involve itself in R&D relationships between universities and private firms? Government agency production of public goods, where the agency directly uses the R&D results, presents the clearest case. Government efforts to strengthen university-industry interaction in support of specific government agency goals are illustrated by the Department of Defense Advanced Research Projects Agency (DARPA) "coupling programs" in materials R&D. Support of national research programs or research facilities involving both university and industrial participants represents another example

Table 1. POLICY OBJECTIVES OF MEANS TO PROMOTE UNIVERSITY-INDUSTRY INTERACTION

Means to Promote Interaction	POLICY OBJECTIVE						
	Promote Industrial Innovation	Support Local and Regional Development	Obtain R&D Results for Government Programs	Support National Research Base	Provide University Support	Improve University Training	Upgrade Industrial R&D
Direct corporate funding of university research	P				S		P
Cooperative (cost-sharing) research programs	P	P		S	S	S	
National research programs or facilities	S		P	P			
Small business R&D	P	P					
Extension services	P	P					
Innovation centers	P	P				P	
Technology licensing & brokerage programs	P				P		
Academic consulting to industry	P						P
Advisory boards & visiting committees						P	P
Exchange of people (academic sabbaticals in industry; visiting professors from industry)	S					P	P
Corporate fellowships at universities					P	P	
Continuing education and training	S				P		P
Industrial associates programs	S				P		
Industrial parks near universities	S	P				S	P

P = Primary objective
S = Secondary objective

(see p. 22).

Similarly, government may want to encourage industrial financial support of universities as a public good, over and above the effects such support may have on industrial innovation or regional economic development. This is the rationale underlying tax deductions for corporate contributions to universities. It could be extended to argue for special tax credits or other subsidies for industrial research funds spent at universities (see p. 17).

When private sector firms are the primary users of university R&D results, a nonappropriability or market failure argument must be used to justify government intervention. As a general principle, intervention is warranted when the net social benefits are positive and exceed the private benefits that would be expected without government action. The NSF Industrial Program has presented this argument well in its 1978 Program Report. However, applying it to government programs to promote industrial innovation or support economic development raises a number of specific issues, as outlined below.

Issues Relating to Promotion of Industrial Innovation

As illustrated in Table 1, primary means of promoting industrial innovation through university-industry interactions include direct corporate support of university research, cooperative (cost-shared) research, and speeding knowledge transfer through such means as consulting, technology brokerage, or extension services. The federal role in encouraging direct industrial support of university research focuses on making such support financially more attractive, or removing any federally imposed barriers. Issues include:

- o Should the federal government provide subsidies or tax credits to industrial firms for R&D funds spent at universities?
  - How much would this increase industrial support of university research?
  - Would such support displace or enhance industry's in-house R&D spending?

- Should antitrust policies be changed to encourage firms to form consortia for the support of R&D at universities?

Cooperative research programs involve shared funding by government and industry, with university participation in the research. To justify government funding, the research should be relevant to subsequent commercial developments, but confer too little proprietary advantage for full industrial support. Such work has been termed "generic" research and is the subject of specific proposals in S.1250, H.R.4672, and the Innovation DPR. Questions and issues include:

- Where is the research best done--at a university, in industry, at a government laboratory, or at a nonprofit research institute?
- How will the research fields and specific project agendas be defined?
- Who will direct the research? What kind of governance arrangements are best?
- Should government provide institutional and/or project support? Should such support be on a continuing basis, or phased out over a period of years?
- What should determine the degree of industry cost sharing or other tangible evidence of industrial interest?
- Should such programs be oriented toward large, technically sophisticated firms or to technologically lagging industries?
- Should programs seek industrial sponsors nationwide or have a local or regional focus?
- How will the links between university disciplinary research and industrial product line development be made?
- By what criteria should such programs be evaluated?

Similar questions and issues surround federal efforts to stimulate knowledge transfer as a spur to innovation:

- o Where should such activities be located?
- o Will federal funding substitute for, or enhance, private sector support?
- o How can the government best stimulate market interest and avoid technology or information "push"?
- o Can third parties such as professional societies or industrial associations play useful roles?
- o Should the federal government expect to phase out support or continue it indefinitely?

Finally, federal programs intended to support local and regional development as well as industrial innovation raise additional issues:

- o How can such programs avoid becoming conduits for pork-barrel subsidies?
- o What criteria should be used to determine university and industrial participants?
- o How should such programs be evaluated and, if necessary, terminated?

THE CURRENT STATE OF KNOWLEDGE REGARDING UNIVERSITY-INDUSTRY RELATIONSHIPS

The published literature provides some guidance on these issues, but few answers. The author's earlier paper includes references to the literature on university-industry interactions up to mid-1976; some more recent articles are listed in the bibliography to this paper.

This section first outlines a few general findings from the literature on innovation (presented, in the interest of brevity, without discussion). It then reviews specific university-industry interactions that can stimulate industrial innovation.

Factors Influencing Industrial Innovation

The predominance of market pull over technology push in successful

innovation is now well established. This strongly suggests that government efforts to increase technological innovation concentrate on the demand rather than the supply side. With some notable exceptions, government efforts to push technologies into commercial markets through demonstrations or technology transfer programs have not proved very successful. Other related and now well accepted findings from the literature include:

- o More spending on R&D does not necessarily lead to greater innovation.
- o Innovation success almost always involves a strong product or process "champion."
- o Informal communication channels among professional colleagues encourage knowledge transfer and innovation.
- o Direct links between developers and users favor innovation; problems increase as more institutional actors enter the process.
- o Cost sharing in federally funded programs encourages commercial use.
- o Largely because they are more organizationally complex, public agencies adopt innovations more slowly and with more difficulty than do private firms.
- o The total return to society from an innovation generally exceeds the return to individuals, often by a substantial margin.

Although innovation is clearly linked with relative economic advantage and certain entrepreneurial characteristics of individuals and institutions, no generic models exist with strong explanatory or predictive powers. Historical trends of R&D and innovation differ substantially among U.S. industries, and among nations. Although cultural differences make national comparisons difficult, several studies suggest that government support of technologically leading firms and industries is more effective than support of lagging industries in increasing exports and overall sales.

Direct Corporate Support of University Research

Industrial support of university research, like all other corporate expenditures, ultimately depends on its perceived value to the firm. Because it meets this market test, direct support carries incentives for other strong interactions, including faculty consulting, graduate student hiring, and exchange of people.

While corporations provide institutional and fellowship support as well as research grants, direct funding of university research projects or programs brings the closest links. Firms fund such projects not because of some general interest in university relationships, or to support universities as a public good, but rather for the specific research results and flows of information that will result. Industrial research managers seek to support individuals rather than institutions, and they often try to obtain patent rights or other proprietary advantages for their support.

Firms with substantial R&D programs generally fund some university projects of this sort. Most, however, are relatively small and short term. The most notable recent exception is the long-term relationship established in 1975 between Monsanto Corporation and the Harvard Medical School. The Harvard-Monsanto arrangement provides for a 12-year, $20 million level of support from Monsanto for basic biological research at Harvard. Harvard researchers also can use advanced instrumentation available at Monsanto laboratories. Under the agreement, the Harvard participants can publish their research findings, while Monsanto essentially has first rights to patent inventions arising from the research program. The agreement also establishes an independent advisory board that can review plans for publication, patent rights, and the exploitation of discoveries made under the program.

Many other universities have looked at the Harvard-Monsanto agreement with envy, and some industrial firms have expressed interest in similar arrangements. A few negotiations are underway, but no new agreement of the Harvard-Monsanto type has yet been announced.

Industrial support of university research can take the form of

equipment gifts rather than direct funding. This can be particularly important in such fields as microelectronics and computer science where industrial research often leads that at universities. Recently, for example, the Xerox Corporation has given versions of its proprietary distributed computing system to university researchers at MIT, Carnegie-Mellon University, and Stanford. While Xerox has sound commercial reasons for making such gifts, the result is likely to advance university research in computer science more than would gifts of equivalent sums of money. The federal government is not involved in such transactions, except to the extent that antitrust and tax issues are involved.

Direct funding of university research by consortia of industrial firms represents a clear extension of these bilateral arrangements. The Silicon Structures Project at the California Institute of Technology is one such example. Several U.S. universities have established formal research centers that are primarily financed by and serve industrial users, particularly in the paper, chemical, and textile industries. Table 2 lists some of them. Their work tends to fall somewhere between basic disciplinary research and development, much like the research proposed for new generic technology centers (see p. 19). The importance of the existing centers to innovation in the industries they serve has not been established.

Table 2

INDUSTRY-SUPPORTED RESEARCH CENTERS AT UNIVERSITIES

Lawrence University	-	Institute of Paper Chemistry
McGill University	-	Pulp and Paper Research Institute
Lehigh University	-	Center for Surface and Coatings Research
University of Delaware	-	Catalysis Center
Princeton University	-	Textile Research Institute

Cooperative Research Programs

Continued funding of the university-based centers listed in Table 2 means that firms in at least some industries will support

non-appropriable research at universities. More firms in more industries might participate, and more such centers might be viable if some of their initial costs were shared by government.

With this rationale, the University-Industry Cooperative Research Centers Experiment began in 1973 as part of the NSF Industrial Innovation Program. The experiment comprised three cooperative research centers operated by MIT, North Carolina State University and the Mitre Corporation to work with the polymer processing, furniture, and electric power industries, respectively. Over the five years of the experiment, $2.4 million of NSF funds were matched by an estimated $3 million from 24 participating firms (Burger, 1979).

By all measures--continued funding by industry, active involvement of industry research staff and management, participation by university faculty and students, and general acceptance as a mainstream activity within the university--the MIT Polymer Processing Program has been remarkably successful. With NSF support of slightly over $500,000, the program has attracted more than twice as much funding from the twelve industrial participants listed in Table 3. It is now fully self-supporting from industry funds.

Success of the MIT Polymer Processing Program seems due in large part to the managerial and entrepreneurial talents of the director, Professor Nam Suh, who combines solid academic credentials with established ties to industry. Aided by an Industrial Advisory Council, Professor Suh has responsibility for project and staff selection, research supervision, and liaison with the participating firms. Early doubts among some MIT faculty about the academic quality of the program have evidently been assuaged, and both faculty and administration now fully support it. Student participation in the program's research has also been high. As a consequence, the program meshes well with the traditional university values and incentives. MIT's prestige undoubtedly has also helped the program attract the technically sophisticated firms shown in Table 3.

Table 3
INDUSTRY PARTICIPATION IN THE
MIT POLYMER PROCESSING PROGRAM

AMP, Inc.	ITT Corporation
Eastman Kodak Company	Kendall Company
General Motors Corporation	Lord Corporation
Gleason Works, Inc.	Rogers Corporation
Goodyear Tire & Rubber Company	USM Corporation
Instrumentation Laboratory, Inc.	Xerox Corporation

In contrast, the two other experimental centers have proved less successful. The Furniture R&D Applications Institute at North Carolina State University has worked with smaller firms in the furniture industry that have little R&D capability and experience. During its five year period of NSF funding, the Institute went through three directors and a recession in the furniture industry. The expected level of funding from participating firms never materialized. Consequently, the Institute will operate at a substantially reduced level, if it continues at all.

The New England Energy Development Systems (NEEDS) Center, located at the Mitre Corporation, acted as a technological broker between universities and New England electric utilities. The brokerage function did not match well with Mitre's primary interest in Air Force system engineering, and the need for a third party broker was never well established. The NEEDS center closed down after NSF funding ended in 1978.

The NSF University-Industry Cooperative Research Center Experiment thus has produced one clear success story at MIT. Whether that model can be replicated at other universities remains to be seen. And, as the earlier paper concluded, "these three contrasting examples support the view that universities can more easily create research partnerships with large, technically sophisticated companies than with small firms" (Baer, 1978, p. 92).

NSF has also funded three Regional Research Experiment Centers directed toward strengthening university links to firms and industries within their region. The program goals, as stated in 1978 Program Report, are:

> The Carnegie-Mellon Center is testing the ability of the small business consulting company to aggregate the research interest and financial support of firms in the area. The Georgia Tech experiment is testing the degree of support and service attainable to determine how much it would cost the state to operate such a regional center. The University of Arkansas is a test of the industrial equivalent to the Agriculture Extension Service (NSF 1978, p. 26).

These experiments have not been in operation long enough for evaluation.

Knowledge Transfer and Exchange of People

Studies over many years support the concept of knowledge transfer through the exchange of people as important to successful innovation. A variety of mechanisms exist to promote the exchange of people between universities and industrial firms, including consulting, advisory boards and visiting committees, student internships and faculty sabbaticals in industry, and industrial adjunct professors at universities. Exchanges generally parallel university-industry interactions in research. University faculty and industrial scientists who share common research interests will meet at conferences, exchange papers, and otherwise keep in touch professionally. More extended interactions either at the university or at the industrial firm may then follow. However, given their different career incentives, one can expect professors and industrial scientists to spend only brief sojourns in the other's territory.

In the early 1960s the Ford Foundation encouraged junior faculty members to spend sabbaticals in industry through a program of "Residencies in Engineering Practice." More recently, some professional societies have undertaken to increase university-industry interactions.

As one example, the American Physical Society has since 1973 sponsored a Visiting Physicists Program, under which physicists working in industry speak at universities and graduate students in physics visit industrial R&D laboratories. The program has involved more than 30 industrial laboratories and 60 university physics departments in such exchanges (Millman, 1978). Similarly, the Industrial Research Institute supports programs for industrial scientists to speak at universities. The American Physical Society also sponsors industrial post-doctoral fellowships and industrial summer intern programs for graduate students in physics.

University programs to select and educate entrepreneurs and inventors have proved popular in recent years. NSF has supported Innovation Centers at MIT, Carnegie-Mellon, the University of Oregon, and the University of Utah. The centers are intended to become self-supporting on the basis of licenses, royalties, and industrial fees from products they develop. The success of these centers in attracting students, generating new product ideas, and stimulating new businesses has been well documented by NSF. Other studies, however, indicate that successful inventors and entrepreneurs display intuitive, iconoclastic traits not well matched to most university programs. As George Bugliarello, President of the Polytechnic Institute of New York, notes, engineering schools "do very poorly in training inventors and innovators" as opposed to designers, analysts and project managers (Bugliarello, 1977).

Technology licensing and brokerage remains a valid means for knowledge transfer, although the federal role is still unclear. Federal agency efforts to support university-based dissemination centers or technology clearinghouses have not generally appeared cost effective in terms of stimulating innovation or commercialization. Such activities all too often have had the flavor of "technology push" rather than "market pull."

Questions surrounding the exploitation of patents derived from university research deserve further exploration. Although a few universities have their own patent licensing organization, most rely on firms such as Battelle Development Corporation or Research Corporation. But universities may become more interested in direct arrange-

ments with industrial firms, perhaps along the lines of the Harvard-Monsanto agreement. How such bilateral agreements will work, and whether they pose conflicts with other university patent exploitation arrangements, are currently important questions for academic administrators.

POLICY OPTIONS

New programs and policies to strengthen university-industry interactions have been proposed in the 1979 Innovation Acts (S.1250 and H.R.4672), the President's Domestic Policy Review on Innovation, and planning documents of the National Science Foundation, as well as by various individuals and committees. This section discusses a number of such options, their strengths and weaknesses, and their likely contributions toward the policy objectives described in the section on Policy Issues. Options considered here include:

- o Antitrust guidelines for industrial research consortia.
- o Tax credits or matching funds to stimulate corporate support of university research.
- o Research equipment gifts and sharing arrangements.
- o Generic Technology Centers.
- o Small business programs and regional technology centers.
- o Joint research programs or facilities.
- o Programs to enhance knowledge transfer.

The paper concludes with some general observations on university-industry relationships and suggestions for further policy analysis.

Antitrust Guidelines for Industrial Research Consortia

The Antitrust Division of the Department of Justice could prepare clear, operational guidelines for industrial firms that want to join together to support R&D projects. Although many contend that antitrust poses little problem for joint research efforts, and is often used by firms as an excuse for decisions not to support research, it

is still spoken of by some industrial R&D managers as a significant barrier. Clear guidance from the Antitrust Division on the conditions under which firms can join together to fund R&D, permissible arrangements for carrying out the work, patent policies, and other such issues would be helpful, especially to small firms that may want to support research efforts at universities.

This option would have no material impact on the federal budget.

Tax Credits or Matching Funds to Stimulate Direct Corporate Support of University Research

The Advisory Subcommittee on Direct Federal Support of Research and Development, established as part of the Innovation DPR process, has recommended that the government provide tax credits or matching research grants for private firm investments in university research. Research topics would be determined by agreements between universities and firms; multi-firm projects would be encouraged. Universities would hold patent rights--firms that wanted to retain proprietary rights would not receive the tax credits or federal matching funds.

The subcommittee favors the tax credit approach because of its administrative ease, but recognizes the political difficulties in passing such legislation. Moreover, tax credits favor large established firms, as opposed to small, new R&D-intensive firms that may operate in the red and hence have no income taxes to reduce. An indefinite tax-loss carry forward, as the proposal recommends, would not eliminate this bias.

Federal matching grants could vary by company size to give small firms added leverage on R&D expenditures at universities. For illustration, the subcommittee suggests that the ratio of government to private funds could range from 10:1 for companies spending less than $10,000 annually on R&D, to 0.5:1 for firms with annual R&D expenditures above $100 million. Because total government funds would be set by appropriation, presumably below the level of requests, federal agencies would need programs and staff to allocate them.

Such proposals have the advantage of stimulating the demand side of the innovation process. Their cost-sharing features and reliance

on direct university-industry project decisions would serve to strengthen links between a variety of universities and private firms. As a contrast, a new NSF program encourages joint university-industry research proposals, but subjects them to the usual peer review competition for funding. This, one can contend, may lead to better science, but it will likely restrict the interactions to large firms with established research capabilities.

The principal difficulty with tax credits or matching grants lies in estimating their benefits, or even their costs to the government. There is little analysis to suggest how much additional corporate R&D funds would flow to universities,* or whether the funds would substitute for in-house industry R&D. It would also seem difficult to assess the success or failure of such programs, since changes in industrial support of university research could be due to a variety of causes. Consequently, the social or private return from matching grants or tax credits for corporate support of university research appears highly uncertain. However, their recognition as a "positive" step toward encouraging stronger university-industry interactions, as well as their relatively small budget impact, make tax credits or matching grants politically attractive.

Research Equipment Gifts and Sharing Arrangements

Firms might be given special encouragement to upgrade university research equipment or share industrial facilities with academic researchers. With the rapidly increasing sophistication and cost of research instrumentation, more and more university departments find it difficult to keep up with the equipment state-of-the-art. Industrial grants for equipment purchases or gifts of advanced research instruments would be warmly welcomed by universities.** In other cases,

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*One estimate made for the Innovation DPR suggests that a 10% tax credit or subsidy would increase industrial support of university research by 50%, although no analysis supporting the estimate is presented.

**The Tax Reform Act of 1969 reduced industrial incentives to give research apparatus to universities, since it permits firms to deduct only the equipment manufacturing cost and not its market value. Congress might reconsider this provision in light of the pressing university need for state-of-the-art research equipment.

universities and industrial firms can jointly purchase and use new equipment, as Lehigh University has done with an electron microscope and mass spectrometer. Finally, more firms should consider allowing university faculty and graduate students to use advanced equipment in their laboratories as a way of strengthening research interactions. Access to advanced instrumentation in Monsanto's laboratories by Harvard Medical School researchers has been an important feature of the Harvard-Monsanto arrangement.

Generic Technology Centers

The Innovation Initiatives announced by the White House in October 1979 include the creation of new centers with government, industry, and university participation to perform generic research--i.e., applied research on industrially relevant problems. Each center would be located at a university or private sector site, and would concentrate on a generic technical area such as corrosion prevention and control, robotics, or industrial welding and joining (see Table 4). S.1250 and H.R.4672 contain similar proposals.

The Generic Technology Center Initiative combines features of earlier proposals by the Department of Commerce and the National Science Foundation. Four centers would be established in Fiscal Year 1981 with total federal funding of $6-8 million. The centers will aggressively seek industry support, with the expectation that federal funds will drop to 20 percent or less of total center costs in five years. The future size of the program "will depend on the proposals received, and the experience gained from this initial effort" (White House Fact Sheet, 1979).

Although the Department of Commerce will sponsor three of the first four proposed new centers, the model appears to be the NSF-supported Polymer Processing Program at MIT. The proposed university (or other private sector) siting, industrial cost sharing, and phase-down of federal support over five years reflect knowledge gained from the NSF Cooperative Research Centers Experiment. A principal question is estimating how many successful university-based centers can be created on the MIT model. Professor Suh's success at MIT may be so

Table 4

PROPOSED RESEARCH AREAS FOR GENERIC TECHNOLOGY CENTERS

Topics Proposed By The Department of Commerce	Topics Proposed By The National Science Foundation
Semiconductor fabrication	Computer aided design algorithms
Flexible manufacturing (including robotics, AI, CAD, CAM)	Functional and reactive polymers
Food processing	Polymeric coatings
Food distribution	Vitreous materials
Textiles	Metal fusion
Process control technology	Computer aided manufacturing
Composite materials	Flexible materials
Welding and joining	Real capital formation
Industrial coatings	Microcircuit fabrication
Powder metallurgy	Marine biology
Corrosion	Artificial intelligence
Radiation processing	Metal drawing and forming
	Technical information systems
	Materials research
	Surface absorption and catalysis
	High energy wave propagation
	Light-sensitive molecules
	Optics
	Mathematical linguistics
	Mathematical decision theory

unique that few individuals and institutions can emulate it without descending into research mediocrity or creating administrative nightmares. Certainly one should expect failures as well as successes from attempts to create new centers. In a political environment with strong university, industry, and geographic claims for support, it will take courage to turn off the failures in order to concentrate on the successes. Yet this must be done if the new Generic Technology Centers are to become effective agents for innovation.

Small Business Programs and Regional Technology Centers

Reflecting the political popularity of programs to aid small businesses, a variety of proposals to favor small business R&D have emerged in recent years. In fiscal year 1978, for example, Congress directed the NSF to place 12.5 percent of its applied science and research applications funding with small businesses. The Advisory Subcommittee on Small Business to the Innovation DPR recommended that a similar target of 10 percent be established for all government R&D programs.

Other proposals dating back at least to the early 1960s would link the establishment of university-based, regional technology centers or extension services to small business assistance. The objectives are to support regional economic development, as well as to promote industrial innovation. The centers would concentrate on applying technology to industries within their regions, analogous to the role of the agricultural experiment stations allied with universities. Industrial extension services patterned after the agricultural model would then be natural affiliates to the regional technology centers. Current programs at the Georgia Institute of Technology and the University of Arkansas incorporate many of these features.

Proponents claim that the relatively low cost and high productivity of scientists and engineers in small firms, as evidenced by patents and growth rates, justifies the preference for small business R&D. Whatever the merit of this argument, the links between universities and small business R&D seem relatively weak. Research colla-

boration between small businesses and universities is generally ad hoc and depends on past personal interactions. Additional federal funds to universities to support R&D programs relevant to small businesses would seem to involve more research "push" than market "pull" and thus would not be particularly effective. It would seem more appropriate to fund small business R&D programs in their own right, as part of a national program to enhance innovation,* rather than link them to efforts to strengthen university-industry interactions.

Joint Research Programs or Facilities

Industrial participation in national research programs, or as users of national research facilities, seems appropriate when the objective is the search for new knowledge, rather than the promotion of industrial innovation. As noted above, the federal government has final responsibility for maintaining the strength and momentum of the nation's basic research effort. Although much has been written about industry's declining role in basic research, industrial scientists are actively productive in a variety of disciplines and play leading roles in such fields as solid state physics, computer science, and organic chemistry. As a consequence, government efforts to link industrial science more closely to university research may prove productive in fields where there is an important national interest in basic research.

One such current example involves the long term health effects associated with low level exposure to chemicals and radiation. This has emerged as a critical national issue involving many federal and state regulatory agencies, and affecting the chemical, pharmaceutical, energy, and other major U.S. industries. Significant research on the physical and biological mechanisms of harm from toxic substances, the observable effects of exposure to such substances in animals, and human

*NSF's Small Business Innovation Research program appears successful in attracting sound research proposals from small business firms. The NSF program also includes incentives for firms that obtain follow-on funding from private venture capital sources. This seems a sensible way to stimulate rapid development and commercialization of federally funded research.

perceptions of and attitudes toward risk, takes place in industrial, university, nonprofit, and government laboratories. Yet the state of knowledge surrounding long term, low level human exposure to toxic materials badly lags current needs for information to make sensible policy decisions.

The time may thus be ripe for greater federal efforts to generate new knowledge on the long term health effects of toxic substances and radiation. Such a program could involve direct funding of research at university, industry, nonprofit, and government laboratories that have proven competence in these fields. It could include the creation or expansion of national research facilities for large, long term animal experiments in which scientists from all sectors could participate. Surveys to determine public attitudes toward risk, and the factors influencing personal decisions about risk, would be an important part of such a program. The resulting data base should be accessible to university, industry, nonprofit and government researchers on an equal basis. Here the established models of national research centers with university user groups in the physical sciences can be extended to include industrial user groups in the biological and social sciences.* The results can benefit both university-industry interaction and important national research efforts.

Programs to Enhance Knowledge Transfer

Activities that promote knowledge transfer and the exchange of people primarily involve direct arrangements between universities and private firms. The federal government role in these activities may be quite modest.

Government support could help professional societies expand their

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*Presidential Science Advisor Frank Press called for expanding the concept of national research facilities in a 1975 editorial, "New Arrangements for Science in the Universities," *Science*, 18 July 1975, pp. 177. See also Baer, 1978, pp. 81-82.

efforts to encourage the exchange of people through speakers, laboratory visits, summer internships and the like. Federal funding could well be limited to sharing start-up and administrative expenses; the societies and their industrial participants could pay stipends and other program costs. All in all, the sums involved are not large and would appear to generate visible, if modest results.

NSF's Innovation Center Program has proved politically popular and has evidently attracted substantial student and industrial interest. So long as the centers obtain significant support from non-federal sources and thereby meet a sort of market test, the concept seems sound and well worth continuing. Because the centers support local and regional economic development as well as innovation, they could also logically be part of university-based regional technology centers or extension programs.

Information Gathering and Analysis

It is always easy for, if not incumbent upon, an author to call for additional research and study. It is particularly easy to do so in this area, since we lack basic data on which to develop policies for innovation. Systematic data collection and analysis could help illuminate the current trends in university-industry interactions, the influence of federal interventions on these interactions, and the importance of the interactions themselves in promoting industrial innovation or other policy goals. Some specific topics for further study include:

- The current level of and trends in industrial-university cooperative research by industrial sector; and its influence on industrial innovation and productivity.
- The contributions of university-based research institutes, such as the Lawrence Institute for Paper Chemistry or the Princeton Textile Research Institute, to industrial innovation.
- The extent to which industrial support of university research substitutes for or stimulates additional in-house industrial R&D.

- o Models of cooperative research and knowledge transfer in countries with high productivity levels, such as the Max Planck Institute in West Germany.
- o The influence of university research, training, or extension programs on local and regional economic development.
- o The importance of faculty consulting to knowledge transfer and innovation.

Some Concluding Comments

Some past government efforts to stimulate university-industry interactions seemed to lack a conscious strategy for achieving specific policy objectives. This review, however, suggests that considerable thought has been given recently to designing such strategies and programs. The hearings on S.1250 and H.R.4672, as well as the discussions surrounding the President's Domestic Policy Review on Innovation have helped focus attention on specific program plans.

Although we have scant knowledge about how university-industry interactions affect industrial innovation, enough seems to be known to support some modest additional efforts by the federal government. Both universities and industrial firms appear ready to welcome such efforts. Modesty, however, is not the hallmark of new political initiatives; consequently, one must beware the danger of overselling university-industry collaboration as an innovation breakthrough.

Indeed, although programs such as those described above may improve innovative activity through strengthening university-industry relationships, direct measures to improve the economic returns from innovation would probably bring more substantial results. These include changes in the personal and corporate income tax codes, including liberalization of the capital gains tax; and changes in the regulations governing partnerships, Sub-Chapter S corporations, and other new business ventures. Although beyond the scope of this paper, such improvements in the general economic climate for innovation are likely to stimulate faculty entrepreneurship and otherwise prove more effective

than measures directed specifically toward university-industry interactions.

BIBLIOGRAPHY

Advisory Committee on Industrial Innovation, *Direct Federal Support of Research and Development: Draft Report*, Washington, D.C. Industrial Innovation Coordinating Committee, 21 December 1978 (NTIS # PB-290 407).

Atkinson, Richard C. Statement before the Subcommittee on Science, Space and Technology, Committee on Commerce, Science and Transportation, United States Senate, June 27, 1979.

Baer, Walter S., "Universities and Other R&D Performers," in B.L.R. Smith and J.J. Karlesky, ed., *The State of Academic Science, Volume II: Background Papers*, New Rochelle, N.Y., Change Magazine Press, 1978.

Baer, Walter S., *University-Industry Interactions in Civil Sector R&D*, Santa Monica, Ca., The Rand Corporation, P-5724, October 1976.

Bearinger, Van W., "Improving Cooperation Between Industry and Engineering Educacors," *Engineering Education*, November 1977, pp. 171-175.

Branscomb, Lewis M., Statement before the Subcommittee on Science, Space and Technology, Committee on Commerce, Science and Transportation, United States Senate, June 27, 1979.

Brodsky, Neal et al., *"University/Industry Cooperation: A Preliminary Analysis of Existing Mechanisms and Their Relationship to the Innovation Process,"* New York University, Center for Science and Technology Policy, July 1979.

Bugliarello, George, *"Industry-University Interaction,"* presentation at the Conference on Mechanisms of University-Industry Interaction, Reston, Virginia, 1978.

Bugliarello, George, "The Problem of Industry-University Interaction," in Fred Landis, ed., *Proceedings, Engineering and Science Research for Industrial Development*, Washington, D.C., National Science Foundation, October 1977, pp. 317-332.

Burger, R.M., *An Analysis of the National Science Foundation's University-Industry Cooperative Research Centers Experiment*, Research Triangle Institute, Research Triangle Park, N.C., 1979.

David, Edward E., "Science Futures: The Industrial Connection," *Science*, Vol. 203, 2 March 1979, pp. 837-840.

Drucker, Peter F., "Science and Industry, Challenges of Antagonistic Interdependence, *Science*, Vol. 204, 25 May 1979, pp. 806-810.

"Innovation: Has America Lost Its Edge?" *Newsweek*, June 4, 1979, pp. 58-66.

Millman, Sidney, "Visiting Physicists Program," *Physics Today*, February 1978, pp. 32-36.

National Science Foundation, Directorate for Applied Science and Research Applications, *Fiscal Year 1980 Budget to the Congress*, Washington, D.C., 1979.

National Science Foundation, Directorate for Applied Science and Research Applications, *Program Report: Intergovernmental Science and Public Technology*, Program Report, Vol. 2, No. 6, September 1978.

Office of the White House Press Secretary, *"Fact Sheet: The President's Industrial Innovation Initiatives,"* October 31, 1979.

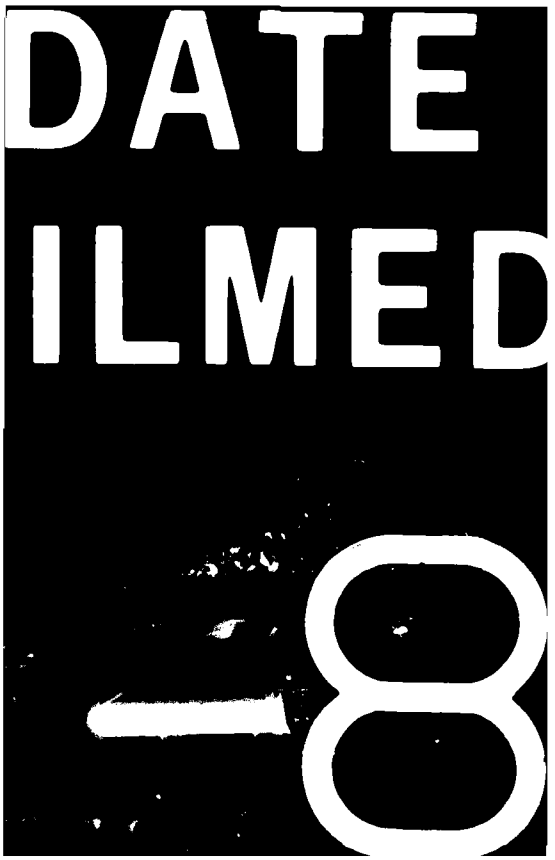
Rahn, H.W. and E.P. Segner, Jr., "Technical Research: Pathways for Improving Interaction Between Academia and Industry," *Engineering Education*, May 1976, pp. 794-795.

Stauffer, Thomas M., "Expanding Business - Higher Education Coordination on Research and Development," *SRA Journal*, Summer 1979, pp. 41-46.

Throdal, M.C., "The University-Monsanto Research Interface," in Fred Landis, ed., *Proceedings, Engineering and Science Research for Industrial Development*, Washington, D.C., National Science Foundation, October 1977, pp. 390-396.

Udell, Gerald G., Ken Baker and Robert M. Colton, "The Innovation Center Program," *Research Management*, July 1979, pp. 32-38.

Wolek, F.W., *The Role of Consortia in the National R&D Effort*, University City Science Center, Philadelphia, Pa., July 1977.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