Industrial Support of University Training and Research: Implications for Scientific Training in the "Steady State"

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Executive Summary

During the past 15 years, a levelling off of governmental support for scientific research in universities and a decline in college enrollments have produced a phenomenon sometimes referred to as a "steady state" for American university science. University-industry relationships (UIRs) may be one way in which universities have sought to accomodate these changes in governmental policy and demography. The growth in UIRs has been especially prominent in the life sciences where university laboratories have produced scientific results with strong commercial potential in the fields of biotechnology. This paper considers the implications of industrial funding of research and training for the way in which universities train new scientists during this period of "steady state."

The steady state is characterized by new scarcities of or constraints on university resources. The research university allocates resources in the sciences among several activities which can be classified under one of three "missions" for the university: (1) to conduct scholarly investigation, especially research that extends fundamental scientific understanding, (2) to provide other institutions in society, especially government, with expert advice on issues under public consideration, and (3) to insure an adequate supply of newly trained scientists and engineers. This paper is concerned with the third of these missions.

There are at least two schools of thought about the best way in provide society with trained scientists. The first holds that there is a constant, fundamental set of skills expected of any Ph.D. and foremost among these is the ability to conduct independent, basic research. Subscribers of this view would believe the best way to give new scientists these skills is to provide an open training experience in which students are free to choose research topics based on their academic merits. This school fears that an industrially funded training experience may not give trainees an adequate amount of independence to acquire the skills necessary for science. The other school of thought holds that university science and training should reflect the current needs of society. Hence, universities should help industry by prepare students who are able to develop commercially new areas of scientific progress (like biotechnology). To the extent that UIRs help universities fulfill this goal, subscribers of this view see them as an asset.

The merits of industrial support for university training depend on the actual benefits and risks associated with this type of UIR. Hence, the extent to which industrial support alters students' ability to conduct independent research, or the degree to which it helps them develop commerical applications of science is largely an empirical question. Although no conclusive data exist, some empirical evidence analyzed by the author and collected through surveys of firms involved in biotechnology, administrators at research intensive universities[1], and life science faculty and trainees at these universities sheds light on these questions. In examining the implications of industrial funding, one can group the various characteristics of training experiences into three categories: (1) the degree to which the training experience socialize students to the workings of science, (2) the scientific content of the training experience, and (3) the length of the training period and scientists' subsequent career patterns.

Socialization to Science

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[1] "Research intensive universities" are defined as those academic institutions receiving the most federal R and D funds.

In 1984, the biotechnology industry provided between 1775 and 2665 training grants and scholarships to graduate students and post-doctoral fellows in the life sciences at a $8 and $24 million. This represents between 4 and 10 percent of all funds for training grants and scholarships provided for trainees. The federal government provided almost all of the remainder. The average amount of an industrial award is about one-half that provided by the federal government. The data yield no evidence on how recipients make up any deficit in the cost of their educations. Among life science graduate students and fellows in the most research intensive universities, 19 percent of these trainees receive training grants, scholarships or salary support directly from industry. Another 15 percent receive no funds themselves directly from industry, but they work in the laboratories of faculty advisors who receive research support from industry.

While industry appears to be making a significant contribution toward the training of new scientists, the public sector still maintains the most influence over resources for students' graduate and post-graduate educations. In addition, cursory analysis suggests that industrial funds are qualitatively different from governmental support. One third of the recipients of training grants and scholarships from firms indicated that they must perform some service of benefit to the company in return for their awards. One assumes that research and salary awards also carry some obligations. Hence, cursory analysis suggests that some industrial support is more restrictive than that provided by the public sector. The data provide no direct evidence of how this might affect trainees' ability to conduct independent research.

The faculty advisor plays a key leadership role in the socialization of trainees in his or her lab. One finds a strong correlation between an advisor having some relationship with industry and trainees in his or lab having some contact with private firms. However, the data do not indicate that faculty relationships with industry in any way undermine faculty commitment to traditional academic activities or the amount of time advisors spend with their students. Faculty with industrial research support actually appear more committed than their uninvolved peers. The same appears true for the 8 percent of faculty who own equity in a firm whose products or services are related to their research.

Along one dimension, trainees with industrial support appear somewhat less productive: they publish significantly fewer articles than other students and fellows. However, this may just reflect a predilection on the part of some trainees toward the norms of industry rather than an indication that trainees have had a less than optimal training experience. These may be the individuals who seek industrial careers. Industry support of trainees is also associated with a higher rate of patenting and maybe trade secrecy. Hence, industrial support may help trainees gain exposure to commercially relevant research.

Academia's ability to foster a commitment to the open communication of scientific information may be somewhat diminished by industrial training funds. Although the data is only suggestive and warrants further investigation, some trainees report trade secrecy, delays in publication and a reluctance to discuss research with colleagues as a result of industrial support.

Content of the Training Experience

The data offer no evidence of how relationships with private firms affect the specific scientific fields and techniques that trainees study. However, the relatively short duration of industrially funded projects and the potential commercial productivity of such projects suggests that support from the private sector increases somewhat the applied nature of the training experience. The degree to which industrial projects also contribute to basic research may depend on whether the faculty advisor encourages trainees to explore the fundamental extensions of industrially supported work. Overall, trainees in the universities and departments surveyed rated the quality of their training experiences highly regardless of where their support originated.

Length of the Training Experience and Career Patterns

While many have feared that the steady state has created a pool of non-faculty Ph.D. researchers in universities who cannot secure regular academic appointments, some indirect (and inconclusive) evidence from the survey of trainees suggests that in life science departments at the top few universities this phenomenon may not occur in large numbers. While these data may be misleading, they do point out the need to measure accurately the number of non-faculty researchers.

Based on the plans of trainees, industrial training support is not associated with a significant increase in the proportion of student and fellows planning industrial careers. Regardless of their relationships with private firms, about 75 percent of all trainees plan academic careers.

In sum, industry appears to be making an important marginal contribution to the training of new scientists. Firms provide the benefits of increased resources for the university, students and faculty as well as the opportunity to work on commercially relevant projects. Even within particular labs, the magnitude of industrial support does not seem great enough to damage a trainee's socialization to science, the scientific content of the training experience, or the trainee's subsequent career. Some instances of risks to the traditional socialization of students may exist. University and government policy makers should continue to monitor these relationships and explore ways in which they may control the undesireable behaviors. In this way, the two schools of thought about scientific training suggested in the paper might continue to coexist.

Industrial Support of University Training and Research: Implications for Scientific Training in the "Steady State"

Observers of American science such as Harvey Brooks have long recognized the sophisticated and interdependent relationship between graduate training and scientific research. While on the one hand, Brooks suggests that the availability of trained manpower be regarded as the most constrained scientific resource[2] he also notes "the importance in graduate training of the total envicronment of the university--of the research atmosphere . . . ."[3] Scientific investigation and training come together in the research university. At least two changes have added to this already complex relationship. First, the growth in government support of scientific research in universities has levelled off in most fields after a period of unprecedented growth during the 1960s. At the same time, industrial support of university research and training, especially in the life science fields of biotechnology, has grown. These changes in the way research universities get money for the activities they carry out have consequences for the training of new scientists and the research environments in which they work.

This paper examines such consequences. Its purpose is not to measure exhaustively how industrial funding affects academia. Work published elsewhere by this author and others has begun to quantify the extent and consequences of

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[2] Harvey Brooks, "The Problems of Research Priorities," G. Holton and R. S. Morrison, eds., <u>Limits of Scientific Inquiry, Proceedings of the American Academy of Arts and Sciences,</u> New York: Norton, 1979, pp. 171-190.

[3] Harvey Brooks, "The Future Growth of Academic Research: Criteria and Needs," <u>Science Policy and the University</u>, Harold Orlans, ed., (Washington, D.C.: Brookings Institution, 1968), p. 75.

several types of university-industry relationships (UIRs) in biotechnology.[4] In addition to reviewing this empirical evidence, this paper tries to make explicit the complex relationships among university research, education, and their funding as well as the assumptions underlying discussions of changes in academia. By clarifying these issues, I seek to suggest a structure to guide future research and policy debates. In the first part of the paper, I consider the characteristics of "science in the steady state" and the various missions of the research intensive university with particular attention to the expectations one might have of the Ph.D. training experience. I then turn my attention to the particular phenomenon of industrial funding of university research and training and its implications for the university's educational activities.

Science in the Steady State

As suggested above, the phrase "science in the steady state" describes the current period in American science, contrasting with a period of sustained

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[4] David Blumenthal, Michael Gluck, Karen Seashore Louis, Michael A. Stoto and David A. Wise, "Industry Support of University Research in Biotechnology: An Industry Perspective," Science, 231 (January 17, 1986a), 242-246. David Blumenthal et al. "University-Industry Research Relationships in Biotechnology: Implications for the University," Science, 232 (June 13, 1986b), 1361-1366. David Blumenthal et al., "Commercializing University Research: Lessons from the Experience of the Wisconsin Alumni Research Fund," The New England Journal of Medicine, (June 19, 1986c), 1621-1626. Michael E. Gluck, David Blumenthal, Michael A. Stoto, "University-Industry Relationship on the Life Sciences: Implications for Students and Post-Doctoral Fellows," Research Policy, Forthcoming, 1987. Karen Seashore Louis, David Blumenthal, Michael Gluck, Michael A. Stoto, "Entrepreneurs in Academe: An Exploration of Behaviors Among Life Scientists," Unpublished Manuscript, 1987. Michael Gluck, University-Industry Relationships in Biotechnology: Implications for Society, Unpublished Ph.D. Dissertation, Cambridge, MA: Harvard University, 1987. Sheldon Krimsky, "Corporate-Academic Ties in Biotechnology," geneWatch, September-December, 1984, pp. 3-5.

growth that peaked in the middle to late 1960s. At the heart of this expansion and its subsequent end are university enrollments and federal funding of university research, training, buildings and tuition. While federal expenditures on university research grew from $234 to $1905 million in constant 1972 dollars between 1953 and 1968 (a 714% increase), it only grew to $2259 million in the next 15 years ending in 1983 (a 19% increase).[5] Between 1965 and 1974 first degrees awarded each year in science and engineering in the United States jumped from about 160,000 to just over 300,000. From 1975 to 1982, the number of such degrees awarded each year has remained about constant. Full-time enrollments in American universities are expected to actually drop-off through the middle of the next decade.[6]

At least one observer has described the period in the 1960s as one of "abnormal" growth.[7] Regardless of the basis one uses to define normality in the size and funding of American research universities, the changes in enrollment and finances during the 1970s and 1980s have had important implications for the

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[5] Report of the White House Science Council, Panel on the Health of U.S. Colleges and Universities, Washington, D.C.: U.S. Government Printing Office, February 1986, p. 50.

[6] Office of Technology Assessment, U.S. Congress, Demographic Trends and the Scientific and Engineering Work Force--A Technical Memorandum, Washington, D.C.: U.S. Government Printing Office, December 1985, pp. 35-36.

[7] Don Phillips, "Introduction: The Future of Academic Research," in Don I Philips and Benjamin S. P. Shen, eds., Research in the Age of the Steady-State Uniersity, (Boulder, Colorado: Westview Press, 1982), p. 6.

way in which research universities function. In economic terms, universities face new scarcity; the resources at their disposal are more constrained.

The term "steady state" describes one attribute of the research university--its resources, or more specifically, its budget. However, the term does not extend to other characteristics of academia. "Steady state" does not mean "static." As Omenn and Frager point out, "universities are vital institutions . . . dynamic, almost organic entities which respond to opportunity." They also note that the top academic institutions are largely unaffected by the decline in college and graduate students.[8] At the same time that observers have noted the emergence of a "steady state," at least two other changes have taken place that affect the amount and allocation of resources available to universities.

First, there have been rapid breakthroughs in the life sciences over the last ten years in fields known collectively as biotechnology. These developments are in the areas of recombinant DNA, monoclonal antibodies, gene synthesis, gene sequencing, and their applications in cell or tissue culture, fermentation, large scale purification and enzymology. The research opportunities in the life sciences increase its attractiveness to students and federal funders of future investigation.

Second, the commercial potentials of research, particularly in biotechnology, have led to an increase in university-industry relationships (UIRs). Bec-

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[8] Gilbert S. Omenn and Denis J. Frager, "Research Universities and the Future: Challenges and Opportunities," in Phillips and Shen, pp. 23 and 24.

ause biotechnological advances have taken place almost exclusively in university labs, firms wishing to develop biotechnology commercially or to build their in-house expertise in the fields have had to cooperate with universities. In addition, the amount of time and effort necessary to move from scientific research to marketable products appears to be relatively short in biotechnology[9]. Firms have had an incentive to work with universities to bring these products quickly to market. And finally, universities and faculty in the life sciences who have recognized the commercial potential of their research have had an unusual opportunity to profit financially and to participate in its transformation into products that benefit the economy and the public health. As examined in the research cited at the beginning of this paper, these UIRs include examples of innovative organizational forms designed to help industry meet its commercial objectives and to help universities mitigate the constraints of a "steady state."

The Universities' Accomodation of the "Steady State"

The Missions of the University. So far, I have suggested some characteristics of the "steady state" and the context in which it has emerged. In determining how a particular university mechanism for accomodating the "steady state" (in this case, UIRs) affects any particular "mission" or activity of the research university (in this case, the training of new scientists), it is first useful to consider the several activities among which the university or government allocates resources in academia.

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[9] Sandra Panem, *The Interferon Crusade*, Washington, D.C.: The Brookings Institution, 1984. pp.75-76.

First. research universities conduct scholarly research in the sciences, social sciences and humanities. In the sciences, society entrusts the vast majority of its research and development efforts to universities through federal grants and contracts. This research support is a societal investment toward improved economic and public health. From the university perspective, most research funds at the disposal of its investigators come from the federal government. Even among professors supported by industry, most receive the bulk of their research budgets from the federal government.[10] Almost all university personnel and trainees contribute directly or indirectly to these research activities through their involvement in or support of laboratory work.

Second. society depends on research universities for scientific expertise and other advice. By relying on the university's commitment to open and disinterested pursuits of knowledge, the government believes it can use academic advice to make better decisions in the public interest. The range of topics on which university personnel may provide their expertise covers all areas in which the school conducts scholarly research or has other experience.

Third. universities train individuals to meet future needs for skilled personnel in academic and other sectors. This paper concentrates on Ph.D. and post-doctoral training in the sciences. Underlying much discussion about recent changes at research universities and their training programs are differing assumptions and expectations of the training experiences themselves. One can distinguish at least two schools of thought.

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[10] Blumenthal, _et al._, 1986b.

On one side are those who believe that a Ph.D. in any discipline requires a set of fundamental and constant skills to conduct independent research. This includes the ability to structure and define problems in addition to being able to apply the methodologies of the scholar's chosen field. Proponents of this theory would hold that graduate institutions can best impart these skills by providing an open academic environment in which trainees have the greatest possible freedom to choose their research topics under the guidance of a qualified faculty member. It follows from these assumptions that requiring trainees to work on applied, technical projects detracts from their educational experiences.

The alternative notion of graduate education views the Ph.D. degree in a broader context. According to this theory, the research universities' mandate to train scientists include preparing them to meet demands for industrial investigators, especially in light of diminished demand for academics and enhanced commercial opportunities in fields like biotechnology. The private sector needs individuals with advanced training in order to transform basic science into useful products and services. When graduate institutions expose trainees to industrial labs and provide them with the opportunity to work the on directed, applied research topics more common to the private sector, they enhance the trainees' educational experiences.

To the extent that one can move beyond the differing basic assumptions about graduate education represented by these two schools of thought, reconciliation of the viewpoints depends on the answers to empirical questions. If trainees acquire the ability to define and conduct independent research while still gaining exposure to a wide variety of scientific applications, the two notions of graduate education may be able to coexist.

Industrial Funding of Life Science Training

The remainder of this paper addresses the empirical problem posed above. Using data on UIRs in biotechnology, it examines how industrial support affects the university's educational activities. In addition to allowing an estimate of the extent of training support from firms, the data provide some insights into how such support may benefit trainees' educational experiences and how industrial funding may detract from graduate and post-doctoral training.

Table 1 presents a series of variables that describe a research university's training program and some characteristics of the individuals who participate in it. In order to determine the effects of industrial funding, one would want to examine each item in the table controlling for universities' relationships with private firms and other characteristics hypothesized to influence the school's training programs.

Table 1

Characteristics of Training Programs and Their Participants

A. Socialization to Science
- Views of trainees toward industry, academia and government.
- Directedness versus independence of the training experience (i.e. amount of time to do own research versus responsibilities for advisors' research; flexibility of trainees in choosing research topics).
- Accessibilty of faculty for trainees (i.e. faculty responsibilities and interests beyond teaching).
- Availability and type of funding support as a trainee.
- Preparedness for job search after training.
- Preparedness for funding competition for academic scientists.
- Preparedness for publishing, teaching, and other traditional academic activities.
- Openness of communications among researchers and trainees.

B. Content of the Training Experience
- Field and degree of specialization in that field.
- Extent to which research and training experiences are "basic;" extent to which they are "applied."

C. Length of Training and Career Patterns
- Length of Ph.D. programs.
- Post-doctoral fellowships: length and responsibilities.
- Sectors (i.e. academia, government, industry, non-scientific professions) where trainees seek and obtain employment.

The first category of variables is the broadest. It includes non-scientific skills and characteristics that are indicators or determinants of how well trainees become socialized to their scientific professions. Some of the variables attempt to determine the opinions and values trainees acquire about the scientific enterprise and their role in it. Others are characteristics of the training experience hypothesized to influence these values. And still others try to measure practical, non-scientific skills that may be necessary for the trainees' success as scientists.

The second group of variables in Table 1 describes the scientific content of the training experience. This includes learning that takes place in the classroom, in consultation with a faculty advisor, in the faculty advisor's laboratory, and working independently on academic endeavors. In order to evaluate educational content, one would want to know the fields and skills in which students and fellows receive instruction.

In addition, scientific investigation is often characterized according to its "basic" or "applied" qualities. Both basic and applied research are necessary to the process of technological innovation.[11] Because firms do not necessarily have an incentive to support basic research[12], this more fundamental investigation usually falls under the purview of university labs and becomes an important part of a scientist's graduate training. The first of the two notions of scientific training presented earlier would hold that basic research is both the best way to impart students with the ability to conduct independent investigation and the type of research Ph.D.s are most likely to face over the course of an academic career.

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[11] Christopher Freeman, *The Economics of Industrial Innovation*, 2nd Edition. Cambridge, MA: The MIT Press, 1982, pp. 5-15.

[12] Economic Welfare and the Allocation of Resources for Invention." in Richard R. Nelson, ed., *The Rate and Direction of Inventive Activity: Economic and Social FActors*, National Bureaur of Economic Research, Princeton, NJ: Princeton University Press, 1962

Observers of science commonly assume that the basic and applied qualities of research are mutually exclusive. As Stokes points out, however, a piece of research can be both basic and applied.[13] For example, research may help further our understanding of fundamental scientific principles while also developing a directed, technical application. In evaluating the content of research and training, analysts should consider separately the ways in which work is basic and the ways in which it is applied.

The third group of variables describes the length of the training period and the subsequent career patterns of the trainees. This includes the amount of time required to earn a Ph.D., the proportion of trainees who do academic postdoctoral fellowships, and the responsibilities and length of such fellowships. In addition, analysts would want to know how trainees fill society's needs for scientists. What proportions seek and accept industry jobs, remain in academia, work in government, and end up in a different profession? Career patterns are not just a function of the training experience, but they also reflect the changing needs of each sector, characteristics of the trainees and public policies (such as those that require trainees to "payback" government financial support with a certain amount of time teaching or doing research). In examining training and career patterns, analysts would want to control for these factors.

A. Trainees' Socialization to Science

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[13] Donald Stokes, "Perceptions of the Nature of Basic and Applied Science in the United States," in Arthur Gerstenfeld, editor, Science Policy Perspectives: USA-Japan, New York: Academic Press, 1982. pp. 1-18.

The previous section suggested a methodology for empirically determining how relationships with industry may affect the training of scientists. The consequences of UIRs for training may be especially relevant during the current period if they help universities accomodate the "steady-state." In this section and the two major sections that follow, I look at each group of variables laid out in Table 1. To the extent possible, I draw upon my empirical analysis of the magnitude and consequences of industrial support for life science training at those universities receiving the most federal R and D funds. I also suggest some extensions of these data, exploring the complexities and subtleties of the training and research endeavors in universities.

For a trainee who has completed his or her preliminary coursework, I propose that the individual lab is the organizational unit in which the bulk of socialization to the norms of science takes place and that the faculty advisor is the primary actor in this process. The lab sits at the juncture of the university's research, teaching and advisory missions. By determining the division of labor within the lab, the faculty advisor (who also usually wears the hat of "principal investigator") may affect the research productivity of the lab and determines a large part of student and fellows' training experiences. By their own example, advisors also impart trainees' with ethical standards for the conduct of science and a set of attitudes toward non-university science including industrial work. Advisors are unlikely to determine all of trainees' socialization. Students and fellows likely enter their labs with some scientific attitudes and norms already formed. They may even choose to work with faculty members whom they perceive to mesh well with their own personalities and preconceived attitudes. However, these possibilities do not invalidate the primary importance of the lab and advisor in the socialization process. This hypothesis about socialization is consistent with the data discussed below, and as I show, it is useful in understanding the implications of UIRs for the training of new scientists.

Extent of Industrial Training Relationships. The extent and magnitude of UIRs bound their potential consequences for the training of students and fellows. Empirical evidence suggests that among the most research intensive universities, industry frequently provides training support, but the public sector remains responsible for the vast majority of funds for the training of scientists. The data also reveal that trainees' relationships with industry can take several different forms. This empirical evidence comes from two sources. The first is a 1984 survey of 106 firms known to conduct or support research in biotechnology, and the second is a 1985 survey of 693 life science graduate students and post-doctoral fellows from six universities. The design of each survey and the sampling methodology of each is reported elsewhere.[14]

The data from industry show that of Fortune 500 companies involved in biotechnology, 70 percent provided funds for training while only 24 percent of smaller companies offered training support. Table 2 summarizes the magnitude of this support. The three sets of estimates (represented by the three rows in the table) reflect differing assumptions about support provided by non-responding

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[14] Blumenthal, et al., 1986a and 1986b. Gluck et al, 1987.

firms. In 1984 biotechnology firms provided between 1735 and 2665 training grants and scholarships to life science graduate students and fellows at a cost of between $8 and $24 million. The best guess estimates for these figures are 2301 grants and scholarships at a cost of $15 million. Analysis not presented in Table 2 indicates that support from industry represents between 15 and 21 percent of all training grants and scholarships in basic and clinical biomedical sciences, and between 4 and 12 percent of funds for such support. As data from the survey of trainees presented below indicates, these figures may underestimate the influence of industry on the training experience. They do not necessarily reflect trainees who do not get direct industry support themselves, but who work in the labs of faculty advisors whose research is supported by industrial funds.

Table 2
Magnitude of Biotechnology Industry Support of University Life Science Training in 1984: Estimates from the Industry Survey

	Number of Training Grants & Scholarships Provided	Total Funds Provided for Training Grants & Scholarships ($ millions)	Average Award Size ($/award)
Minimum Estimate (Assumes no nonrespondents support training)	1738	$ 7.91M	$4551
Middle Estimate (Assumes nonrespondents support training at same rates as respondents)	2301	$15.39M	$6688
Maximum Estimate (Assumes all nonrespondents support training)	2663	$24.45M	$9181

The figures also show that on average industry awards are smaller than government awards. Government awards in 1984 ranged from $12,385 for predoctoral grants to $22,425 for post-doctoral trainees. Dividing the figures in the previous paragraph suggest that on average industry awards run betwen $4551 and $9181 with a best guess of about $6700.

It is difficult to draw conclusions from the smaller size of industrial training grants and scholarhships. First, there is no evidence that government awards represent the true cost of training a scientist. In addition, while the recipients of public training awards may be limited in the amounts of money they can receive from sources other than the government award for family resources, the recipients of industrial funds problably do not face such constraints. They may supplement industry awards with funds from other sources. In addition, firms may view these grants as a means to search out talented trainees for possible recruitment or, in some cases, to solve industrially defined technical problems through trainees' research, rather than as a means of paying for a student's entire education. Hence, industry may tend to give smaller awards.

This evidence about the prevalence of industrial support parallels information collected in a survey of 1238 faculty at research intensive universities.[15]. While 22 percent of faculty who do work in biotechnology receive research support from industry, most of these faculty still receive the bulk of their research funds from the government. Only 5 percent of all biotechnology

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[15] Blumenthal *et al.*, 1986b.

faculty receive more than 60 percent of all their research support from industry. Among chemists and engineers, the proportions are somewhat higher, but the trend remains the same. Of these faculty, 45 percent receive research support from industry, and 15 percent receive more than 60 percent of their funds from private firms.

Data from the survey of trainees indicate that 19 percent of students or fellows in the departments and schools surveyed receive research, salary, training grants or scholarships directly from industry. Another 15 percent receive no direct industry support themselves, but their faculty advisors get research funds from private firms. The remaining 66 percent have neither type of industry involvement.

This classification has an analytical appeal since it categorizes trainees according to their level of industrial involvement. It also has a methodological appeal since enough respondents from the survey fall into each of the three categories to allow statistical comparisons of the groups. However, students and fellows have involvements that are not captured by the three categories. As Table 7 shows, some respondents consult with industry, help train scientists from private firms, or collaborate informally with industry. These data point to the diversity of forms that UIPs can take besides industrial grants to support trainees or their faculty advisors' research. In addition to the relationships reported by respondents to this survey, universities may attempt to garner equity in organizations that commercialize research on its campus. Faculty may consult with firms. Universities and industry can come together to form an independent research consortium or center. Each of these means of university-industry cooperation is likely to have its own set of consequences for involved parties. Hence, in trying to provide a fuller analysis of the affects of industrial relationships on university training than is possible with current data, one should explicitly control for the detailed organizational context in which the relationship occurs.

Table 3
Industry Involvements of Students and Fellows

	Category		
	Receives Research, Salary, Training Grants or Scholarship Support Directly from Industry	Receives No Industry Support, But Faculty Advisors Receive Industry Support	Has Neither Industry Involvement
Proportion of the Whole Sample (n=693)	.19	.15	.66
Proportion of Each Category . . .			
Helping to train industry personnel	.11	.06	.03
Consulting for pay	.05	.04	.01
Informally collaborating with industry personnel	.26	.19	.11
Receiving Research Funding	.63	0	0
Receiving Salary Support	.52	0	0
Receiving Training Grants or Scholarships	.33	0	0
Whose Faculty Advisors Receive Industry Support	.58	1.0	0
TOTAL	1.0	1.0	1.0

Taken together, these data suggest that trainees' socialization to science takes place in an enviornment where industry has a presence through direct financial support and a variety of other types of relationships.

Conditions Placed on Industrial Support of Trainees. Data from the survey of trainees also yield evidence about the degree to which an industrially funded training experience allows a scientist to develop the ability to conduct independent research as opposed to constraining the trainee's choice of research topics or first jobs. In examining constraihts placed on trainees, it is important to compare the conditions attached to industrial support with the limitations imposed by public sponsors. Even if firms constrain the beneficiaries of their support, their expectations may be no more stringent than those of federal agencies. Indeed, at some future point, policy makers may wish to consider the question of how conditions placed on public training funds affect awardees' socialization to science.

Government training grants and fellowships require recipients to "pay back" their support by doing research or by teaching. However, life science National Research Service Awards given by the National Institutes of Health and other federal agencies do not restrict recipients' research topics. Industrial sponsors, on the other hand, may place conditions upon trainees they support. Firms may restrict the reserach topics students and fellows may investigate, they may obligate trainees to work for the supporting firm, or they may require students and fellows to perform other services of benefit to the company. Excessive obligations may make an industrial training experience qualitatively different (perhaps more narrowly focused) than a government supported education.

This analysis of potential restrictions concentrates on training grants and scholarships since they seem the least likely form of industry support to have conditions or restrictions attached. Firms are likely to expect some direct return on its investment in research projects, and salary support is given in return for work. Thus understanding the requirements placed by industry on training grants and scholarships provides an indication of the minimal conditions attached to industrial support of training in universities.

Of the six universities from whose students and fellows answered the trainee survey,[16] only two (Harvard and MIT) had policies regarding the requirements that firms may make upon graduate students they support. Both schools indicated that industry cannot require trainees to perform any of the tasks mentioned in the preceding paragraph.

Of the 43 students and fellows responding to the student survey who receive training grants or scholarships, three reported that research sponsors expect them to work on problems defined by the firm. Three are required to work for the firm during the summer, and one is expected to work for the company after completing training. Nine said that they are required to perform some other activity that might directly benefit the firm. In total fifteen individuals, or 35 percent of the students and fellows receiving training grants or shcolarships from private companies indicated that the firms place at least

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[16] The six universities are: Harvard, Stanford, MIT, University of Pennsylvania, Johns Hopkins, and UCLA.

one of the above restrictions on their support. These figures confirm results from the survey of firms which indicate that 32 percent of firms that support life science graduate students impose at least one of the restrictions on recipients of such funds.

The data suggest that industry support of training is not a simple substitute for government support. A considerable portion of funds for training (and presumably most for research) provided by industry come with some conditions attached. Cursory analysis indicates that these conditions differ somewhat from those imposed by governmental agencies, which generally do not limit the students' choice of research topics, their use of summer time, or their subsequent career plans beyond requiring that they spend some time doing the research or teaching that most plan do do anyway. However, as suggested at the outset, a more in-depth analysis is necessary to determine if some public support carries restrictions beyond the "pay back" period and how these obligations may alter the training experience. For example, if some agencies fund graduate training in a very specific field or if they require prospective awardees to write a research proposal, the training experience may become as narrow as some fear an industrially funded education may become.

Trainee Relationships With The Faculty Advisor. Once in a laboratory with financial support, a trainee's relationship with his faculty advisor affects his educational experience. By directing the work of the laboratory, the advisor determines the trainee's responsibilities and a large part of the scientific expertise the trainee must acquire to fulfill these responsibilities. In addition, as the nomenclature implies, the advisor is responsible for reviewing the trainee's dissertation or post-doctoral research. Accessibility of the advisor is an indicator of how well he or she can fulfill his integral role in the socialization process.

The data on UIRs in biotechnology shed some light on the implications of relationships with industry on training and socialization to science in particular. The information presented in Table 3 from the survey of trainees shows a strong correlation between student and faculty financial support from private firms. Of the 19 percent of trainees who receive research, scholarship or salary support from industry, 58 percent indicate that their advisors also receive research support from industry. This suggests that the advisors may be responsible for connecting the student or fellow with his potential benefactor or that the presence of industrial funding for the faculty member may create the opportunity for a trainee to consider the merits of such such support for himself.

While faculty research funds from industry may signal a laboratory environment hospitable to industrial cooperation, they may also suggest faculty members whose commitments to private firms limit the amount of time they have available to fulfill their educational responsibilities. Data from the survey of faculty, however, do not support this hypothesis. Professors receiving research support from industry actually report significantly more ($p<.05$) university and professional activities on average than do their colleagues not receiving research funds from private firms. Faculty with industrial research support also report more hours of student contact each week than do professors without industrial support although this differant is not statistically significant at the .05 level.

Despite these results, industrial research funding may still lead to a lessened commitment to educational responsibilities.[17] However, the positive association between industry funding and university responsibilities probably reflects the fact that private firms fund the most productive faculty. This suggests that students in laboratories with industrial support may be in the most educationally vital university environments.

Another faculty activity that may influence the socialization of new scientists and the accessibility of faculty for trainees is equity holding in a private firm. This type of UIR may result from faculty efforts to commercialize their own research.[18] A professor who owns stock in a firm related to his or her own research has responsibilities and interests more closely tied to the financial success of the firm than does a professor only receiving research support from industry. One might hypothesize that the potential influence of such relationships upon the training of students and fellows may also be more profound than when faculty only receive research support. Involved faculty may face conflicts of commitment. In addition, if the involved firms provide support for the research and training of students and fellows in the labs of faculty owners, then those professors face a particularly worrisome conflict of

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[17] To examine this question further, one would need to know the number of professional activities and hours of student contact faculty with industrial support would have reported *in the absence of industrial support*.

[18] Henry Etzkowitz, "Entrepreneurial Scientists and Entreprenurial Universities in American Academic Science." *Minerva*, **21**, 232 (1983). Derek C. Bok, "Balancing Responsibility and Innovation," *Change*, (September 1982), 16-25.

interest, since they could profit personally from the work of trainees. In this situation, faculty could be tempted to direct students into projects that serve their companies' purposes, rather than the career or educational goals of the student.

The data suggest the existence of these risks in small numbers. Of biotechnology faculty responding to the faculty survey, only 8 percent reported owning stock in a firm whose products or services are based on their own research. Among chemists and engineers, the figure is 6 percent. In the sample of trainees, however, 14 percent of the students and fellows report that their faculty advisors own stock in biotechnology firms, while another 55 percent do not know if their advisors hold such equity. Of those answering affirmatively, 7 percent receive research support from the company, and 3 percent get salary, training grants or scholarships. Among this selected group of universities, a substantial minority of students and fellows work with faculty who hold equity in companies related to the research, and a very small number of students or fellows are supported by such companies.

An analysis of how equity holding affects the amount of time faculty report spending with trainees or other university activities yields results similar to those for faculty receiving research support. On average, equity holders report involvement in the same number of university or professional activities and more hours of student contact as non-equity holders. This latter difference is almost significant at the .05 level (p=.06).

Hence, except for the small number of cases in which equity holding faculty face potential conflicts of interest, the data reveal minimal risks to the socialization of trainees due to the industrial involvements of their faculty advisors.

Scientific Productivity. Part of the socialization process involves learning how to share scientific results with the community of one's peers. In addition to learning how to write scientific papers and choose appropriate journals or forums for their presentations, publishing is one accepted measure of academic productivity. Authorship aids trainees (and all academic scientists) in searching for jobs or securing research funds. Some observers worry that scientists involved with private furms may display less commitment to traditional academic activities.[19] Others suggest that industrial support will actually increase the academic productivity of researchers.[20] Enhanced academic productivity could give students and fellows receiving industrial support a competitive edge in seeking jobs or grants. A less impressive record could have the opposite effect.

To ascertain whether industry involvement is associated with the number of papers students and fellows publish, the trainee survey asked how many articles respondents have authored or co-authored in referreed journals. Those with direct support from industry report significantly fewer ($p<.01$) fewer publications on average (2.62) than do those woith no industry support (3.67) or those

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[19] Bok, 1984. Nicholas Wade. The Science Business, New York: Priority Press, 1984.

[20] D. C. Pelz and F. Andrews. Scientists in Organizations: Productive Climates for Research and Development, New York: John Wiley and Sons, 1966.

whose faculty adviosrs receive funds from industry (3.91). The difference in average publications betweeen those who are uninvolved with industry and those whose advisors receive support is not statistically significant.

Multivariate analysis confirms this pattern. In an ordinary least squares regression, only one factor was significantly related to publications--direct industry support of research, salary, training grants or scholarships. Other variables included in the model were: the faculty advisor's relationships with industry, whether the respondent is a graduate studetn or post-doctoral fellow, the year the respondent entgerd graduate school, the respondent's sex, whether the respondent does research involving any of the new biotechnologies, and whether the respondent does most of his or her research in a medical school setting.[21]

There are at least two interpretations of this finding. First, industry may support more applied research that leads to fewer academic publications than does work supported by other sources. However, similar analyses of publications reported by faculty respondents to that survey reveals that faculty members receiving research support from industry report significantly <u>more</u> publications than other faculty. If the nature of the work supported by industry inhibits

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[21] Since one would expect numbers of publications to be distributed in a Poisson fashion, the regression model used to approximate this process was of the form: $\ln(1+P_i)=\alpha + X_i\beta + \epsilon_i$ where P_i is the number of articles published by respondent i, X_i is the vector of characteristics described in the text, ϵ_i is a normally distributed disturbance term, and α and β are estimated parameters. See Jerry Hausman, Bronwyn H. Hall and Zvi Griliches. "Econometric Models for Count Data With an Application to the Patents-R&D Relationship," Econometrica, 54:2 (July 1984) 909-938.

publication, we would expect faculty with industry support to publish less as well.

A second potential explanation for the lower publication rates of students with direct industrial support is that the most academically productive students and fellows seek and obtain other sources of funds. This interpretation is also consistent with the disparity between faculty and trainee publications. One would expect faculty to be a more academically homogeneous group than trainees; faculty have probably already demonstrated some commitment to academic activities like publishing by securing a university position. The talents of trainees may vary more. Some may want jobs in industry or other sectors where publishing is not as highly valued as it is in academia. Although the existing data do not allow one to distinguish with certainty between these alternative interpretations of the findings, the second seems more consistent with the results presented here.

Another form of scientific productivity is patenting. Like publications, patents are a means of sharing scientific results. They are also designed to protect the proprietary rights to discoveries. Industrial support of student and post-doctoral research and training could encourage commercial productivity among trainees, perhaps by sensitizing them to commercial applications of their research. Data from the survey of trainees indicate that this effect may occur.

Students or fellow with direct industry support were substantially more likely than uninvolved students or fellow to report that patents or patent applications resulted from their work (12 versus 4 percent, $p<.01$). Of those who lack direct support but whose faculty advisors get industrial funds, 8 percent reported patents or patent applications, a greater proportion than among those with no involvements (p=.08). Students and fellows reported trade secrets[22] less frequently than patents: 4 percent of those with direct support, 2 percent of those whose faculty advisors get support, and 2 percent of those with neither type of support. These difference are not statistically significant.

These data suggest that life science students and fellows are contributing somewhat to potentially profitable research results and that the frequency with which they report patents and trade secrets may increase with the level of industry involvement. In addition, since the trainee survey only asked respondents about their own commercial productivity, trainees' contributions to their faculty advisors' patents and trade secrets remain unmeasured. Hence, the patent and trade secret figures above are likely to underestimate the extent that students and fellows contribute to research with possible commerical utility, and could also understate the relationship between industrial support of research and training and the commercial productivity of trainee research. Taken together, these results support the notion that industrial funding in a laboratory may add a commercial component to socialization of trainees.

<u>Secrecy</u>. A commitment to the open communication of scientific information is an important academic norm. Since it is vital to the educational process itself as well as to research advances, it is an idea whose importance the univ-

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[22] One can define trade secrets as another measure of commercial productivity. Unlike patents, however, the owners of trade secrets do not disseminate them among the scientific community.

ersity seeks to impart to new scientists.[23] Industrial support of research and training may create conflict between a firm's need to protect the propietary value of research it sponsors and this academic norm of open intellectual exchange among scientists. The data on publications reviewed above suggests an association between involvement with industry and student publications worthy of further investigation. Two other items from the trainee survey suggest that in some cases students and fellows believe involvement with industry may inhibit publication and the discussion of research results. However, because of very low response rates to these two questions (47 and 58 percents of those answering the survey), future empirical work should examine in greater detail how industrial funding affects intellectual exchange among scientists and trainees.

B. Content of the Training Experience.

As the discussion above demonstrated, it is sometimes difficult to distinguish between trainees' socialization to science and the actual scientific skills and knowledge they acquire. The data at my disposal allow little if any opportunity to look for any associations between industrial involvement and the specific scientific topics studied by trainees. The surveys did not collect this information. However, I can usefully turn my attention to the basic and applied qualities of work conducted labs with industrial funding.

Basic and Applied Work. Research with basic qualities extends fundamental scientific understanding. Research with applied qualities seeks to employ .

23A. Bartlett Giamatti, "The University, Industry and Cooperative Research," Science, **218**, 1278 (1982).

fundamental science to create useful products or processes. As discussed earlier in this paper, basic and applied science are not mutually exclusive. The data on UIRs in biotechnology offer some indirect evidence that industrially funded work is more applied than that supported by other sources, but they yield little information about the degree to which UIRs also extend fundamental scientific understanding. Since research forms the basis for the training of advanced graduate students and post-doctoral fellows, the qualities of such laboratory research also reflect, at least in part, the characteristics of training in that laboratory. While the average length of grants awarded by NIH is 3.2 years[24], data from the survey of biotechnology companies shows that the average length of academic projects sponsored by just over half of all firms funding university work is a year or less. Only 28 percent of sponsoring firms report the average length to be over two years in length. Projects of short duration seem likely to be applied in nature, perhaps undertaken to solve specific technological problems necessary to manufacture and market a product. Projects that are largely designed to further basic scientific understanding are more likely to be funded for a long period of time since no one can fully anticipate results from such investigation.

Moving from the qualities of research to those of training, the issue becomes the same as that underlying obligations attached to industrial training

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[24] Thomas D. Morris, "Current Organizational Structure of the National Institutes of Health," in Institute of Medicine, Responding to Health Needs and Scientific Opportunity: Organizational Structure of the NIH, Washington, D.C.: National Academy Press, 1984.

support--the tension between independence and directedness in trainees' education. The narrow focus connoted by applied research may not allow trainees to acquire knowledge, techniques and practice necessary to conduct independent scientific research in the future. At the same time, however, a laboratory engaged in applied work may not shun fundamental science. The real question may be whether a lab conducting industrial or other applied research is open to pursuing leads that may extend basic scientific understanding. If trainees are regularly exposed to their advisors trying to recognize fundamental patterns in scientific results, training in a lab conducting applied research need not deprive new scientists of exposure to the broad skills necessary to conduct independent, basic research.

Regular pursuit of the basic implications of applied research, however, requires more than intellectual commitment. The serendipitous nature of science suggests that luck may play some part. In addition, financial resources are necessary to follow scientific leads. During the period of "steady state," such funds may not as readily available as in earlier times. Faculty may not encourage students in their labs to pursue tangential leads as commonly as they might have 15 years ago.

Trainee Assessment of the Quality of the Training Experience. Although the survey of trainees contains no direct indicators of the scientific content of trainees' educational experience, it did ask respondents to characterize the quality of their training on a five point scale from "poor" to "excellent." All responding students and fellows tended to give their experiences high marks. Over half of the sample reported their training to be excellent, and another 45 percent rated it as good or very good. The difference in mean ratings between those who receive direct industrial support and other respondents was not statistically significant. On the basis of this simple measure, industry support of trainees does not seem to be associated (positively or negatively) with students' overall assessments of the quality of their training. Unfortunately, the survey offers little additional insight into the content of the training experience.

C. Length of the Training Period and Career Patterns

The third category of variables potentially affected by UIRs includes the amount of time new scientists spend in training as well as the types of employment they obtain subsequently. It is difficult to hypothesize any important implications of industrial funding for the amount of time trainees spend as students or fellows. However, one phenomenon of the "steady state" does deserve some mention here--the protracted post-doctoral fellowship.

Some observers have suggested that retrenchment in faculty hiring has led to the creation of a body of Ph.D. scientists who work in university labs without full faculty appointments. In essence, these researchers have continued to be post-doctoral fellows beyond the usual length of time for such appointments.[25] It is interesting to note, however, that in constructing the sample for the survey of trainees, only 10 out of 707 otherwise eligible respondents reported serving as post-doctoral fellows for more than three years. This small

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[25] Albert H. Teich, "Research Centers and Non-Faculty Researchers: A New Academic Role," in Don Phillips and Benjamin S. P. Shen, 1982.

number is no doubt due in large measure to the fact that these non-faculty researchers are probably not called "post-doctoral fellows" after a certain length of time and thus did not receive (or return) the trainee questionnaire. However, this statistic does point out the need to gather reliable data about the extent of this phenomenon. Such information is necessary to draw any useful implications of protracted post-doctoral fellowships for American science.

Returning to UIRs, involvement in industry supported research and training may affect the career patterns of scientists. It may make employment in industry more appealing to students. The survey of trainees attempted to assess this potential effect in the life sciences by asking respondents to indicate whether they intend to seek their first job in academia, industry, government or some other sector. As Table 4 shows, students and fellows who receive direct industry support or whose faculty advisors receive support appear similar in their career plans to their counterparts without these exposures to industry. The bulk of students and fellow anticipate academic careers with about 15 percent planning industry jobs. Students and fellows who receive direct support are slightly more likely (19 percent of this group) to indicate an intention to work in industry. Of the subset who receive direct support but whose faculty advisors do not get industry support, primarily graduate students, 21 percent indicate an intention to work in industry. Neither of these differences, however, is statistically significant.

The ultimate behavior of students could differ from their stated intentions. A longitudinal study of scientists' career patterns beyond graduate school would yield useful information. Nevertheless, expectations that industry support of university research and training will encourage large numbers of very talented trainees to forsake academic careers do not seem justified, at least among the universities and departments surveyed.

Table 5
Training UIRs and the Career Choices of Students and Fellows

	Receives Direct Industry Support	Faculty Advisor Receives Industry Support	Has Neither Industry Involvement
N in each category	132	104	457
"Where do you expect your first (or next) full-time job to be?" (proportions)			
University	.75	.75	.78
Industry	.19	.17	.14
Government	.01	.03	.03
Other	.05	.05	.05

Conclusions.

The empirical evidence reviewed above helps illuminate the process of training scientists during a period of steady state as well as the impact of university-industry cooperation upon this process. In 1984 firms involved in biotechnology research provided a sizeable contribution for the training of scientists in the life sciences in universities--between $8 and $24 million. In the most research intensive universities, 19 percent of life science students and fellows receive such support in the form of training grants and scholarships. Another 15 percent receive indirect support from industry through their faculty advisor's research budget. The magnitude of this support is also one of its greatest benefits. It helps to finance the training of new scientists. While such support may be an important contribution at the margin, however, it is important to keep in mind that government provides the bulk of all training funds. In 1984, industrial support represented between 4 and 12 percent of all direct training grants and scholarships for graduate students and post-doctoral fellows in the life sciences. The remainder came from the public sector.

Industrial training support is also associated with potential commercial benefits. Life science students and fellows who receive direct industry support are three times (and statistically significantly) more likely to report patents resulting from their research than are trainees without such relationships with industry. While the proportions of these groups who report trade secrets resulting from their work display a similar pattern, the differences are not statistically significant. Hence, trainees with industrial support are producing research results that either the faculty advisor, university or sponsoring firm believes may yield profitable products or research. In the life sciences, this phenomenon reflects the emergence of new technologies in university as opposed to industrial labs. UIRs involving students and fellows serve the dual purposes of furthering scientific research and development while teaching trainees the technologies current in academic and industrial science.

Despite these benefits, however, the evidence indicates that industrial training support differs from that provided by the government in both the restrictions placed on recipients and the scientific content of the training experience. About a third of all recipients of industrial training grants or scholarships responding to the trainee survey report that they must perform some activity of direct benefit to the sponsoring firm. A cursory comparison indicates that these obligations may make an industrially funded training experience more restrictive for students and fellows than one funded by government training grants. There is no evidence about how such restrictions affect a trainee's ability to conduct independent research as one expects of Ph.D. scientists. The relatively short duration of industrially funded research in universities and the commercial potential of such work suggests that training and research supported by private firms is also more applied in nature than that funded by the public sector. Little evidence exists about the basic qualities of industrially supported research and training, although this characteristic may depend on the degree to which faculty advisors encourage the lab to pursue fundamental science that evolves from industrially funded work.

Although industrially supported training experiences do not seem to be characterized by excessive risks to academia, the data suggest a few undesireable phenomena worthy of close consideration. In a few cases industrial training grants and scholarships may be associated with increased levels of trade secrecy, delayed publication, and inhibited scholarly discussion. The data are not conclusive, and the risk of increased secrecy deserves further empirical investigation. A related finding indicates that trainees with industrial support may publish significantly less than those without this private funding. These results may reflect a predilection on the part of trainees involved with firms to publish less rather than indicate an actual effect of industrial funding. This finding also contradicts a similar analysis of faculty publishing behavior. Finally, at least 14 percent of trainees responding to our survey indicated that their faculty advisors hold equity in a firm whose products or services are based on their own research. An extremely small number of these trainees also receive research, salary or training support from the company, thus posing a potential conflict of interest for the faculty advisor who could direct the trainees for the benefit of the company rather than for the benefit of the trainees' educations and careers.

The potential presence of these risks is tempered by at least two important points. First, if they occur, they do not appear with great frequency. Of those trainees receiving industrial support, only a minority report each of the behaviors reviewed above. In addition, the data on the extent of industrial funding shows that while firms provide a large sum of money, this is only a marginal contribution to the total training effort in universities. If these risks occured among a majority of training grant or scholarship recipients, or if the total industrial influence on campuses were greater, academia may have greater cause for concern.

Second, university policy may be able to ameliorate some of the risks that do occur. University administrators may wish to consider guidelines for the involvement of students and fellows with industry, and in some cases prohibit certain types of behavior altogether. For example, they may wish to consider limitations on trainee involvement with firms in which a faculty member holds a significant financial interest. The survey of university administrators suggests that many institutions have already adopted guidelines promoting open communication of research and the disinterested pursuit of knowledge. In many cases, these policies are quite specific in their proscriptions. However, a preliminary analysis of data from the faculty and trainee survey indicates that a majority of individuals at these univeristies do not know about the existence or content of the policies.[26] Because universities are decentralized institutions and because the training experience revolves around the lab and the faculty advisor's leadership, university administrators should carefully consider the mechanisms at its disposal to publicize guidelines they adopt and indirectly to insure compliance. A full analysis of potential policies and enforcement mechanisms a university might adopt would vary by institution and also is beyond the scope of this paper and available evidence.

By way on conclusion, there are a few other issues that arise from this paper. First, there is no evidence to suggest the existence of at least two other risks to academia commonly mentioned in discussions about the implications of industrial funding. Students and fellows who receive industrial funding are also no less likely to choose academic careers than are trainees without industrial support, and faculty involved with industry display no less commitment to teaching and other traditional academic activities than do their uninvolved colleagues. The evidence actually indicates that industrially supported labs are *more* productive than other labs.

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[26] Gluck, 1987, pp. 189-193, 221-225.

The second issue concerns the proper definition of a "research university." In order to understand fully the implications of industrial funding for graduate training, it may be necessary to examine a broad range of universities. This paper has defined a research university according to the amount of federal R and D funds it receives. The data on UIRs in biotechnology analyzed by the author come from the top such schools. The student and fellow survey represents six of the ten schools with the most funds. Using this same definition, another survey gathered information from administrators at the top 100 schools, and a third collected data from faculty at the top 40 campuses. Implicit in this analysis is the assumption that the most research intensive schools have the best training programs, and that they train the future "leaders" of their scientific fields. The values and experiences of these individuals will have a marked influence on the course of science in years to come.

However, an examination of only these schools may be too narrow. The impact of industrial funding may be greatest at those institutions with fewer federal funds. They may face greater competition for students and more of an incentive to seek industrial support than the schools with the most federal research dollars. Further research should examine the numbers of scientists trained at institutions not receiving the highest amounts of federal R and D funds, the extent of industrial training funds on these campuses, and the ways in which such funding affects the educational experiences of new scientists.

The third issue concerns how analysts generalize from one scientific discipline to another. At any point in time, the opportunities and resources available to chemistry and engineering may be quite different than those available to the life sciences. Even within the life sciences, research funds and career opportunities may vary. The constraints of "steady state" as well as the commercial incentives for industrial investment may not be as great in some fields as in others. Hence, the data presented in this paper may be at once too general and too specific. They may mask important distinctions within the life sciences, and they may present little evidence relevant to the physical sciences or engineering. Future work may wish to address these shortcomings.

The fourth issue, which may be the most important, concerns public policy. As suggested throughout this paper, the public sector is actively involved in the research university. Indeed, governmental intervention may be an appropriate way to ameliorate some of the detrimental effects of the "steady state" or industrial funding for society's interest in the training of new scientists. As I suggested for university policy, the analyses in this paper may have implications for and insights into public policy, but they do not yield specific policy recommendations. Such recommendations require detailed analyses of current policies and their alternatives--a task beyond the scope of the statistical analyses of university training presented in this paper.

The American research university is an evolving institution. It shows evidence of adapting to both demographic changes and fluctuations in government policy. Such flexibility allows it to accomodate changing societal needs. Evidence suggests that industrial funding of university training and research may be such a development. Industrial support is an important marginal contribution to the training system, but government remains responsible for funding the bulk of all scientific training. Industrial support may also help those trainees with an interest in the application and development of science to acquire the skills useful for their careers. While industrial funds are no simple substitute for government funds, there is no evidence that such relationships with the private sector by themselves diminish a trainee's ability to conduct independent or basic research. To avoid these and other risks, analysts should continue to monitor the impact of university-industry cooperation, and universities should seek mechanisms to insure that they work within the public interest.