

Special Article

PARTICIPATION OF LIFE-SCIENCE FACULTY IN RESEARCH RELATIONSHIPS WITH INDUSTRY

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ABSTRACT

Background Recent research on academic-industrial research relationships in the life sciences has examined their frequency, benefits, risks, and evolution from the standpoint of industrial sponsors of research. We collected information on the extent and effects of academic-industrial research relationships from the standpoint of faculty members who participate in them.

Methods We used a mailed questionnaire to collect data between October 1994 and April 1995 from 2052 faculty members (of 3169 eligible respondents; response rate, 65 percent) in the life sciences at the 50 U.S. universities receiving the most research funding from the National Institutes of Health.

Results Twenty-eight percent of the respondents received research support from industry. Faculty members receiving industrial funds had more peer-reviewed articles published in the previous three years, participated in more administrative activities in their institutions or disciplines, and were more commercially active than faculty members without such funding. However, faculty members receiving more than two thirds of their research support from industry were less academically productive than those receiving a lower level of industrial support, and their articles were less influential than those by researchers with no industrial support. Faculty members with industrial support were significantly more likely than those without industrial support to report that trade secrets had resulted from their work (14.5 percent vs. 4.7 percent, $P < 0.001$) and that they had taken commercial considerations into account when choosing research topics (35 percent vs. 14 percent, $P < 0.001$).

Conclusions Faculty members with industrial research support are at least as productive academically as those without such support and are more productive commercially. However, faculty members who have research relationships with industry are more likely to restrict their communication with colleagues, and high levels of industrial support may be associated with less academic activity without evidence of proportional increases in commercial productivity. (N Engl J Med 1996;335:1734-9.)

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RECENT research indicates that academic-industrial relationships in the life sciences have substantial benefits for industrial sponsors and that the rate of industrial support of academic life-science research may have increased over the past 10 years.¹ However, little is known about the current extent of academic-industrial research relationships in the life sciences and the effects of these relationships on the involved faculty. Research from a decade ago indicated that faculty members who received industrial support for their life-science research had more papers published, applied for more patents, and participated in more academic administrative activities than faculty who did not receive such support, and also taught as much.² Faculty members with industrial research support were also more likely to report that they had kept research results secret to protect their proprietary value.²

This previous work, however, is of limited use in understanding the current extent, benefits, and risks of academic-industrial relationships in the life sciences from the academic perspective. The sample of faculty members on which the study was based underrepresented clinical research and was thus atypical of the life sciences as a whole. Also, the extent and effects of research relationships between industries and academic institutions in the life sciences may have changed in important ways over the past decade.

To explore the implications of these research relationships for academic institutions, we analyzed the responses of 2052 life-science faculty members to a questionnaire about their participation in research arrangements funded by industry.

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METHODS

Sample Selection

The data presented here were collected from a survey of life-science faculty conducted between October 1994 and April 1995. A sample of 3742 faculty members was selected in a three-step process.

First, we identified the 50 U.S. universities that received the most extramural research support from the National Institutes of Health in 1993.

Second, we chose a sample of life-science departments and programs from those institutions. Using *Peterson's Guide to Graduate Programs in the Biological and Agricultural Sciences* for 1994³ and catalogues from medical schools, we identified all medical school departments and other academic life-science departments and graduate programs at the 50 universities. The medical school departments were classified as clinical or nonclinical according to whether their names referred to a clinical or a nonclinical discipline, and the clinical departments were designated as medical or other clinical. Medical clinical departments consisted of departments of medicine, internal medicine, and medical subspecialties that were listed as separate departments. Other clinical departments consisted of departments of pediatrics, family medicine, anesthesiology, dermatology, emergency medicine, radiology, and pathology, as well as various surgical departments, such as urology, otolaryngology, orthopedics, and obstetrics-gynecology. The nonclinical category consisted of medical school departments of and graduate academic programs in biochemistry, molecular biology, genetics, biology, microbiology, anatomy, and so on. At each university, we randomly surveyed one nonmedical clinical department, one medical clinical department, and two nonclinical programs or departments. Medical clinical departments were oversampled in this way because they often receive the preponderance of research funds at academic health centers.

Third, we developed a stratified sample of life-science faculty members from our samples of clinical and nonclinical departments, so that half were from clinical departments and half were from nonclinical departments. To avoid the inclusion of fellows and hospital staff members not truly functioning as faculty, clinical faculty members were eligible for the sample only if they had an article other than a review or a letter listed in the National Library of Medicine's Medline data base for the period from 1990 through 1994.

Survey Design

The survey instrument was a modified version of an instrument administered to 1238 faculty members in the life, chemical, and engineering sciences during a similar study of academic-industrial relationships in 1985.² In the current survey, we collected data on demographic characteristics, productivity, and involvement with industry.

The survey was conducted by mail in collaboration with the Center for Survey Research at the University of Massachusetts. Of the 3742 faculty members included in our initial sample, 573 were ineligible because they were listed in more than one department, were deceased or retired, did not hold a faculty appointment, or could not be located (no return address was provided on an undelivered questionnaire and telephone follow-up was unsuccessful). Of the remaining 3169 faculty members, 2052 completed the survey, for an overall response rate of 65 percent; 927 (63 percent) of the respondents were from clinical departments, and 1125 (67 percent) were from nonclinical departments. Subsample response rates were computed as the number of completed responses in a subsample divided by the number of eligible respondents in that subsample. Table 1 shows the characteristics of the respondents in the clinical and nonclinical subsamples.

One hundred twenty-four nonrespondents were interviewed briefly by telephone to determine how they may have differed from the respondents. The nonrespondents were significantly more likely to have non-tenure-track or junior appointments

TABLE 1. CHARACTERISTICS OF THE STUDY SAMPLE.*

CHARACTERISTIC	ALL FACULTY (N=2052)	CLINICAL FACULTY (N=927)	NONCLINICAL FACULTY (N=1125)
	number (percent)		
Male sex	1677 (82)	772 (83)	905 (80)
Years in profession			
0-5	26 (1)	16 (2)	10 (1)
6-10	221 (11)	85 (9)	136 (12)
11-20	823 (40)	386 (42)	437 (39)
21-30	593 (29)	256 (28)	337 (30)
31-40	275 (13)	121 (13)	154 (14)
>40	92 (4)	54 (6)	38 (3)
Academic rank			
Professor	937 (46)	338 (36)	599 (53)
Associate professor	555 (27)	277 (30)	278 (25)
Assistant professor	483 (24)	255 (28)	228 (20)
Other	73 (4)	53 (6)	20 (2)

*Because of nonresponses to questions, the numbers of faculty do not sum to 2052 for years in profession and academic rank. Percentages may not sum to 100 because of rounding.

(such as lecturer or instructor), were significantly less likely to have any extramural research support, and were significantly less likely to have industrial research support.

Publication Trends and Influence

Two variables were created to measure different aspects of publication: publication trends and publication influence. The publication-trends variable for a faculty member was the difference, if any, between the number of his or her peer-reviewed articles published in the previous three years and the average number of peer-reviewed articles published per three-year period over his or her whole academic career, excluding the most recent three years.

The publication-influence variable was created by using the methods of Pinski and Narin.⁴ They developed a set of citation-influence weights for 3100 journals covered by the *Science Citation Index*, according to the following process. Each journal was classified according to field. For each journal, an influence weight was computed by dividing the total number of citations that journal receives by the number of references the journal gives to other journals in the same field. Then the average influence of an article in a given journal (the average number of citations a paper in a journal receives, weighted by the influence of the referencing journal) was computed. To compute the publication-influence variable, we asked the respondents for the names of the journals in which their last five peer-reviewed articles had appeared. Using the influence data derived by the procedures mentioned above, we assigned each article an influence score after correcting for differences in referencing patterns among scientific fields (dividing by the average unadjusted influence score within a scientific field). Articles in journals that primarily publish reviews were excluded from the estimates of influence in order to focus on the comparative influence of publications reporting original research.

Statistical Analysis

The data were analyzed by standard statistical techniques. Unless otherwise noted, the statistical significance and the direction of reported associations between faculty participation in academic-industrial research relationships and other reported activities and behavior were tested by multivariate linear and logistic regressions adjusted for professional age (the number of years since the highest degree was earned), sex, academic rank, clinical or nonclinical de-

partment, and total research budget (direct costs) from all sources. Furthermore, because we calculated the statistical significance of the various comparisons after adjustment for the influence of the above-mentioned factors, adjusted P values are presented.

RESULTS

Prevalence and Magnitude of Industrial Research Support

Twenty-eight percent of the respondents reported receiving industrial support for their academic research in the life sciences. A significantly greater proportion of respondents in clinical departments (36 percent) than in nonclinical departments (21 percent) reported receiving industrial funds ($P<0.001$). Industry supplied 8.9 percent of all the research funds (excluding overhead) available to faculty members responding to our survey. Industrial funds constituted a significantly greater proportion of the research support for clinical faculty members (11.9 percent) than for nonclinical faculty members (6.4 percent, $P<0.001$).

Academic Activities of Faculty Members

Table 2 shows the respondents' reported levels of participation in several academic activities. The table also includes the publication-trends score and the mean influence score per article for each faculty member's most recent five articles (see the Methods section).

Respondents with industrial funding had significantly more published articles and participated in significantly more service activities in their institutions or disciplines than respondents without such funding. Publication rates in the most recent three-year period were greater than average lifetime rates for all faculty members, but the difference was significantly larger among those with industrial support. However, the average influence score of the most recent five articles by respondents with industrial support was the same as that of the articles by respondents without industrial support.

We examined the relation between the level of industrial research support (defined as the proportion of the faculty member's total direct research budget in 1995) and participation in academic activities. Rates of publication in the previous three years, numbers of service activities, and publication-influence scores were highest for faculty members with minimal or moderate support from industry (one third or less of the person's total research budget), but these variables tended to decline as the proportion of research funds from industry increased. Respondents with more than two thirds of their funding from industry had significantly lower rates of publication and less influential articles than respondents with less support from industry.

TABLE 2. SELECTED MEASURES OF ACADEMIC ACTIVITY.*

VARIABLE	NO. OF PUBLICATIONS†	TEACHING TIME (HR)‡	NO. OF SERVICE ACTIVITIES§	PUBLICATION-TRENDS SCORE¶	PUBLICATION-INFLUENCE SCORE
	adjusted mean ±SE				
Industrial support					
Yes	14.6±0.42	16.9±0.58	2.3±0.07	4.2±0.34	1.2±0.04
No	10.1±0.27**	16.6±0.37	1.8±0.04**	2.1±0.21**	1.2±0.03
Amount of industrial support (% of research budget)					
1–33	16.8±0.76	17.7±0.89	2.8±0.10††	5.0±0.58	1.3±0.06
34–66	16.4±1.16	19.3±1.36	2.2±0.16	5.3±0.89	1.2±0.10
67–100	12.1±1.18††	15.8±1.38	2.1±0.16	2.3±0.90††	1.0±0.10††
All respondents	11.3±0.04	16.5±0.29	1.9±0.04	2.7±0.17	1.2±0.02

*The means have been adjusted by multivariate analysis of variance to control for differences due to academic rank, years in profession, sex, total research funding, or clinical department.

†This variable indicates the average number of publications in refereed journals during the previous three years.

‡This variable indicates the average number of hours per week of teaching contact with predoctoral and postdoctoral trainees (including students, interns, residents, and fellows).

§This variable indicates the number of university or professional activities (in university administration, professional journals, or professional associations).

¶This variable was calculated as the difference between the number of publications in refereed journals during the previous three years and the number of publications in an average three-year period during the faculty member's career.

||This variable indicates the mean influence of a faculty member's most recent five publications, as calculated by the methods of Pinski and Narin⁴ (see the Methods section).

** $P<0.05$ for the comparison with the subgroup receiving industrial support.

†† $P<0.05$ for the comparison with both subgroups receiving different levels of industrial support.

Commercial Activities and Industrial Research Support

Table 3 shows the percentages of respondents with and without industrial funding who reported that their academic research had resulted in specific commercial outcomes, ranging from the most preliminary (a patent application) to the most advanced (a product on the market or a new company). Faculty members with industrial funding were more likely than those without such funding to report that their research had some commercial outcome.

Figure 1 shows the relation between the level of industrial support for faculty research and the rate at which the research resulted in commercial outcomes, according to the stage of advancement of the outcome. Both the frequency of commercial outcomes and their stage of advancement increased with the level of industrial research support but peaked at an intermediate level (between 34 and 66 percent) and then declined slightly as the level of support increased further.

Restrictions on Communication and Effect on Choice of Research

Faculty members with industrial support were more likely than those without such support to report restrictions on their communication of the results of their research. As shown in Table 3, 14.5 percent of faculty members with industrial support and 4.7 percent of those without such support reported that trade secrets had resulted from their research ($P < 0.001$). Trade secrets were defined as information kept secret to protect its proprietary value. Faculty members with industrial support were significantly more likely than those without such support (11.1 percent vs. 5.8 percent, $P = 0.008$) to report that they had refused requests from other academic scientists to share research results or biomaterials. Faculty members with industrial support were also significantly more likely to report that their choice of research topics had been affected somewhat or greatly by the likelihood that the results would have a commercial application (35 percent vs. 14 percent, $P < 0.001$).

Changes in the Extent and Effects of Industrial Research Support over the Past Decade

To understand how faculty involvement in academic-industrial research relationships has changed over the past decade, we compared the results of our 1995 study with those of a similar survey we conducted in 1985.¹ The 1995 sample included faculty members in all the life sciences and thus was broader than the sample in our 1985 study, which focused on investigators in nonclinical departments who were working with what were then called the “new biotechnologies”: recombinant DNA, monoclonal antibodies, gene synthesis, gene sequencing, cell and tissue culture, enzymology, and large-scale fermentation. Therefore, in comparing the results of these

TABLE 3. COMMERCIAL OUTCOMES OF RESEARCH BY LIFE-SCIENCE FACULTY MEMBERS ACCORDING TO TYPE OF OUTCOME.*

INDUSTRIAL SUPPORT	OUTCOME OF RESEARCH						
	APPLIED FOR PATENT	PATENT ISSUED	PATENT LICENSED	TRADE SECRET	PRODUCT UNDER REVIEW	PRODUCT ON MARKET	NEW COMPANY
	percent of respondents						
Yes	42.0	25.0	18.5	14.5	26.7	26.1	14.3
No	24.0	12.6	8.7	4.7	5.5	10.8	6.0

* $P < 0.001$ for all comparisons between the subgroup with industrial support and the subgroup without such support.

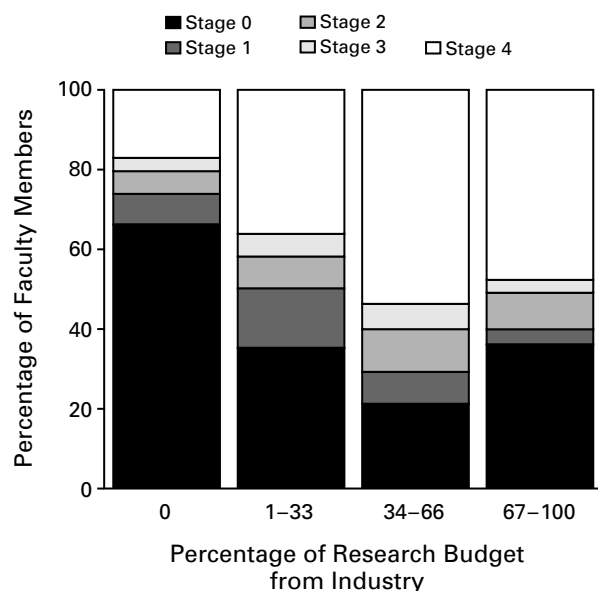


Figure 1. Commercial Outcomes of Research Reported by Faculty Members, According to the Level of Industrial Support and the Stage of the Outcome.

Stage 0 indicates no commercial outcome, stage 1 a patent application, stage 2 an issued patent, stage 3 a licensed patent, and stage 4 a product under regulatory review or being marketed or a new company.

two studies, we used data provided by the 561 respondents in the 1995 survey who reported using these same techniques in their research.

In 1985, 23 percent of faculty members using these techniques reported that they were principal investigators on research projects funded by industry, as compared with 21 percent in 1995 ($P \geq 0.05$). For these faculty members, industry supplied 7.4 percent of their total research budgets in 1985, as compared with 5.8 percent in 1995.

Table 4 shows the rates of participation in academic activities in 1985 and 1995, according to

whether or not the faculty members received industrial support. The direction and magnitude of the differences were identical in the two studies.

The experiences of faculty members in 1985 and 1995 were similar in other ways as well. In 1985, 12 percent of the respondents with industrial support reported that trade secrets had resulted from their research, as compared with 3 percent of those without such support ($P < 0.001$). In 1995, these rates were 17.2 and 6.6 percent, respectively ($P = 0.003$).

In 1985, 30 percent of faculty members with industrial support and 7 percent of those without such support reported that their choice of research topics had been affected to some extent or to a great extent by the likelihood that the results would have commercial applicability ($P < 0.001$). In 1995, 30 percent of faculty members with industrial support and 14.5 percent of those without industrial support responded positively to the same question ($P < 0.001$).

DISCUSSION

Our data indicate that in 1995 slightly more than one quarter of all faculty members in the life sciences participated in academic-industrial research relationships and that faculty members from clinical departments were significantly more likely to receive industrial support than other life-science investigators. Overall, industry supplied about 9 percent of the research funds available to academic life-science investigators.

Data from comparable investigations in 1985 and 1995 show that the rate of faculty participation in academic-industrial research relationships has remained stable over the past decade, although industry may now support a slightly lower proportion of the academic research conducted by life scientists who use the "new biotechnologies."

Our survey results suggest that faculty members receiving industrial support are at least as productive academically as those who do not receive such support and are markedly more productive commercially. These findings have been remarkably stable over

the decade between our two studies. Whether the receipt of industrial funds is causally related to the high productivity of faculty members is impossible to judge from our data, but it seems reasonable to conclude that industrial research support is associated with greater participation of faculty members in the commercialization of their research and thus increases the probability of a successful commercial outcome.⁵ If accurate, this conclusion suggests that academic-industrial relationships enhance commercial productivity among some of the nation's most distinguished academic investigators and do not compromise their participation in traditional academic activities.

However, evidence of the beneficial effects of academic-industrial research relationships must be balanced against data indicating potential risks or problems. Our data suggest that investigators with industrial support are at least twice as likely to engage in trade secrecy or to withhold research results from colleagues as are investigators without such support. Thus, academic-industrial research relationships are clearly associated with decreased communication among academic life-science faculty members.

Second, the results of our 1985 and 1995 surveys indicate that relationships with industry may encourage some investigators to pursue research with commercial applicability, which may reduce the involvement of some faculty members in fundamental research.

Third, our data suggest that faculty members who receive more than two thirds of their research support from industrial sources have lower academic productivity than those with less support from industry. This finding may merely reflect the inability of less academically successful faculty to attract peer-reviewed support from federal and other nonindustrial sources. However, our data do not allow us to exclude the possibility that, for at least some faculty members, academic productivity declines as industrial support grows over time.

In the context of previous research on academic-industrial research relationships,^{1,2,6} the results of this study have several implications for policy. Evidence from both the industrial and the academic perspectives suggests that academic-industrial research relationships facilitate the practical application of research findings by some of the nation's most productive academic scientists. This process of translation need not be associated with any decline in academic productivity or involvement in the academic community.

However, academic-industrial research relationships result in higher levels of secrecy than do other types of academic research relationships and also seem likely to encourage investigators to focus on research with a potential for commercial application. Furthermore, high levels of dependency on industrial research support are associated with reduced levels of academic activity, without evidence of propor-

TABLE 4. SELECTED MEASURES OF ACADEMIC ACTIVITY IN 1985 AND 1995.*

INDUSTRIAL SUPPORT	MEAN NO. OF PUBLICATIONS		MEAN TEACHING TIME (HR)		MEAN NO. OF SERVICE ACTIVITIES		MEAN PUBLICATION-TRENDS SCORE	
	1985	1995	1985	1995	1985	1995	1985	1995
Yes	14.6†	16.3†	22.2	19.6	1.4†	3.0†	3.3	4.3†
No	11.3	10.8	20.3	19.3	1.1	2.0	2.2	2.2

*See Table 2 for an explanation of the measures. Data in the table are unadjusted.

† $P < 0.05$ for the comparison between the subgroup with industrial support and the subgroup without such support.

tional increases in commercial productivity. Thus, beyond some point, increases in the participation of academic institutions in relationships with industry may have costs that outweigh their benefits.

A limitation of this study is that, like all survey-based data, our data may suffer from certain biases. The faculty members who did not respond to our survey differed systematically from those who did, though these differences suggest that the non-respondents were less involved in industrial relationships and may have found the questionnaire less relevant than the respondents. Similarly, the respondents may have underreported behavior or activities that they considered confidential or sensitive, such as their involvement in founding companies or keeping research results secret. If so, we may be underestimating both the potential commercial benefits and the potential academic risks of academic-industrial research relationships.

Nevertheless, we are encouraged by the consistency of our findings in similar samples of scientists over time. These findings suggest that academic institutions should be moderate and vigilant in their

pursuit of industrial support for research in the life sciences.

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