The Sustainability of University-Industry Research Collaboration: An Empirical Assessment[1]

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ABSTRACT. The concept of university-industry collaboration is an important social experiment in the nation's innovation system. This study examines the sustainability of this collaborative experience by focusing on the actual "give-and-take" outcomes between university faculty members and industrial firms. Based on two separate but similar surveys conducted in 1997, one for faculty members and another for industry technology managers, the study reports that participants in research collaboration appear to realize significant benefits, some expected and others unexpected. The most significant benefit realized by firms is an increased access to new university research and discoveries, and the most significant benefits by faculty members is complementing their own academic research by securing funds for graduate students and lab equipment, and by seeking insights into their own research. Reflecting on their collaborative experience, an overwhelming majority of these participants say that in the future they would expand or at least sustain the present level of collaboration.

1. Introduction

During the past two decades in the United States, the concept of university-industry collaboration has become an important social experiment in the national innovation system. In a historical sense, this marks a triumph of American academic science. Within a short time span since World War II, not only has American academic science achieved world leadership in basic research, but it also has accumulated a vast reservoir of scientific talents and technological resources that undergird the nation's technological frontier. The idea of university-industry collaboration in the United States predates the Civil War with the establishment of the landgrant college system but more realistically with the installation of agricultural experiment stations beginning in 1887. But it is really during the last 20 years, beginning in 1980, that university-industry collaboration has gained serious policy attention. Underlying this policy attention is what is generally known in the U.S. scientific community as a "social contract" between science and society, an embodiment of postwar science policy (Bush, 1945). As Brooks (1986) articulated, the bargain is that academics would return the benefits of their basic scientific research to society in return for the generous and unfettered support they receive from the public. The contract is a potent reminder that the relationship of science to American democracy is a "fragile" one (Guston and Keniston, 1994).

Beginning in 1980, spurred by the so-called "competitiveness crisis," the national policy debate produced a series of structural changes in the intellectual property regime accompanied by complicated incentive programs, all of which were designed to promote collaboration between universities and industry (Lee, 1997). Many state governments also followed suit. Meanwhile, universities were also under pressure, from industry and the public at large, to reconcile their ivory tower orientation—e.g., "publish or perish"—with the earthly needs of global technological competitiveness and general economic development.

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Journal of Technology Transfer, 25: 111–133, 2000

Now that the experiment of university-industry collaboration has been under way for nearly 20 years, it is appropriate to examine their experience relative to actual benefits and draw inferences about the future of their collaboration. The initial wave of policy research in this area has produced a reasonably good understanding of what structural adjustments are needed when universities and industry collaborate, and what institutional self-interest, together with cultural bias and prejudices, they must overcome if collaboration is to become a successful enterprise (Blumenthal *et al.*, 1986; Cohen *et al.*, 1994; Campbell and Slaughter, 1995; Lee, 1995; Matkin, 1994; Rahm, 1995) As we know now, the landscape is not so sanguine as initially expected by some lawmakers, but certainly more promising than the skeptics are willing to admit. With respect to the sustainability of collaboration, empirical research is in short supply. If we are to have a realistic understanding of whether the concept of university-industry collaboration can be a vital and sustainable component of the national innovation system, we need to have a good knowledge base of what each sector is actually getting out of their collaboration. Of course, this line of inquiry does not suggest that an effective collaboration between university and industry is part of the social contract of academic science to American society. But for better or worse, the idea of social contract arguably raises an expectation of this sort.

This study makes a preliminary assessment of university-industry collaboration by focusing on what the participants, faculty members and firms, actually get out of their collaboration. Specifically, it gauges whether the concept of university-industry collaboration can be a sustainable element in the nation's innovation system, and what the underlying condition might entail for sustainable collaboration between university faculty members and industrial firms. The approach taken in the study is to focus on "behavioral outcomes" —that is, perceived benefits. For the behavioral outcomes it looks at the experience of individual faculty members who recently have collaborated with firms on various research and development (R&D) projects, as well as the experience of industrial representatives whose firms have worked with university faculty on various R&D projects.

2. Focus on behavioral outcomes

Literature often alludes to university-industry collaboration as though it is an investment on both parties. This ideation prompts some researchers to employ the language of "return on investment" and proceed on an examination of the relationship between the resources invested and the returns derived. This requires that we delineate the costs incurred to collaboration and the benefits derived from it. In reality, precise delineation, especially in university-industry collaboration, is not generally possible because the costs and benefits, for the most part, cannot be reduced to commonly agreeable economic measures. What is more, the costs and benefits are not closely related in time and space. While collaborating with a firm on an R&D project, the university faculty member may serendipitously gain a valuable insight into a personal research area. The return-on-investment approach, if applied literally, requires that we express this theoretical insight in monetary terms. Likewise, we would be required to express all in economic terms about the learning of practical knowledge relevant to teaching, the creation of internship opportunities for students, and the personal networks developed out of collaboration.

The firms are in no better position. The National Science Foundation-supported Engineering Research Centers study (hereinafter ERC) by Ailes *et al.* (1997) also demonstrates this dilemma. To gauge the extent of possible monetary benefits out of ERC participation, they asked the firms, "Does your firm attempt to assign a dollar value to benefits from ERC participation?" The responses were uniformly negative. One respondent replied: "It's hard to do. How do you put a value on information?" Another respondent answered: "Monetary benefits are hard to define." Still another respondent said: "It's fairly hard to do. The benefits were significant, though. ERC findings led to significant competitive advantage. The findings were incorporated into a broad range of products; improved yields saved substantial personnel costs in pursuing false R&D leads; the findings were worth an awful lot." In an interview in connection with the present study, technology managers from a large pharmaceutical firm also explained why it is not possible to put a dollar value on faculty contribution:

> Our R&D projects are not like the faculty projects in the university. Ours is a team effort. We have scientists and engineers working together in a long series of the development cycle, from "blue sky" research to testing, prototype designing, and so forth. When we invite university faculty to get involved in this process, he or she joins in a team of scientists and engineers at a particular cycle in the product development process. This makes it very, very difficult to isolate the amount of faculty contribution, let alone to assign a dollar value.

Of course, in a simpler situation, some costs (like dollar support for the faculty) and benefits (patent development) may be amenable to some quantification. But simplicity of this sort is more an exception than a rule.

For practical reasons of measurement, this study approaches the outcomes of university-industry collaboration by employing a simplified measurement system called "behavioral outcomes" (e.g., degree of satisfaction). The behavioral measures, grounded in the theory of "bounded rationality" (March and Simon, 1958; Lindblom, 1959; Cyert and March, 1963), are predicated on the assumption that when making decisions, people do not actually try to "maximize" their values by engaging in comprehensive economic calculation, but rather look for "good-enough" answers. By substituting the good-enough criteria for the maximum criteria, individuals and organizations do in fact reduce the burden of calculation drastically. In the bounded rationality framework, people tend to look at outcomes largely in terms of short-term benefits and evaluate them subjectively—e.g., positive or negative, significant or insignificant, satisfactory or unsatisfactory. Of course, calculations will enter where data are available. Yet, any complex decision episode would involve many intangible and judgmental pieces of information not readily amenable to precise economic calculation. This explains why in reality psychological and behavioral measures play an important role in the decision-making process.

The present study also focuses on the individual level of experience. After all, it is the individual faculty member, not the university, who conducts research. And given the faculty job responsibility—teaching and research—collaboration with industry is but tangential to the main mission and essentially a matter of personal choice. This suggests that were faculty members to collaborate with a firm and maintain the relationship, they must realize significant benefits, the benefits that would excite them. Thus, if we are to make any credible statement about the vitality of university-industry collaboration, we must have some idea of how positively these faculty members assess their experience. Likewise, we will need to know how firms assess their collaboration with university faculty.

The task then is to take stock of collaborative experience on both parties and determine what their actual experience is like in terms of the result. Drawing from literature, the study identifies a list of reasons and expectations believed to be "personally important" to the university faculty member when entering into research collaboration with industry (Lee, 1996b; Roessner *et al.*, 1996). The list below is somewhat redundant, but this redundancy is intentional.

Reasons for Academics Collaborating with Industry

- To supplement funds for one's own academic research
- To test the practical application of one's own research and theory
- To gain insights in the area of one's own research
- To further the university's outreach mission
- To look for business opportunity
- To gain knowledge about practical problems useful for teaching
- To create student internships and job placement opportunities
- To secure funding for research assistants and lab equipment
- To look for business opportunity

The reasons firms seek collaboration with university faculty are many and complex. The list below incorporates items that appear frequently in the literature on university-industry collaboration.

Reasons for Firms Collaborating with Academics

- To solve specific technical or design problems
- To develop new products and processes
- To conduct research leading to new patents
- To improve product quality
- To reorient R&D agenda
- To have access to new research (via seminars and workshops)
- To maintain an ongoing relationship and network with the university
- To conduct "blue sky" research in search of new technology
- To conduct fundamental research with no specific applications in mind
- To recruit university graduates

The plan of this study is to determine how participants in university-industry collaboration, faculty members and firms, rate the relative importance of these reasons and assess the extent to which these reasons (goals) are realized subsequently. When conducting a survey of this kind, it is easy to look for the "average experience." The average is an artifact. To avoid the tendency of the respondent to offer a general impression, the study makes a special effort to connect the respondent experience to a specific collaborative R&D episode. This connection is accomplished by asking the industry survey respondent to identify a recent collaborative project and relate the experience to this particular project. Methodologically, this places greater emphasis on a project-specific experience possibly at the expense of average experience. To augment the interpretability of the data the survey then makes an effort to gauge a possible selection bias by asking the respondent to indicate how typical or atypical is the experience as compared to other university-industry project experiences.

3. Methods and data

Until now, empirical research on the outcomes of university-industry collaboration has provided only one side of the story—either the industry experience or the faculty experience, respectively. The present study examines the experience of both sectors using the same questionnaire with relevant variations. Ideally, the experiences of the respondents could be paired over the same R&D projects. A nonexperimental, cross-sectional survey makes this type of paired comparison practically difficult, if not impossible. Most faculty members collaborating with firms sign a confidentiality agreement, so many are reluctant to disclose the identity of their sponsoring firms and the nature of collaborative work. This reluctance is understandable especially when a study evaluates behavioral outcomes. Even if some agree to cooperate with this type of evaluative study, it is difficult to discern the veracity of their response owing to "Hawthorne effect" of some sort.

The method used in this study is a cross-sectoral survey—that is an examination of the experiences of two independent samples similarly situated. Obviously, the design severely compromises the cannons of experimental science. But reality does not permit the ideals of scientific standard in this case. The problem of independent samples is less of a burden in the present study. This is because the objective of the study is not an evaluation of the collaborative R&D projects per se but an understanding of what benefits faculty members derive from collaboration with industry *vis-à-vis* what benefits firms gain from faculty collaborators.

The data for this study are derived from two separate surveys conducted in Spring and Summer 1997, one on university faculty members and the other on affiliate members of the University Technology Managers Association, a professional organization representing U.S. universities collaborating with industry on technology transfer. Faculty members included in the study design were a sample of 671 faculty scientists and engineers selected from a stratified random sample of 40 research-intensive universities on the NSF list of top 100 research universities. All faculty members were at the time, or previously had been, collaborating with firms on R&D projects. The 40 universities consist of 20 landgrant, 9 non-landgrant public, and 11 private universities. The faculty sample was drawn from six disciplines, including biological science, chemistry, chemical engineering, computer science, mechanical engineering, and material science. This resulted in a total of 248 academic departments. To identify faculty scientists and engineers in departments who collaborate with industry on research, I wrote to the chairs (or heads) of these departments asking for assistance in identifying their faculty members, up to five, who were engaged in industry-sponsored research. Of those contacted, 185 chairs (74.6%) responded, with 8 chairs declining to cooperate. From the 177 departments a list was compiled of 716 faculty scientists who were believed to be involved in firm-related R&D. A letter was then written to each of these faculty members asking if they were willing to participate in the proposed survey. Forty-five responded by indicating that they actually did not have experience with industry or that they were unable to participate in the survey due to personal reasons (e.g., travel, leaving the university, or no interest). After an exchange of letters and e-mails with the remainder of these faculty members regarding the nature of the study, 671 expressed willingness to participate in the survey, of which 427 (64%) eventually responded to the four-page questionnaire (See Table I).

Firms surveyed in the study are industrial affiliates with the Association of University Technology Managers (AUTM), a professional association of university technology managers. AUTM affiliate members represent the firms maintaining a broad network with the university community and collaborating closely with university faculty. Industry technology managers were identified from an AUTM mailing list of 754 affiliate members of which 56 represented overseas firms and 698 U.S.-based firms. Foreign firms were eliminated from the survey list due to the logistical difficulty of coordinating a survey. From a consultation with an AUTM official it also was determined that of the 698 U.S.-based affiliate members only about 44% (306 firms) were identified as having an R&D collaboration with a university. The survey then focused on these 306 firms. A preliminary contact was made with industry representatives of these firms to invite their participation in the survey. Twenty-six of these representatives declined to participate in the survey either because they would not be available due to traveling or because the survey questionnaire was not applicable to their situation. This reduced the sample size to 280 firms. A questionnaire structured similar to the one used on the faculty survey was administered to the technology managers of these firms. With two letter reminders the survey obtained a total of 140 usable responses, or a 50% rate.

Firms responding to the survey represented a broad spectrum of industry, quite similar in size

Table I
Characteristics of faculty respondents

	Respondents		Invention disclosures	Patent obtained	Patent pending
	N	%			
Academic ranks					
Assistant Professor	46	10.8	1.6	0.4	0.3
Associate Professor	89	20.8	3.5	1.2	1.2
Full Professor	280	65.6	7.4	4.8*	1.7
Research Scientist	12	2.8	3.2	2.7	0.6
Total	427	100.0			
Academic disciplines					
Biological and Life Sciences	34	8.0			
Chemical Engineering, Biochemistry, and Molecular Biology	143	33.5			
Materials Science	47	11.0			
Mechanical, Aerospace, Industrial Engineering	86	20.1			
Total	427	100.0			

*This average includes one outlier whose number is 165. Exclusion of this outlier drops the average to 4.19.

to those identified by faculty members in their responses. The representation shows in order: 29.8% in information technology (computers, electronics, telecommunications, publications), 19.2% in biotechnology and life sciences (including pharmaceutical, food technology, bioengineering), 13.1% in materials, 8.7% in manufacturing (including appliances, robotics, machinery, mechanical engineering), 7.8% in chemical and polymers, 7.1% in transportation, 5% in energy and utilities, 5% in aerospace, and 4% in other (nuclear, environment, instrumentation).

4. The structure of research collaboration

From a faculty perspective, research collaboration between university and industry means an industry-oriented project supported either fully or partially by sponsoring firms. Thus, the focal point is the experience with R&D projects. Of interest in this situation is how projects are funded and administered, which firms sponsor these projects and how (solo or in group), how long projects last, under what conditions faculty members collaborate, and how they interact with sponsors.

The faculty survey shows that the R&D projects in which faculty have participated comprise a complex funding portfolio. Not surprisingly, the sponsoring firms almost always provide some funding for the projects. Of a total of 425 R&D projects, company support is mentioned in about 82% or 347 instances. It is important to emphasize that universities, federal, state, and local governmental entities also match many of these projects. By far the most frequently mentioned co-sponsor is the federal government, followed by universities and state governments.

Previous studies created an impression that university-industry research collaboration occurs largely through University-Industry Research Centers (UIRCs) (Cohen *et al*., 1994). Perhaps this was because these researchers had focused their attention on research centers. When we shift the focus to faculty members in traditional academic units, the landscape of university-industry research collaboration looks somewhat different. The faculty survey reveals that 52% of faculty members manage their industry-sponsored projects through traditional academic units (departments or colleges), and 26% through UIRCs, including NSF-supported engineering research centers. The remaining 22% manage their projects personally or through consulting arrangements and 8.3% through government agencies. Approximately 10% manage their projects jointly through more than one administrative unit, making the total percentage exceed 100%. Overall, this configuration raises a possibility that industry-sponsored collaborative research may have gained a footing in the traditional academic environment.

Turning to the structure of collaboration, the most frequently reported episodes, 65%, are projects sponsored by single firms favoring one-on-one interaction. About 28% of projects are sponsored by small consortia of 2 to 10 firms, 5% by medium consortia of 11 to 25 firms, and 2% by large consortia of 26 to 94 firms. Looked at from another angle, research projects undertaken by faculty members are supported by firms of all sizes, with over 39% by large corporations (over 10,000 employees), 18.4% by small firms (less than 500 employees), about 14% by medium firms (more than 500 but less than 10,000 employees), and about 11% by start-up firms. About 17% of research projects are sponsored by a mixture of small, medium, and large firms.

These research projects span the average life of 3.6 years, with the median and mode being 3 years. The actual spread, however, is large, ranging from a few months to as long as 33 years. Most projects, 87.4%, stretch 1 to 6 years. A little over 8% of the projects stretch 7 to 11 years. While the projects spanning less than a year are 2.2%, those spanning more than 12 years are also small in number, 2.2%.

Perhaps the most contentious point of faculty-firm collaboration is a confidentiality or nondisclosure agreement often required. While the idea of confidentiality runs counter to academic freedom and openness, it becomes the bedrock of industrial competition—especially when research breaks new ground. How does this dilemma play out at the street level of faculty-firm collaboration? A majority of faculty members in the survey, 57.3%, report that as part of a research contract they have signed a confidentiality agreement promising to keep trade-sensitive information in confidence. Analysis shows that a greater likelihood exists that the faculty member may sign a confidentiality agreement when partnering with single firms as opposed to a consortium of firms. While 31.3% of faculty members have signed a confidentiality agreement with projects supported by more than one firm, 68.7% collaborating with single firms have signed the nondisclosure agreement. And when a consortium gets very large, more than 25 firms, faculty members are much less likely to sign the nondisclosure agreement.

When the faculty response is compared with the industry survey, the 68.7% probability reported by the faculty members may be an underestimation. In the industry survey, 84% of industry technology managers say that they required faculty members to sign a confidentiality agreement. The questionnaire asked: "In general, is the signing of confidentiality agreements a common practice in your firm?" Fifty-seven percent responded "Always," 33.6% "Most of the time," 7.9% "Some of the time," and 1.4% "Rarely." It seems safe to conclude that in spite of continuing controversy over the confidentiality requirement, the signing of a confidentiality agreement appears to be an "accepted" price when academics collaborate with firms, especially with single firms.

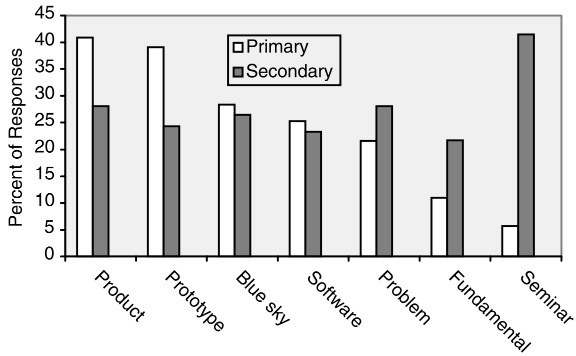
When faculty members get involved in firm-sponsored research, how do they interact with their sponsoring firms? The questionnaire asked faculty members to indicate how they interacted with firm scientists and engineers in connection with their R&D projects. The questionnaire used four multiple response categories: periodic reports with final delivery, frequent meetings with the firm's scientists and engineers, spending an extended period of time at the firm's lab, and inviting the firm's scientists and engineers to the university lab for an extended period of time. The survey shows that the most frequently responded category is "frequent meetings" with 67.7%, followed by "periodic reports with final delivery" at 55.2%. The spending of an extended period of time at the firm's lab by faculty or the university lab by the industry scientist is not a frequent event. These categories received only 17.2% and 11.6%, respectively. Similarly, industry technology managers responded to the question with 77.1% for periodic reports with final delivery, 58.6% for frequent meetings, 10% for an extended time at university lab, and 8.6% for an extended time at firm lab. Overall, the two response sets appear to be roughly equal.

5. Motivations for collaboration

What does industry seek from academics?

Speculations abound in regard to the reasons and motivations of why industry might want to collaborate with academics. To establish an empirical base of industry motivations at the street level, faculty members were asked: "What were the objectives of this project as agreed to with the sponsoring firm(s)?" the same general question also was posed to industry technology managers: "In this project/program, what were your firm's interests in working with university scientists and engineers? In other words, what did you want university scientists and engineers to provide for your firm?" Respondents were provided with a list of eight potential objectives to check where applicable (a multiple response scheme) by indicating how important each objective was in their view—whether primary, secondary, or not applicable. The two answer categories, "Primary Objective" (or "Interest") and "Secondary Objective" (or "Interest") were used here as a way to further delineate the real motivations underlying research collaboration. The results of the two surveys are plotted in Figure 1a and 1b.

Comparison of the two figures shows that although the two samples are independent of one another, the response patterns are remarkably similar in all but software development.[2] Could this similarity be a coincidence? To ascertain the generalizability of this observation, an additional question was posed to these technology managers: "How typical or atypical are these interests as compared to other university-industry collaborative projects/programs in which your firm has been involved?" Of those who responded, 94% indicated that their firm's interests (reasons for research collaboration) expressed in the project were typical of their other university-industry collaborative projects. Which lends support to the null hypothesis that the similarity between the two graphs is not a coincidence.



Product refers to "Conducting research related to existing product line,"
Prototype refers to "Design of prototypes,"
Blue sky refers to "Conduct exploratory 'blue sky' research in search of new technology,"
Software refers to "Development of software,"
Problem refers to "Testing instrumentation and technical problem solving,"
Fundamental refers to "Fundamental research with no specific application in mind," and
Seminars refers to "Provide seminars and workshops on new research and discoveries

Figure 1a. Objectives of firm-sponsored R & D projects as viewed by faculty members.

A further observation is in order. Except for the development of a software category, the two groups are basically in agreement with the hierarchy of importance; that is, with respect to primary importance and secondary importance. Of interest in this hierarchy are the two motivational considerations: access to new research (seminars and workshops on new research and discoveries) and research on product development. Literature is replete with comments that the primary reason for firms to engage in research collaboration with universities is (and should be) to keep abreast of

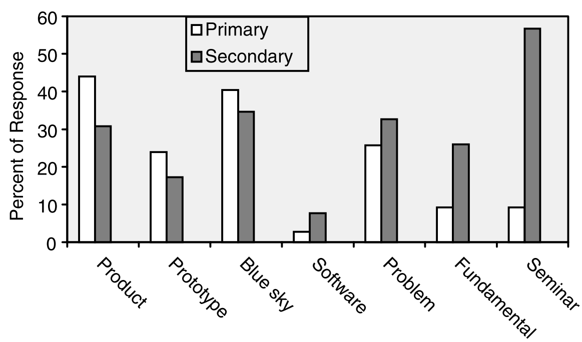


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Figure 1b. Objectives of firm-sponsored R & D projects as viewed by firms' technology managers.

new research, not research on product development (Stern, 1989; Government-University-Industry Research Roundtable, 1991, 1995; Fusfeld, 1994). Feller (1997), however, thought that "no single answer is possible" (p. 33). The data from the present survey offer a different picture. When the inquiry is turned to specific R&D projects—rather than the general view of university-industry collaboration—industry technology managers define their leading "primary interest" as being *research related to product development*, and the leading secondary interest as *seminars and workshops on new research and discoveries*—that is, access to new research. On this point, faculty members and technology managers are in full agreement.

Nearly 37% of faculty members stated that product development was a primary objective as they saw it when they were involved in industry-sponsored projects. Twenty-seven percent saw it as a secondary objective. The remaining 42.5% stated that their involvement had none of this objective. By contrast, only 5.2% of faculty members reported that a sharing of new research and discoveries through seminars and workshops was a primary objective of their involvement in industry projects. However, over 40% saw it as a secondary objective. To the remaining 64.3% this objective was not a concern to their involvement.

How did industry technology managers react to this question? Very much the same. A majority of these technology managers, 59.3%, agreed that product development was a primary interest of having university faculty involved in their research projects. Only 20% said that research on product development was of secondary interest. The remaining 20.7% said that research on product development was not part of their reason to get faculty involved in their research projects. The response to the item of new university research and discoveries also followed the same pattern as proffered by faculty respondents. While only 7.1% of technology managers expressed that learning from faculty on new research and discoveries was of primary interest in getting faculty involved in their R&D projects, 42.1% expressed it as of secondary interest. The remaining 50.7% of industry technology managers stated that this learning activity was not part of their objective in research collaboration. Closely related to research on development was the design activity. Not surprisingly, the response pattern was about the same as that of research on product development since both are part of the focused applied research. A larger percentage of both faculty members and technology managers indicated that the design of prototypes was a primary objective for their research collaboration.

The exploratory "blue sky" research, the second leading objective, deserves comment. The "blue sky" research is an exploratory research in search of new technology, and firms generally consider it to be fundamental applied research. Faculty members and technology managers are basically in agreement on this exploratory research. Compared with faculty respondents (25.6%), a slightly larger percent of technology managers (31.4%) stated that exploratory research was a primary or secondary objective. Similarly, 19.5% of faculty members saw that the exploratory research had been the "secondary" objective of their involvement, and 25.7% of industry technology managers saw it as the "secondary" objective of having university faculty involved in their R&D projects.

A general claim also exists among industry leaders that an important reason for their research collaboration with a university is to support universities. On the surface at least, this claim makes sense when one looks at the rising support of academic research by industry during the past decade. According to NSF science and engineering indicators (1997), industry support for academic research over the last two decades has risen from about 3% to 7% of total academic research expenditures. According to the present survey, the claim of corporate generosity must be placed in a proper context. At least as it can be gleaned from the industry survey specific to R&D projects, the philanthropic claim does not fare very well. When technology managers were asked to state whether their collaboration with university faculty on specific projects was part of a larger mission of "supporting universities," only 4.3% stated it was their primary concern, while 26.4% stated it as their secondary concern. Nearly 70% expressed that "supporting universities" was not a reason related to having faculty involved in their projects. This response pattern holds true across the board, small or large firms, research-intensive firms or research-weak firms. And it bears no particular relationship either to firm size or the firm's research intensity (measured by the number of research scientists and engineers).

What motivates academics to collaborate with industry?

When faculty members collaborate with industry, they are obviously engaged in an exchange relationship of some sort. What do academics seek from industry in exchange for their time and expertise? Using a 5-point behavioral scale, the questionnaire asked: "How important were the following personal expectations for your decision to become involved in this R&D project?" The degree of importance was scaled as "Most Important" (coded as "5"), "Very Important" (coded as "4"), "Important" (coded as "3"), "Somewhat Important" (coded as "2"), and "Least Important" (coded as "1"). The questionnaire also provided respondents with a list of eight related motivational items for them to consider when making their personal assessment. The responses are summarized in Table II.

Responses in Table II show that a hierarchical pattern may exist in faculty motivations. First, responses show that faculty members engaging in research collaboration with firms are primarily driven by the need to advance their own research agenda. This is evidenced by the fact that the top four reasons all coalesce with faculty members' own research agenda. Specifically, the reasons of overriding importance are to secure funds for their graduate students and lab equipment, to gain insights into their own research, to test the practical application of their own theory and research, and to supplement funds for their own academic research. In terms of percentage distributions, when we combine the two categories, "Most Important" and "Very Important," the response rates for these four reasons are 69.4%, 68.5%, 64.7%, and 61.1%, respectively. The distant next in the hierarchy is of the university's outreach mission. The scale average is 2.77, which places the ranking somewhere between "Important" and "Somewhat Important." Related to the outreach mission is the teaching function: to create student internships and job placement, and to gain practical knowledge useful for teaching. According to this survey, the least important reason for faculty involvement in industry-sponsored research is to look for business opportunity (e.g., consulting opportunity or possibly starting a business).

In the literature on university-industry collaboration faculty members collaborating with industry are portrayed variously from being concerned with the societal objective of economic development to being motivated to cash in on scientific expertise. This survey puts these speculations in proper perspective. First and foremost, faculty

Table II
Reasons and motivations for university faculty collaborating with industry

Reasons and motivations	Responses (%)* MOST	VERY	IMP	SOME	LEAST	Mean rating
Secure funds for research assistant & lab equipment	39.8	29.6	17.5	3.8	9.2	3.87
Gain insights in one's own research	31.8	36.7	17.8	4.7	9.0	3.77
Test application of theory	36.7	28.0	13.0	8.1	14.2	3.65
Supplement funds for research	29.1	32.0	20.1	7.1	10.9	3.61
Assist university's outreach mission	9.5	23.0	27.7	14.9	24.9	2.77
Create student jobs & internships	9.2	22.5	24.9	18.5	24.9	2.73
Gain practical knowledge for teaching	7.3	19.0	26.1	21.1	26.5	2.57
Look for business opportunity	7.6	13.3	16.8	18.5	43.8	2.22

N = 422.
*MOST = Most Important (coded as "5"); VERY = Very Important (coded as "4"); IMP = Important (coded as "3"); SOME = Somewhat Important (coded as "2"); LEAST = Least Important (coded as "1").

members who participate in industry-sponsored research have their own research agendas, and they are engaged in an exchange relationship with their sponsors. As shown by the data, entrepreneurship is the least of faculty concerns. As teachers, they do show an interest in collecting practical knowledge useful for their own pedagogical function and creating internship and job placement possibilities for their students. But these are not their primary reasons for collaboration with industry, nor is the university's outreach mission an important concern. All these reasons appear to be of secondary importance. The most important motivational consideration for them is to complement their academic research agenda. Whether faculty members get what they want is a different question.

6. Benefits resulting from collaboration

Benefits experienced by academics

How do faculty members assess their experience with industry? What kind of benefits do they actually gain from industry-sponsored projects? Since the interest of this study is in part to determine the relationship between expectations (motivational considerations) and outcomes, faculty members were provided with a set of eight benefit indicators that closely parallel their motivational concerns. Faculty members then were asked to indicate on a 5-point scale how they have benefited from industry-sponsored research on each item. As in the previous case, "5" was used to indicate that benefits are "Substantial," "4" to indicate that benefits are "Considerable," "3" to indicate that benefits are "Moderate," "2" to indicate that benefits are "Marginal," and "1" to indicate "No Benefits." Table III summarizes the distribution with the mean ratings.

Faculty benefits in Table III parallel the hierarchical pattern manifested in the motivational structure described in Table II. A large majority of faculty members expressed that they had experienced substantial and considerable benefits to their academic research dimension. When the two categories, "Substantial" and "Considerable," were combined, over 67% agree that they had acquired a substantial or considerable amount of funds necessary to support graduate students and to purchase lab equipment. Similarly, over 66% agreed that from participation in industry-

Table III
Faculty benefits experienced with industry-sponsored R&D projects

Faculty benefits	Responses (%)*					Mean rating
	SUBS	CONS	MOD	MAR	NONE	
Acquired funds for research assistant and lab equipment	42.7	24.4	19.7	4.3	9.0	3.87
Gained insights into one's own academic research	31.5	34.8	23.0	5.0	5.7	3.82
Supplemented funds for one's own academic research	29.9	27.7	21.1	9.7	11.6	3.55
Field-tested one's own theory and research	31.0	25.1	21.3	7.3	15.2	3.50
Acquired practical knowledge useful for teaching	15.6	22.3	28.7	17.3	16.1	3.04
Created student internships and job placement opportunities	17.3	21.1	25.1	14.5	22.0	2.97
Led to patentable inventions	16.4	13.0	19.0	13.0	38.6	2.55
Created business opportunities	8.5	10.2	15.6	17.8	47.9	2.14

N = 422.
*SUBS indicates that benefits are substantial (coded as "5"); CONS indicates that benefits are considerable (coded as "4"); MOD indicates that benefits are moderate (coded as "3"); MAR indicates that benefits are marginal (coded as "2"); NONE indicates no benefits (coded as "1").

sponsored research they gained substantial or considerable insights into their own academic research. Over 56% also stated that their collaboration with industry on projects enabled them to field-test their own theory and research.

By contrast, benefits to teaching appear to be modest. Only about 38% agreed that from industry-sponsored research they benefited substantially or considerably in acquiring practical knowledge useful for teaching. About 29% expressed a moderate gain, and over 33% almost no gain. Related to this teaching function, only about 38% of these faculty members also agreed that their involvement in industry-sponsored research had been helpful in locating student internships and placement opportunities. About the equal number, 37%, however, experienced no such opportunities.

Previously in Table II we observed that creation of business opportunity is the least important reason for faculty members to get involved in industry-sponsored research. The outcomes data show a similar pattern. Only 21% of faculty respondents agreed that research collaboration with industry provided them with substantial or considerable entrepreneurial and financial opportunities. About 66% reported no such benefits, while 15.6% reported a moderate gain. In this connection, the survey asked faculty members to assess if research collaboration with industry helped them in developing patentable inventions. Approximately 29% agreed that collaboration with industry helped them substantially or considerably in patent-related research. While 19% stated that the benefit on patent-related research had been moderate, a majority, about 52%, stated no such benefit.

Benefits experienced by industry

Although the industry survey is independent of the faculty survey, the results appear to corroborate well with faculty assessment. The questionnaire asked industry technology managers at the outset to select one current (or most recent) collaborative project and relate their experience to this specific project. To maintain comparability with the faculty survey, the industry questionnaire provided a list of eight benefit indicators with the same 5-point behavioral scale: "Substantial," "Considerable," "Moderate," "Marginal," and "Not At All." The eight benefit indicators also were to correspond to the objectives of research collaboration as expressed by the firms' representatives. Table IV summarizes the responses.

According to industry technology managers, the sponsoring firms realized substantial or considerable benefits in two main areas: access to new research and product development. When the two behavioral anchors, "Substantial" and

Table IV
Industry benefits derived from collaboration with university faculty

Industry benefits	Responses (%)*					Mean rating
	SUBS	CONS	MOD	MAR	NONE	
Gaining access to new research	37.9	37.9	15.0	6.4	2.9	4.01
Developing new product/process	32.9	27.9	25.0	8.6	5.7	3.74
Maintaining relationship with the university	26.4	27.9	31.4	9.3	5.0	3.61
Developing new patents	28.6	24.3	16.4	17.1	13.6	3.37
Solving technical problems	18.6	25.0	24.3	17.1	15.0	3.15
Improving product quality	6.4	16.4	20.0	22.9	34.3	2.38
Reorienting R&D agenda	2.1	14.3	25.7	31.4	24.4	2.34
Recruiting students	1.4	5.0	17.1	20.0	56.4	1.75

N = 140.
*SUBS indicates that benefits are substantial (coded as "5"); CONS indicates that benefits are considerable (coded as "4"); MOD indicates that benefits are moderate (coded as "3"); MAR indicates that benefits are marginal (coded as "2"); NONE indicates no benefits at all (coded as "1").

"Considerable," are combined, nearly 76% agreed that collaboration with university faculty had increased their access to university research substantially or considerably. In this connection, over 54% of these technology managers also stated that collaboration with faculty members contributed substantially or considerably toward the development or maintenance of an ongoing relationship with the university community. On the objective of developing new products or processes, nearly 61% of industry technology managers agreed that research collaboration with university faculty had benefited their firms substantially or considerably. Twenty-five percent rated this benefit as "Moderate." Overall, the assessment by technology managers is reassuringly positive. And this assessment appears consistent with the recent SRI study (Ailes *et al.*, 1997).

Industry technology managers also stated that collaboration with university faculty contributed significantly to their research on patents. Nearly 53% agreed that faculty collaboration had contributed substantially or considerably toward the development of new patents. About 16% rated faculty contribution as being moderate, and about 31% as marginal or not at all. On technical problem solving only about 44% of these technology managers rated faculty contribution to be substantial or considerable.

By contrast, according to industry technology managers, faculty members did not have much impact on the improvement of product quality and the reorientation of R&D agenda. Over 57% stated that they had benefited little from faculty members with respect to product quality. Only about 23% thought that the benefit had been substantial or considerable, and 20% thought the benefit had been moderate. Technology managers also felt that faculty contribution to the orientation of R&D agenda was moderate at best. Nearly 56% stated that they had benefited little from faculty members in the shaping of their R&D agenda. Only about 26% rated the faculty contribution to be moderate, and 16% rated it to be substantial or considerable. Not surprisingly, these technology managers stated that research collaboration with university faculty had not contributed much to the recruitment of students—not surprising in that faculty members in the survey also rated this item as among the least important reasons for their participation in industry-sponsored projects.

7. Factors related to benefits

When university-industry collaboration is looked at from the street level, the question of immediate interest is, "Who benefits more and how, and who may be wasting their time?" More generally, how would benefits gained from collaboration relate to faculty characteristics, firm characteristics, faculty inventions, participant goals and motivations, and patterns of interaction? We first look at faculty experience and then industry experience.

Faculty experience

To carry out this correlational analysis more effectively, the motivational and benefit variables are factored into a smaller, manageable number of variables. Table V describes the factor scores computed on the basis of the principal component analysis using the varimax rotation. To preserve the interpretability of data the factor scores are constructed using the same 5-point behavioral scale. As Table V shows, the eight motivational items are reduced to a set of three motivational factors, and the eight benefit variables to a set of three benefit factors. Each factor variable is a simple arithmetic mean of the items under each underlying factor.

Expectations are closely related to benefits. In Table II we observed that the leading motivation for faculty members participating in industry projects was to support their own academic research, and the next was to enhance their own teaching function. The least important reason was entrepreneurship. Similarly in Table III, we observed that faculty members experienced substantial benefits in their own academic research, moderate benefits in teaching function, and marginal benefits in entrepreneurial opportunity. These were a general observation, and we now turn to their underlying relationships. Analysis shows that motivation (expectation) is strongly related to benefits subsequently realized.

Table V
The new factor variable sets (in bold face) for faculty motivations for and benefits realized from research collaboration with industry*

New factor variables	Mean rating	STD
Motivation for academic research support	3.728	1.114
—Secure funds for research assistants & equipment		
—Supplement funds for one's own research		
—Gain insight into one's own research		
Motivation for teaching function	2.698	0.960
—Gain knowledge useful for teaching		
—Create student jobs and internships		
—Assist university outreach mission		
Motivation for entrepreneurship	2.936	1.086
—Test practical application of theory		
—Look for business opportunity		
Benefits to academic research support	3.710	1.184
—Secure funds for RAs & equipment		
—Supplement funds for own research		
Benefits to teaching function	3.276	.992
—Gain knowledge useful for teaching		
—Create student internships and jobs		
—Gain insights into one's own research		
Benefits to entrepreneurial opportunity	2.729	1.035
—Test the practical application of theory		
—Contribute to the development of patents		
—Open business opportunities		

N = 427.
*All variables are measured on a 5-point scale. The behavioral anchors for the motivation variables are "Most Important" with "5," "Very Important" with "4," "Important" with "3," "Somewhat Important" with "2," and "Least Important" with "1." The behavioral anchors for the benefit variables are "Substantial" with "5," "Considerable" with "4," "Moderate" with "3," "Marginal" with "2," and "Not at all" with "1."

As Table VI describes, faculty members collaborating with firms for personal research reasons tend to derive significant benefits from their involvement in industry projects. The emphasis on personal research, however, does not transfer well to other benefits. Similarly, faculty members interested in strengthening their teaching function tend to derive substantial benefits from research collaboration with industry. But, again, they do not gain much benefit in other areas. This pattern holds true for those interested in entrepreneurial opportunity. These faculty members draw substantial benefits on entrepreneurial opportunity but not on others. While the linear pattern observed here seems to make sense at first glance, there may be a perceptual selectivity operating in this type of behavioral data. It is possible that when faculty members are interested in gaining support for personal academic research, they may be oblivious to other windows of opportunity that may still be available to them. What is "objectively real," therefore, cannot always be discerned in the data based on perceptions.

More inventions do not necessarily mean greater benefits. Compared with other ranks, full professors far exceed others in the number of patents acquired and inventions disclosed (See Table I). Does this mean that full professors would have a penchant for getting involved in industry relative to the other junior ranks? Not really. Data show that the relationship between the record of invention and the behavior of faculty members appears to be more complicated than generally expected. Table VII compares faculty behaviors among the three ranks by showing the relationship between the number of invention disclosures and initial motivations, as well as subsequent benefits. The

Table VI
Correlation between faculty motivations and benefits associated with research collaboration with industry

Motivation to collaborate with industry	Benefits gained: Support for academic research	Enhanced teaching function	Opened entrepreneurial opportunity
Support academic research	.606**	.150**	0.13
Enhance teaching mission	.107*	.621**	.034
Create entrepreneurial opportunity	.031	.193**	.630**

*$p < 0.05$.

table depicts only the number of invention disclosures because the patent record is sparse among assistant professors.

Table VII shows clearly that invention disclosures per se bear little relationship to the behavior of full professors. Nor do they have any impact on the behavior of assistant professors. Interestingly, however, the invention disclosures show a positive relationship to the behavior of associate professors. Considering that the number of invention disclosures would be an indication of faculty attitude toward user-oriented applied research, one would expect that the more invention disclosure that faculty members make, the greater the interest they would show toward collaboration with industry. But the data, at least the frequency of it, do not support this hypothesis—with the exception of associate professors.

For full professors, would the patent data, rather than invention disclosures, provide a different picture? Not really. Analysis indicates that the patent record also shows no "measurable" impact on the behavior of full professors either in the motivational dimension or in the benefit dimension. Just as with invention disclosures, the relationships between the patent record and the motivational and benefit dimensions are all negative, albeit weak for full professors. The larger the number of patents acquired, the lower the motivation to seek research support from industry ($r = -0.199$; $p \leq 0.01$), and the lower the motivation to augment teaching function ($r = -0.147$; $p \leq 0.05$). This is puzzling because if anything, the empirical relationship should be positive rather than negative. This conundrum cannot be resolved in the present data. Perhaps full professors may already have their basic support needs met by virtue of past achievements and may no longer be driven by needs that have already been met. Better yet, full professors with strong invention records may be in high demand, so they may have become a "willing victim" of their own success.

Equally puzzling is the behavior of assistant professors, generally the untenured rank. As Table VII shows, the record of their invention disclosures bears little relationship to why they

Table VII
Correlation between invention disclosures and motivations to collaborate with industry, and benefits derived from collaboration

Motivations and benefits	Number of invention disclosures: Full professors ($N = 270$)	Associate professors ($N = 88$)	Assistant professors ($N = 45$)
Motivation for research support	−.105	.151	.007
Motivation for teaching function	−.082	−.053	−.072
Motivation for entrepreneurship	.167**	.264*	−.041
Benefits of research support	−.100	.275**	.239
Benefits of teaching function	−.111	.104	−.170
Benefits of entrepreneurship	.009	.522**	.081

*$p \leq 0.05$; **$p \leq 0.01$.

get involved in industry projects or what they get out of their collaboration. Without controlling for invention disclosures, however, assistant professors are better motivated than other ranks to secure research support from industry, and they experience greater research support from industry. One may argue that, after all, the record of invention disclosures (that is, user-oriented applied research) may not be particularly relevant to such research activity as occurs in NSF-supported ERCs where assistant professors may possibly cluster. Analysis, however, shows that assistant professors are not concentrated in any particular research setting, small or large firms, single firms or consortia. The relation of academic rank to firm size only has a chi-square value of 9.88 ($df = 8$, $p = 0.273$). This leads us to speculate that these assistant professors may be on a "fishing expedition" casting a wider net for research dollars.

The behavior of associate professors is as expected. In fact, insofar as the theory of university-industry collaboration is concerned, the behavior of associate professors appears to be reasonable. The record of their invention disclosures is positively related to an interest in entrepreneurial opportunity ($r = 0.264$, $p \leq 0.01$) and similarly to subsequent benefits in business opportunity ($r = 0.522$, $p \leq 0.01$), as well as increased research support from industry ($r = 0.275$, $p \leq 0.01$).

Some firms are a better bargain. Data suggest that some firms may be better a bargain than others. Faculty members participating in industry-sponsored projects seem to gain greater benefits in the order of mixed firms, large firms, medium firms, small firms, and start-up firms. This hierarchical ordering is true with respect to support for academic research and teaching function. With respect to an entrepreneurial opportunity, however, start-up firms and mixed firms tend to offer a better opportunity (See Table VIII).

Specifically, faculty members agree that mixed firms and large firms offer larger research support benefits than small or start-up firms (Tukey's HSD [Honestly Significant Difference], $p \leq 0.002$). Medium firms also seem to be doing better than start-up firms (HSD, $p \leq 0.002$). The difference between small firms and medium firms is negligible. In general, data indicate that small firms have the least to offer in terms of research support or teaching function (HSD, $p \leq 0.046$).

With respect to teaching function, large firms appear to offer the best bargain of all (HSD, $p \leq 0.032$). Mixed firms also offer a consistently better opportunity for pedagogical function than start-up firms or small firms (HSD, $p = 0.000$). Medium firms and small firms show no significant difference from others. As in the case of research support, start-up firms have the least to offer on teaching when compared with large and mixed firms (HSD, $p \leq 0.02$).

Start-up firms, however, appear to have an edge over other firms with respect to entrepreneurial opportunity—although the differences are subject to random errors. Start-up firms offer a better entrepreneurial opportunity than small firms (HSD, $p \leq 0.089$), medium firms (HSD, $p \leq 0.056$), or large firms (HSD, $p \leq 0.048$).

Table VIII
Relationships between types of firms and benefits faculty experience in research support, teaching function, and entrepreneurial opportunity

		Mean benefits		
Types of firms	N	Research support**	Teaching function**	Entrepreneurial opportunity**
Mixed firms	73	4.035	3.276	3.042
Large firms	167	4.027	3.315	2.620
Medium firms	60	3.602	3.289	2.548
Small firms	78	3.365	3.051	2.611
Start-up firms	47	2.794	2.826	3.087

**The statistical hypothesis is that at least two categories of firms are significantly different in their means. $p \leq 0.002$.

Mixed firms appear to offer just as good an entrepreneurial opportunity as do start-up firms.

The longer the life span of a project, the greater the benefits. Analysis supports the hypothesis that the longer the duration of a project, the greater the benefits to a faculty member in research support, teaching function, and entrepreneurial opportunity. Projects spanning at least 3 to 5 years, or possibly more, tend to offer greater benefits in all counts—research support, pedagogical support, and entrepreneurial opportunity. The lowest benefit is associated with projects that last less than 1 year. Projects spanning 1 to 2 years also do not fare very well. Data show that on average projects sponsored by start-up firms, small firms, and medium firms span about 3 years or less, and projects by large firms 3.7 years. Projects sponsored by mixed firms (consortia) extend the average life span more than 5 years. Taken as a whole, it appears that a long-term project (more than 3 years) sponsored by a consortium of mixed firms or at least by large firms would be an ideal bargain for a faculty member seeking support for academic research, enhancement of teaching function, and entrepreneurial opportunity.

Frequent interactions spell greater benefits. In the literature on university-industry collaboration it has been argued that technology and knowledge transfer is really a "body contact sport," implying that the more frequent the contact, the greater the diffusion of knowledge and technology (The Government-University-Industry Roundtable, 1991; Lederman, 1994). How does this theory fare in the present study? To test this hypothesis, the questionnaire asked faculty to respond to a four-item "multiple response" question. The four items included periodic reports, frequent meetings, the spending of an extended period of time at the firm's lab, and the spending of an extended period of time by the firm's engineers at the university lab. The respondents were asked to report all that apply. For the purpose of this analysis, I constructed a four-item index by assigning "1" to "periodic reports," "2" to "frequent meetings," "2" to an extended time at the firm's lab, and "2" to "an extended time at the university lab."[3] The construction shows that the interaction index is approximately normally distributed with the mean of 2.5 and the standard deviation of 1.52 on the basis of 415 responses.

Analysis shows that although the correlation coefficients are relatively low, the relationships are all statistically significant ($p \leq 0.01$). Intensity of faculty-firm interactions is correlated with research support ($r = 0.138$), teaching function ($r = 0.243$), and entrepreneurial opportunity ($r = 0.195$). If we were to transform the intensity of interaction to "High," "Medium," and "Low," the relationship between the intensity of interaction and the level of benefits becomes clearer. On research support, the mean benefit for high interaction is 4.12 (slightly higher than "considerable"), and the mean benefit for medium interaction is 3.55 (between "considerable" and "moderate"). On teaching function, the average benefit is 3.66 for high interaction, and the mean benefit is 3.02 for low interaction. On the entrepreneurial opportunity, the mean benefit is 3.10 for high interaction, and the mean benefit rating for low interaction is 2.53 (between "moderate" and "marginal"). The point of this discussion is to clarify the fact that faculty-firm interaction does positively and systematically affect the benefits faculty experience from collaboration with industry.

Industry experience

The benefits experienced by firms have been described in Table VI. Since in industry data the eight benefit variables are conceptually distinguishable from one another, no effort is made to reduce them to a smaller set of factor variables. Analysis indicates that the benefits reported by industry technology managers show little variance in terms of the types of firms (start-up, small, medium, and large). In general, benefits reported by technology managers tend to show a remarkably consistent pattern amongst themselves across all types of firms, irrespective of size.

A point of interest in the data is the relationship between firms' R&D intensity and their perception of faculty contribution, particularly to the development of new products and processes. The larger the number of R&D scientists and engineers a firm has on staff, the less likely the firm is to feel that academics contribute much to the development of products and processes ($r = -0.241$, $p \leq 0.01$). Conversely, firms with a smaller number of scientists and engineers on staff show a greater appreciation for faculty contribution in the development of new products and processes.

In sum, evidence is clear that firms collaborating with university faculty on R&D projects derive *significant* benefits by gaining increased access to new research from the university, making progress toward the development of new products and processes, and maintaining an ongoing relationship with the university community. To these firms faculty members serve as an important bridge to the university community. With respect to the discovery of new products and processes leading to new patents and solutions to specific technical and design problems, industry technology managers believe that faculty contributions are only *moderate*. Furthermore, according to these technology managers, firms gain little benefit from faculty participation in the improvement of product quality, the shaping of firms' R&D agenda, and the recruitment of university students.[4]

Are firms getting what they need and want from academics participating in their R&D projects? As far as the precise empirical relationship between expectations and outcomes is concerned, the proper answer should be both "Yes" and "No." This is because the expectation-outcome relationship in this case is not necessarily linear —that is, benefits occur unintendedly or unexpectedly. Table IX relates firms' "primary" objectives to subsequent benefits. Two primary objectives, "develop software" and "supporting universities," are excluded from the table because less than 10 firms identified them as their "primary" objective in research partnership with faculty.

Table IX shows clearly that the relationship between what firms had initially desired ("primary interests") and what they subsequently gained from collaboration is not linear. A close look shows that regardless of "pronounced" primary objectives, firms experience benefits in a broad R&D spectrum. Still, there is a reasonably good fit between primary objectives and outcomes. Of firms expressing a primary interest in "conducting research related to existing product line," 59% agree that they have gained substantial or considerable benefits from faculty in "developing new products or processes." The emphasis on this developmental aspect of research also con-

Table IX
Relationship of firms' primary objectives of collaboration with faculty members to outcomes they have realized

	% of Firms Realizing 'Primary' Objectives "Substantially" or "Considerably"*					
Industry benefits from collaboration with faculty	Product develpmt ($N = 83$)	'Blue sky' research ($N = 44$)	Problem solving ($N = 28$)	Prototype design ($N = 26$)	Fundmtal research ($N = 10$)	Seminars/ workshops ($N = 10$)
Gaining access to new research	79.6	86.4	64.3	76.9	70.0	100.0
Developing new products	59.0	59.0	78.6	77.0	30.0	90.0
Maintaining relationship with the university	61.4	70.0	42.8	65.4	70.0	80.0
Developing new patents	56.6	61.4	39.3	61.6	50.0	80.0
Solving technical problems	46.4	38.6	67.8	57.7	20.0	80.0
Improving product quality	21.7	15.9	42.9	34.6	20.0	30.0
Reorienting R&D agenda	20.5	22.8	3.6	23.1	20.0	30.0
Recruiting students	8.4	6.8	7.2	3.8	10.0	20.0

*Product develpmt refers to "conducting research related to existing product line"; 'Blue sky' research refers to "conduct 'blue sky' research in search of new technology"; "Problem solving" refers to "testing instrumentation and technical problem solving"; Prototype design refers to "design of prototypes"; Fundamtal research refers to "fundamental research with no specific application in mind"; and Seminars/workshops refers to "provide seminars and workshops on new research and discoveries."

tributed significantly to research on new products or processes leading to new patents, increased access to cutting-edge university research, and enhanced relationships with the university. Of firms expressing a primary interest in "conducting "blue sky" research in search of new technology," 61.4% agree they have experienced substantial or considerable benefits from their faculty collaborators in "developing products or processes resulting in new patents." The emphasis on "blue sky" research also has contributed significantly to "developing new products or processes," "gaining access to university research," and "maintaining an ongoing relationship with the university." The pattern of this diffused impact continues in the areas of "technical problem solving," "design of prototypes," "conducting fundamental research," and "providing seminars and workshops on new research and discoveries."

Of firms interested in instrumentation and solving technical problems, 67.8% say that collaboration with university faculty has yielded substantial or considerable benefits in "solving specific technical problems, increasing technical solving capability, testing equipment, and improving product design." Similarly, the emphasis on technical problem solving contributed significantly to the development of new products or processes, as well as increased access to new research. While an emphasis on the design of prototype contributed to the development of new products and processes, it also has benefited firms broadly, stretching from research on new patents to technical problem solving and increased access to university research. In the area of fundamental research and seminars/workshops, only a small number of firms identified these subjects as their primary objective for research collaboration with university faculty, and those seem to have gained a great deal from collaboration with faculty members. Seventy percent of firms targeting fundamental research as their primary objective have gained increased access to university research and strengthened their relationship and network with the university. And all firms having a primary interest in new research and discoveries via seminars and workshops from faculty members feel that they have gained substantial or considerable benefits with respect to increased access to cutting-edge research. Furthermore, these firms have experienced benefits on a broad spectrum of the R&D dimension, from access to new research to technical problem solving.

8. Summary and conclusion

As an effort to gauge whether the concept of university-industry collaboration can be a sustainable element in the national innovation system and what the underlying condition might entail for effective collaboration between the two sectors, this study examined the street level experience of university-industry collaboration by focusing on behavioral outcomes. In particular, the study focused on what the participants in the collaborative regime, university faculty and firms, actually get out of their collaboration. On a theoretical plane, this approach is premised on a belief that research collaboration between faculty members and firms is a market of some sort in which partners engage in exchange behavior. The study finds several modalities that depict research collaboration between faculty members and industrial firms. The survey data demonstrate that faculty members collaborating with industry bring with them a set of personal objectives for which they are willing to commit time, energy, and intellectual resources. Likewise, firms have their own agendas for which they are willing to commit corporate resources. These objectives and agendas are not always formalized on paper, but nonetheless must be understood and appropriately recognized. No collaboration will survive in the long run unless each partner satisfies the needs of the other in a growing symbiotic relationship.

Table X summarizes the underlying motivations of university faculty and firms when collaborating on R&D projects (See Figure 1b and Table IV). In Table X, the motivations (reasons) are listed in hierarchical order, from most important to least important. For faculty members, the foremost important reasons, the top four on the list, of collaborating with industry are reasons of academic (basic) research. This must be reassuring to the academic community. Happily, too, the least important reason to these faculty members is entrepreneurial opportunity. When competing against the need for research support, pedagogical functions and outreach obligation also take a

Table X
Hierarchy of underlying motivations of university faculty and firms manifested in research collaboration*

Ranking	What firms seek from academics	Ranking	What academics seek from firms
1	Research on product development	1	Secure funds for graduate assistants and lab equipment
2	Conduct 'blue sky' research in search of new technology	2	Gain insight into one's own research
3	Solve technical problems	3	Field-test application of one's own theory
4	Design prototypes	4	Supplement funds for one's own research
5	Provide seminars and workshops	5	Assist university's outreach mission
6	Conduct fundamental research	6	Create student jobs and internships
7	Support universities	7	Gain knowledge useful for teaching
8	Develop software	8	Look for business opportunity

*This table is adapted from Figure 1b and Table IV.

back seat. In the context of biotechnology research Blumenthal *et al*. (1986) feared that biotechnology faculty with industry support may be unduly influenced by the consideration that "the results would have commercial application," which may occur "at the expense of more fundamental research" (p. 1364). This concern cannot be verified by the survey. What is evident from the present survey, however, is that faculty members look at research collaboration with industry primarily as a means to secure funds for their graduate students and lab equipment, supplement their own academic research, field-test the application of their own research, and gain insights into their own research. If these motivations mean what Stokes (1997) described as "user-inspired basic research," the academic community should be able to afford a fraction of its intellectual resources to user-inspired research.

With respect to industry, the important reasons (motivations) firms use to get faculty members involved in their R&D projects are coalesced with research related to product development of some sort. High on firms' agenda are research related to existing product line, exploratory research in search of new products, instrumentation and technical problem solving, and design of prototypes. Firms' technology managers view that increased access to new research and discoveries via seminars and workshops as extremely important but nonetheless of secondary importance. Similarly, fundamental research without specific applications is viewed as important but not of primary importance. The Government-University-Industry Research Roundtable (1991, 1994) argued that what firms need and want from universities is basic research. The Roundtable, therefore, comes out in favor of university-industry collaboration in the form of consortia in which research focuses on broad and generic topics. While some are skeptical of the practical value of consortia, others strongly affirm the consortia approach as the way of the future. The faculty survey in the present study demonstrates that at the street level, at least, 65% of university-industry collaboration takes the form of single faculty-firm transactions. Moreover, the primary objectives of collaboration as agreed to by faculty members are related largely to *product-oriented research*, including exploratory "blue sky" research in search of new technology.

In the real world of research collaboration, however, initial objectives cannot be overemphasized on face value. In the first place, the language of "objectives" is not discreet but continuous, overlapping, and complementary. Secondly, the relationship between objectives and outcomes is nonlinear. Emphasis on one objective leads yet to another serendipitously.

With respect to the outcomes of research collaboration, a large majority of faculty members, over 67%, say that they are experiencing substantial or considerable benefits to their academic research support by acquiring funds necessary to support graduate students and purchase lab equipment. Similarly, an equally large majority, over 66%, say that from research collaboration with industry they are gaining valuable insight into their own research agenda. Over 56% also agree that they find an opportunity to field-test the practical application of their own research and theory. Faculty members collaborating with firms agree that benefits to their pedagogical function are only modest. Similarly, only a small percentage of faculty members, 21%, believe that research collaboration with firms offers a significant window of business opportunity for them.

Evidence is also strong that motivations and outcomes are related positively and in a linear fashion. Faculty members looking for funds for their own research tend to experience significant benefits from their collaboration with firms, but not necessarily other benefits. Those who emphasize the teaching aspect (i.e., practical knowledge useful for teaching, as well as industry contact for student placement) tend to experience significant benefits to teaching function, but not others. Likewise, faculty members interested in business opportunity tend to gain significant entrepreneurial opportunities largely to the exclusion of other benefits. In sum, data show that for faculty members, motivations play a significant role on the outcomes they experience.

Data also show that firms partnering with faculty members on R&D projects appear to be doing very well. Nearly 76% agree that by partnering with faculty members these firms are gaining increased access to new research and discoveries, and nearly 61% say that with faculty support they are making significant progress toward the development of new products or processes. A majority of these firms, 53%, also express that faculty members are making significant contributions toward research on patentable products or processes. Research collaboration with faculty members also translates directly to the development and maintenance of a working relationship with the university. Fifty-four percent of these firms agree that research collaboration with faculty members is helping them significantly toward a closer relationship with the university. Not all experiences, however, are positive. A majority of firms recognize the limited impact faculty members have on other areas. More than 77% of firms feel that faculty members make only moderate or marginal impact on the improvement of product quality, and nearly 82% think that faculty contribution to firms' R&D agenda is inconsequential. Over 94% also feel that faculty members have little impact on recruiting graduate students from the university. Taken together, firms, irrespective of size, appear to be in agreement with these observations.

In conclusion, how does this behavioral assessment translate to the future of university-industry collaboration? Assuming that no major perturbations in the present structure of university-industry collaboration are on the horizon, what can we say about the sustainability of their collaboration in the future? Considering that experience is demonstrably positive on both sides, it is tempting to conclude that collaboration between the two sectors may continue in the future. After reviewing the literature on university-industry collaboration on technology transfer, Feller (1997) also was tempted to suggest, "Technology transfer . . . has the potential to become a self-propelling force within the university" (p. 36). To gain further insight into the question of sustainability, the questionnaire asked faculty members, "How likely are you to expand your R&D collaboration with industry?" A similar question also was asked of industry technology managers, "Considering your firm's overall experience with university-industry collaborative projects/programs, including the current one, how likely is your firm to expand, continue, or reduce work with universities in the future?" Figure 2 describes the responses from the two groups.

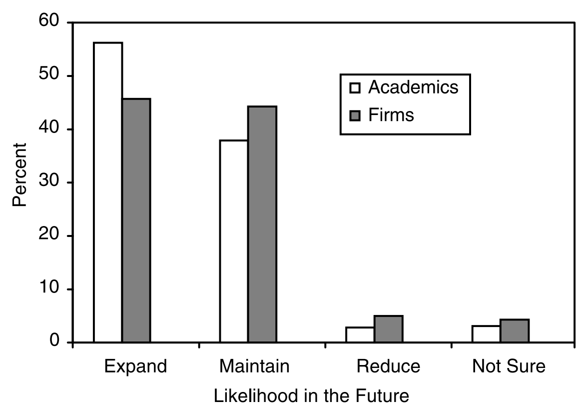

Figure 2. Likelihood of future research collaboration between university faculty and firms.

Figure 2 provides strong evidence that, at least from the street level perspective, university-industry collaboration in the United States is likely to continue in the future. Data show that an overwhelming majority of faculty members, 94%, and industry technology managers, 91%, think they are likely to expand or at least maintain the present level of collaboration with one another. Only about 6% of these faculty members and about 9% of these firms, respectively, are either uncertain about or possibly will reduce collaboration in the future. In sum, data provide ample evidence that university-industry collaboration in the United States is sustainable at least at the street level of interaction. This sustainability is to attribute to the fact that each partner—the individual faculty member and the individual firm —is able to allow the other partner to realize his or her own objective while contributing at the same time to the mutual goal. This conclusion gains force when we consider that the two groups, faculty members and industry technology managers, have arrived at the same conclusion independently.

Notes

1. This study is supported by the National Science Foundation under the sponsorship of Social Dimensions of Engineering, Science, and Technology: SBR9625826. I am grateful to Dr. Rachelle Hollander, Director of this Program, who provided thoughtful comments and guidance throughout the course of this study. I am also grateful to all faculty members and industry technology managers who participated in this study and shared their deep personal experience in this study. Mr. Seok-Eun Kim and Ms Jennifer Bryne were my graduate assistants to whom I owe special thanks. The findings and conclusions are my own and do not represent the views of the National Science Foundation.

2. Speculation is that many faculty members in this survey work with small software firms not affiliated with AUTM.

3. The weights are based on a short exploratory e-mail survey to a sample of 20 randomly selected faculty respondents asking them to assess the relative importance of these four types of interactions. While responses varied among respondents, the general remark was that frequent interactions, including an extended stay in the firm's lab or an extended stay of the firm's engineer in the university lab, are much more important for knowledge and technology transfer than the giving of periodic reports or the final report only. Since it is not possible at this point to assign precise weights on these items, I rely on a rule-of-thumb judgment by assigning a weight of "1" to periodic reports and a weight of "2" to all other categories.

4. It is not entirely clear why the technology managers responded the way they did. One possible explanation is that when the focus is on specific R&D projects requiring a team effort, it may have been difficult for them to single out faculty contribution in any specific area. See the comment made by one technology manager in a large pharmaceutical firm on page XX.

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