ABSTRACT

MEAGHER, BETH MARIE. Faculty Outcomes from Industry-University Collaboration. (Under the direction of Denis O. Gray)

A large amount of research and development in the United States takes place at universities. In spite of the great number of research projects that have been done on industry-university research collaboration and industry-university research centers, the university faculty member has been relatively neglected in these studies. A comprehensive literature review was conducted to determine what information was available about faculty involved in industry-university collaboration. Limitations of the literature are discussed. Though the literature provides a general description of faculty involvement in industry-university collaboration, there is a strong need for further research in this area. This study sought to determine the kinds of benefits and outcomes that faculty members receive from their involvement in industry-university research centers and whether these benefits predict outcomes related to publications and satisfaction. Faculty from industry-university research centers nationwide were surveyed about their center involvement. Results showed variables at three organizational levels, the university, the center, and the individual, predicted satisfaction and scholarly productivity of the faculty member. The receipt of benefits by the faculty member (such as support for graduate students, access to equipment, opportunities for consulting, opportunities for research contracts, chances for promotion and tenure, and interaction with faculty) positively influenced outcomes related to satisfaction, theses and dissertations, total publications and presentations, publications and presentations with students, and publications and presentations with member scientists. Further, faculty symmetry with industry also predicted satisfaction and scholarly productivity.

FACULTY OUTCOMES FROM INDUSTRY-UNIVERSITY COLLABORATION

by
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Biography

Beth Meagher grew up in Western Massachusetts. She attended Smith College in Northampton, MA and graduated with a degree in Psychology in May of 1999. Immediately following graduation, she moved to Raleigh to start graduate school at NCSU. She is currently a graduate student in the Department of Psychology in the Psychology in the Public Interest Program. Her research interests are in the area of industry-university collaboration, satisfaction, and evaluation. She is a research assistant for Dr. Denis Gray, working on the evaluation project for the National Science Foundation's Industry University Cooperative Research Center's Program.

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My fiancé, Ted Coberly, besides being there to listen to all my concerns, made sure I still had some fun in spite of the piles of work in front of me.

One down, one to go!

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LITERATURE REVIEW

The purpose of the literature review is to give a summary of the current literature on faculty and industry-university collaboration. Before covering this literature, a brief overview is given on the nature of industry funding to universities in the US and the types of linkages the university can make with industry. A specific type of linkage, the industry-university research center is described and a brief summary of recent research is given. Finally, the review covers research specifically concerning faculty and industry-university collaboration focused around three themes: faculty views of industry-university collaboration, characteristics of the faculty involved, and outcomes. The literature review concludes by describing a specific collaboration program, the National Science Foundation's Industry-University Cooperative Research Centers Program.

University Research Funding and Industry-University Collaboration

The United States spends an enormous amount of money on research and development (R&D) activities. A great deal of this research takes place at institutions of higher education. In 1998, universities conducted approximately 48% of all basic research in the US. In terms of dollars spent, approximately $26.3 billion dollars was provided by the federal government, the university, state and local government, industry, and other sources towards research at universities and other academic institutions. A large majority of this money went towards basic research (69%) and the remaining funds towards applied research (24%) and development (7%). Of this total amount, industry provided $1.9 million dollars, towards university research and development. This amounts to 7 percent of the total funding for university research. While this amount may seem small in comparison to the money spent by other sources, the amount of industry funding is growing at the fastest rate among all sources of funding to academic institutions (National Science Foundation, 2000). In 1973, $84 million was spent by industry on university research. In 1997, industry spent $1.7 billion dollars (Rahm, Kirkland, & Bozeman, 2000). A closer look at specific disciplines shows that industry provides a significant portion of research funding. A national survey of engineering faculty found that 17% of all funding to individual faculty for university based research and development in engineering for 1993 came from industry. Seventy-nine percent of the engineering faculty surveyed reported that they either currently receive or had received in the past, industry funding for their research. The same percentage of faculty also wanted to see more industry involvement in academic research (Strickland, Kannankutty, and Morgan, 1996).

One of the reasons for the increase in industry funding is the changing nature of business and R&D in the United States. Industry is seeking R& D resources outside of the company because of economic stress, downsizing, and the constant broadening scope of research in many fields. At the same time, the sources of funding for university research have changed over the last few decades. The focus of research has gone away from military uses, which has caused a decrease in the amount of federal funds available for research (Rahm et. al., 2000). While the government still provides the majority of research funds, this percentage has decreased. In 1998, the government provided 59 percent of the total academic research funds, down from a peak of 73 percent in 1966 (National Science Foundation, 2000). Therefore, university researchers are looking to expand their funding sources, the private sector being one of the possibilities.

Changes in public policy over the last two decades have also helped to promote the research collaboration between industry and university. The reasons behind many of the policy changes, particularly those occurring in the 1980's were due to the increased concern of the United State's international competitiveness. Also, there emerged an "intertwining" of science and technology with the rise of such industries as computers, telecommunications, and biotechnology. Much of the seminal research in these areas was located in universities and government agencies. Thus a need was created for linkages between those that produce new knowledge and those that could transform the knowledge into products and processes that had commercial applications (Feller, 1999).

The changes in public policy began with the Stevenson-Wyler Technology Innovation Act of 1980. The act stated that R&D activities that occurred in the university had a significant impact upon innovations in industry. It created several Centers for Industrial Technology, which were affiliated with universities and nonprofit institutions. Several other acts were passed over the next two decades, the most recent one being the National Technology Transfer and Advancement Act of 1995. This act clarifies "the intellectual property rights of private sector partners for technologies created in partnership with one of the nation's federal laboratories" (p. 55) (Rahm, et. al., 2000). This has all helped to lead to an increase in the amount of research collaboration between industry and university (Cohen, Florida, & Goe, 1994).

There are many types of linkages that industry can make with the university. Informal linkages may consist of faculty consulting, student job placement, and student internships. More formal linkages with the university include contract research, research parks, industrial R&D consortia, and industry-university research centers (Rahm, et. al., 2000). Koester and Gray (1990) provide a more in-depth typology of industry-university linkages. In their typology, industry-university linkage mechanisms vary along three dimensions: primary purpose, organizational formality, and the relationship to the university. The different combinations of these dimensions can have a profound effect on the stage of the innovation process that is affected, the degree of alignment with the goals of the industry and the university, or the size, scope, and complexity of work that is done.

A linkage mechanism can have one of five primary purposes: research, knowledge/technology transfer, product/process development, brokerage liaison, or multipurpose. A linkage mechanism with the purpose of research would create new knowledge by using a method of systematic inquiry. A linkage with the purpose of knowledge/technology transfer would transfer knowledge or technology that already existed by activities such as training or consultation. Product/process development linkages assist with the development and marketing of new products and processes. Brokerage/liaison linkages facilitate the relationship between the industry and university. Finally, multipurpose linkages fulfill more than one of these purposes (Keoster & Gray, 1990).

The second dimension in which linkages can vary is in the degree of formality. Formality can be described as "the extent to which the linkage mechanism possesses the structures, procedures, and infrastructure one associates with well-defined organizations or organizational unit" (p. 18). Standard linkage mechanisms are the most formal and have established goals, administrative staff and leadership hierarchy. Adaptive linkage mechanisms are similar to standard linkages except they have a more limited administrative and physical infrastructure. Shadow linkage mechanisms generally have no administrative and physical infrastructures and may exist as an organization on paper only. Finally, informal linkage mechanisms have no organizational characteristics. Examples of this type of linkage are research contracts between a professor and a firm, internship programs, and faculty consulting to firms (Koester & Gray, 1990).

The final dimension is the relationship of the linkage mechanism to the university. Linkage mechanisms that are described as central are part of the organization of the university. They are closely aligned with the norms and goals of the university and have a hierarchical system of control. Cooperative extension programs, which are at many universities, are examples of this type of linkage. Semi-autonomous linkage mechanisms have a higher level of independence from the university. They are usually in charge of determining their own budget, goals, and administrative operations. An example of this type of linkage is the Industry-University Research Center. Finally independent linkage mechanisms are almost completely separate from the university. There is usually an agreement made with the university for the use of building space or other resource. Industrial research parks are an example of an independent linkage mechanism (Koester & Gray, 1990).

The Industry-University Research Center

The focus of the present study is on the industry–university research center. According the typology of Koester and Gray (1990), it would be described as a semi-autonomous, adaptive organization that exists at the university for the purposes of research and product/process development. Industry-university research centers (IURCs) address a wide range of research issues for a number of industry and government sponsors. The basic structure of the IURC is an administrative core at the university that supports and coordinates interrelated research projects involving faculty, students, and staff from multiple disciplines (Gray, Johnson, & Gidley, 1987). Industry funding is provided by industry “sponsors” who pay an annual membership fee. IURC's are diverse in the type of research they do, their size, and mission. The specific characteristics of the center depend on the scientific discipline and industries the center is affiliated with (Cohen, Florida, and Goe, 1994).

There were approximately 1,056 IURCs in the US involving 12,000 faculty, 22,300 doctoral-level research scientists, and 16,800 graduate students in 1991. These IURCs had research expenditures of $2.53 billion. While industry alone provides 7% of funding for academic research, funding for IURCs is provided to the center by both industry and government, accounting for approximately 15% of university research funding. When industry support, government support, and money from traditional collaborative activities of faculty such as consulting are considered together, about 20 to 25% of university research is accounted for (Cohen, Florida, & Goe, 1994). Feller describes the IURC as "the dominant form of industry support for academic R&D" (p. 54)(Feller, 1999).

Research on Industry-University Research Centers

Industry-university research centers have been evaluated using a number of different methods. Ex-ante evaluations looks at the research process before it has begun. It can affect the allocation of resources to the institution, the individual projects, or the principle investigators. There are three levels for this approach. The whole research center program can be evaluated, which is commonly done before a center starts its operations. There can be an evaluation at the center level with the result obtained being primarily qualitative in nature. The evaluation would describe what the center's research plans are. This is usually done through a peer review process. Finally, there can be an evaluation at the project level in which proposals for individual projects are solicited, developed, and evaluated. This is also usually done through a peer review process. Overall, ex-ante evaluation by qualified peer review has become standard operating procedure for most centers (Gray, 2000).

The next category of evaluation is interim evaluation, which is evaluation done during the research process. This type of evaluation addresses "managerial performance and research execution" (p. 61). The level of analysis can range from simple monitoring which would collect information on funding and structure to more complex methods of evaluation, such as process evaluations. Another evaluation technique are site visits, such as the National Science Foundation's annual site visit to the Engineering Research Centers and the Science and Technology Centers. The Industry-University Cooperative Research Centers use an annual process outcome evaluation to get feedback on center research management. This method of evaluation is effective because it provides the center with real-time feedback. However, costs can sometimes be an issue (Gray, 2000).

The final category of evaluation is outcome evaluations, which measure outputs from the center. These are usually very comprehensive evaluations and often involve a combination of all three categories of evaluation. Examples of outcomes that have been evaluated are productivity, quality of the research program, graduate education, and technology transfer. (Gray, 2000).

The results of these evaluations show a number of benefits for industry involved in IURCs. An analysis of IURCs in general showed that one major outcome of the interaction between the two partners was the introduction of new products and processes and the improvement of products and processes that already exist (Cohen, Florida, & Goe, 1994). Lee (2000) listed a number of industry benefits from collaboration with the university; the opportunity to gain access to new research, the development of new products and processes, maintaining a relationship with the university, developing new patents, and solving technical problems. While university research may not lead directly to a new product, it provides information on the essential processes that will make the innovation possible (Mansfield, 1995). In an extensive review of over 120 articles on technology transfer from universities, Feller (1999) states that some of the major reasons for the involvement of firms in IURCs is access to state of the art information, maintaining of relationships with faculty, and access to students.

Individual IURC programs have also reported benefits through the evaluation of their program centers. In a report from the National Science Foundation's Engineering Research Centers Program a number of benefits for member firms were stated such as access to new ideas and new technologies, obtaining technical assistance from the center, the opportunity to interact with other firms in the center, and access to facilities and equipment at the center (Parker, 1997). The Industry-University Cooperative Research Centers Program (also funded by NSF) has reported similar benefits (Gray, Johnson, & Gidley, 1987).

Summary

A large amount of research and development in the United States takes places at universities. While industry currently provides a small percentage amount of the research support received by universities, this amount is growing at the fastest rate among all sources of funding to academic institutions (National Science Foundation, 2000). This is due to the changing nature of business and R&D (Rahm, et. al., 2000). Changes in public policy have also helped to facilitate cooperation between industry and the university in research (Feller, 1999).

There are many types of linkages that industry and university can engage in depending on the purpose for the collaboration. Linkages can vary in their primary purpose, the degree of formality and the relationship of the linkage mechanism to the university. One type of linkage, the industry-university research center, is a semi-autonomous, adaptive organization that exists at the university for the purposes of research and product/process development (Koester & Gray, 1990). In 1990, the 1,056 IUCRCs in the US involved around 12,000 faculty and had research expenditures of about $2.53 billion. Evaluation of this type of linkage has shown a number of benefits among them being: the introduction of new products and processes and the improvement of existing products and processes (Cohen, Florida, and Goe, 1994).

In spite of the large amount of research that has been done on industry-university research collaboration and IURCs in particular, there is one population in the relationship that has been relatively neglected in research. This population is the university faculty member. Gray (2000) mentions that this oversight is significant given that the possible negative consequences for faculty involved in this type of collaborative research are frequently mentioned. Lee (1996) also states that more empirical research needs to be done on faculty. Faculty are an important part of the research relationship with industry and knowing more about their participation in the relationship would help to make this type of collaboration more effective overall. In light of this, a literature review was conducted to determine what information was available about faculty involved in industry-university collaboration.

Faculty and Industry-University Collaboration

A literature search was conducted to locate articles that dealt with faculty and industry-university collaboration. Articles were located via library search engines entering key words such as “research faculty”, “faculty and industry”, and “university and industry”. Any study dealing with faculty interactions with industry was included in the review. Results of the search produced 10 studies published in the last 20 years. These studies focused on three main topics: the characteristics of faculty and universities involved in collaboration with industry, the general attitude of faculty towards the collaboration of industry and the university in research efforts, and possible benefits or unintended consequences for faculty involved in this type of collaboration. The majority of the literature was descriptive in nature. A review table of this literature appears in Appendix A.

Faculty Views of Industry-University Collaboration

A good portion of the literature addresses how academic faculty, in general, view the university being involved in research with industry. Lee (1996) hypothesized university faculty would be more accepting of industry-university collaboration than previously because of factors such as a decrease in federal funds to do research, pressure from state governments to become involved with industry, and desire to increase institutional prestige. Data were collected via a mail survey and field interviews from three types of research universities; public, private, and land-grant. Within each university, faculty from the basic science (biology, chemistry, and physics), engineering applied sciences (chemical engineering, electrical engineering, computer science, and materials science), and social science (economics and political science) departments were surveyed. Within each department, the chair, the person most recently promoted to associate professor and the person most recently promoted to full professor were asked to complete the survey. A total of 986 faculty from 429 academic departments completed the survey. This was a response rate of 43% for faculty and 56% for the departments.

The data showed that 72% of faculty felt that user-oriented research (defined as research that created more commercial outputs such as patents) was acceptable in the university. This implies that this type of research and its outcomes should be given equal weight as basic research. On the issue of obtaining tenure credits for patentable inventions, 73% of engineering and basic science faculty are supportive as opposed to 56% of social science faculty (this difference was statistically significant). There was also an increase in the percentage of academics who approve of collaborating with industry on user-oriented research, 58% in 1980's (based on a retrospective response from the faculty surveyed and not tested statistically) to 70% in 1990's. Faculty in the engineering sciences showed the strongest support of university user oriented research (83.4%) followed by the basic sciences (73%). Only 42% of faculty in the social sciences were supportive (these differences were statistically significant). There was moderately strong support for the development of infrastructure (the article does not specify what types of infrastructure) in the university to support collaboration with industry (64%) and for the encouragement of faculty consulting with industry (56%). However, less than half the faculty (44%) agreed that the university should provide startup assistance to technology based firms and only about a quarter of the participants (27%) felt that the university should make equity investments in firms based on university research. A large amount of exceptions were also added to faculty's support of university research collaboration with industry. Some of these concerns were: a negative effect on long-term basic research, freedom to publish results of research, and a negative effect on the education of students (Lee, 1996).

A multivariate logistic regression analysis was done to see what factors predicted faculty support of user-oriented research and the commercialization of university research. Three variables emerged as being predictors of support of user oriented research: whether the faculty member is from a basic, applied, or social science discipline, his or her institution encourages industrial contract research (according to the perceptions of the faculty member), and the faculty member does not perceive industry-university collaboration as a threat to academic values. This model predicted 78% of the responses of the support for user-oriented research. The most important predictor of support for user-oriented research was the belief that user-oriented research would not interfere with the basic research mission of the university. The next was being a faculty member in an applied science. Institutional support of industrial contract research was the least important predictor. Support for the commercialization of university research was predicted by being in an applied science discipline and by the belief that industry-university collaboration is not a threat to academic values. This model predicted 69.7% of the responses of support for the commercialization of research with the lack of perceived threat to academic values being the most important predictor (Lee, 1996).

The study provides a good deal of information about faculty support of technology transfer from universities to industry. Overall, it appears that faculty are supportive of this type of technology transfer, with particular factors such as no perceived threat to academic values, predictive of greater support. However, there is some concern about the impact that user-oriented research will have on the free flow of information, the choice of research topics, and the university's basic research values. There are a number of methodological issues that can be raised about this study. For instance, comparisons to attitudes in the 1980's were based on retrospective responses and might not be completely accurate. The method of data collection may not have obtained a truly representative sample. All of the participants were tenured faculty members. Non-tenured faculty members may feel pressured to stick with traditional methods of research in order to obtain tenure and therefore may be less supportive of user-oriented research. The department chair may also be more concerned with administrative operations in his or her own department and may not be representative of the faculty in the department. While the departments surveyed in the basic and applied disciplines seem representative of those fields, the two departments surveyed in the social science discipline (economics and political science) might not be a representative of all social sciences.

Campbell (1997) discusses three potential conflicts that may arise out of the industry-university relationship: conflicts of interest, conflicts of commitment, and conflicts of internal equity:

Potential Conflict of Interest. Defined as "financial or economic issues that stem from the use of funds, inappropriate influence, and the ownership of patents and licensing (p. 358)."

Potential Conflict of Commitment. Defined as "issues centering on the allocation of time and energy to fulfill three primary academic roles: teaching, research, and public service (p. 359)." Some academics fear that as industry demands more time from the researcher, teaching and public service responsibilities may be compromised.

Potential Conflict over Internal Equity. Defined as "differing abilities to obtain significant rewards from within the organization (p.359)." This refers to the ability of some academic disciplines to obtain greater amounts of funds because of their ability to associate with industry.

Two hypotheses are stated for the study. The first is that the views of universities, academics, and the industry with which they collaborate will converge on their views of potential conflicts over time. The second hypothesis is these views will be different than the views of individuals who are not involved in this type of collaboration. The authors base their hypotheses on the theory of institutional isomorphism. The theory states that organizations and the individuals involved within the organization become more similar in their views over time (Campbell, 1997).

Questionnaires were mailed out to both industry and faculty asking them to rate the degree to which they agreed with statements about potential conflicts or the extent to which a particular issue could be considered a potential conflict. Faculty surveys were mailed to administrators, department chairs, and faculty in the 12 largest institutions for each of the Carnegie classifications (In each department, the author does specify whether all departments or a selection were chosen, the department head was asked to give one survey to a faculty member who was involved with industry and give one to a faculty member who was not involved with industry.). Surveys were received from 275 faculty members and 95 administrators represented an overall response rate of 34% (Campbell, 1997).

A factor analysis was done to determine the types of factors the participants viewed as potential conflicts. The three factors that emerged from the analysis were similar to those discussed in the literature review; potential conflict of interest, potential conflict of commitment, and potential conflict over internal equity. Next, analyses of variances were done to see if there was a difference between faculty that collaborated with industry and non-collaborative faculty. Overall, the responses showed that faculty are open-minded towards changes in university norms that would facilitate an increase in the amount of collaboration with industry. However, there were significant differing views for potential conflicts of interest between collaborative individuals and non-collaborative individuals. Faculty that are involved in collaborative activity want a greater opportunity to obtain financial rewards and more flexibility. Those not involved in collaborative activity were more negative in their views of financial gain from collaborative activity. There were no significant differences for the potential conflict of commitment and conflict of internal equity between collaborative and non-collaborative faculty. While there was no mention of whether the results of the analyses of variance were statistically significant, no statistical values were given.

One conclusion that the author makes is that while faculty support the involvement of organizations, such as the university, in collaborative activity any inappropriate behavior that happens as a result of this collaboration is attributed to the individuals, in this instance, the faculty member. It is unclear where this conclusion is drawn from based on the results of this study. A major limitation with this study is the data collection method and low response rate. Department heads were asked to hand out the survey to faculty members. This creates a potential for large selection bias. Responses from the industry portion of the survey were not addressed in the analysis or mentioned in the results of the study, leaving the hypotheses for the study largely untested.

In a later study, Campbell and Slaughter (1999) examined the differences in these potential conflicts between faculty and administrators. What are the agreements and disagreements between faculty members and administrators who are involved in industry-university collaboration concerning these potential conflicts? Are these views different from faculty and administrators who are not involved in industry-university collaboration?

The authors made three hypotheses. First, they hypothesized that faculty and administrators would hold different views on potential conflicts and especially over the control of relations with industry. Each party would want control over the relationship. Secondly, compared to those not involved, faculty and administrators involved in collaborative activity would be more likely to respond to potential conflicts in a manner that would expand the collaborative activities. Finally, faculty who are not involved in collaborative activity would be less supportive than involved faculty of inequities across disciplines than may arise from collaborative activities (Campbell & Slaughter, 1999).

Surveys were mailed to targeted faculty and administrative respondents at the 12 largest public institutions in each of the Carnegie classifications, for a total of 86 universities. These individuals were asked to distribute the survey to other faculty members in their department (creating a possible sampling bias). It is interesting to note that department heads were not considered administrators in this study. They were considered regular faculty members. A total of 407 completed surveys were received (the authors estimate the response rate to be approximately 34%). The survey asked participants to rate their agreement with statements and the degree to which they viewed these statements to be potential conflicts on a six point Likert scale. Each of the statements was a part of one of three scales: potential conflicts of interest, potential conflicts of commitment, or potential conflicts of internal equity (see the summary of Campbell, 1997 for a description of each conflict) (Campbell & Slaugher, 1999).

Differences between groups were assessed using analyses of variance. Results were divided into each of the three potential conflicts (conflict of interest, conflict of commitment, and conflict over internal equity). In terms of conflicts of interest, faculty who were involved with industry felt that potential conflicts were less of an issue than those not involved with industry and there was no difference between faculty and administrators. For conflicts of commitment, faculty not involved with industry and administrators (both involved and not involved) held differing views than those of the involved faculty members. Involved faculty were more likely to support the relinquishing of their traditional academic duties in order to facilitate research with industry whereas uninvolved faculty and administrators expect that involved faculty would continue to keep these duties. Finally, for conflicts of internal equity, there were no significant differences between faculty and administrators or between involved and uninvolved faculty. All participants felt that the distribution of responsibilities and resources and especially the faculty member's responsibilities to students should be the same regardless of a faculty member's involvement with industry (Campbell & Slaughter, 1999).

Returning to the three original hypotheses made by the authors, there is evidence to support both the first and the second hypotheses. Faculty who are involved with industry seem to want more control of this relationship in terms of the amount of time they spend working on the collaborative activity, even if this means relinquishing traditional academic duties. This would also support the second hypothesis, that faculty involved with industry would respond to potential conflicts in a way that would foster the collaboration with industry. The positive responses to the conflicts of interest scale also confirm this hypothesis. The final hypothesis, that faculty who are not involved in collaborative activity would be less supportive that involved faculty of inequities across disciplines that may arise out of collaboration. There was no difference between involved and non-involved faculty on the conflict of internal equity scale (Campbell & Slaughter, 1999).

Strickland, Kannankutty, & Morgan (1996) studied engineering faculty via a national survey. They were interested in four issues: 1. The extent to which industry supports academic engineering research and the extent to which faculty support increasing industry involvement in academic research; 2. The changing nature of the industry-university relationship; 3. The characteristics of industry sponsored academic research in universities; and 4. The role of this research in education. The survey used in the study was mailed nationally to engineering faculty. Four criteria were used to include faculty in the analysis: 1. the faculty member was full-time; 2. the faculty member was tenured or on tenure-track; 3. the faculty member's principal appointment was in engineering; and 4. the faculty member was currently or had previously been engaged in university based engineering research. The first three criteria were used to identify a mailing list of faculty from a list of the institutions with highest 200 research expenditures in engineering, the last criteria was used once the completed survey was received. A total of 2,829 faculty met the criteria and were mailed the survey. The number of surveys that were returned and used for the analysis was 1,727 (61% response rate) (Strickland, Kannankutty, and Morgan, 1996).

The results of the survey showed that industry was the first or second choice in a funding source for 56% of the faculty (Strickland et. al, 1996). The specific type of industry funding that the faculty member preferred was not discussed, which is important as there are many different forms that industry funding can take. There can be some distinct differences in the goals, participants, time-frame, and research processes of different programs, which may have a significant effect on outcomes (Gray, Johnson, & Gidley, 1986).

Some faculty feel there have been changes in the nature of industry involvement over time. Thirty-eight percent of engineering faculty feel that there is more industry funding now as compared to when they first became involved. However, about half (53%) feel that the level of funding is the same or less than when they first became involved. While 30% feel that there is more restriction now on the dissemination of information, over half (63%) of faculty feel that the level of restrictions are about the same. Finally, 55% of the faculty felt that the level of industry influence of the areas chosen for research and the pressure for short-term results from the research has increased (Strickland et. al, 1996).

Summary

Unfortunately, in spite of the overall increase in the acceptance of the university's involvement with industry mentioned in the studies above, a majority of the research on this topic mentions the possible unintended consequences of this type of research relationship. A great deal of "ifs" are attached to the statements of support for I/U collaboration. Faculty worry about the loss of the mission of the university: freedom of choosing research topics and the free flow of information (Lee, 1996). Other unintended consequences that are mentioned are a negative effect on the basic research mission of the university (Rahm, 1994) and a threat to intellectual exchange between academic colleagues (Blumenthal, 1986). However, there is little empirical research that actually proves or disproves the existence of these unintended consequences.

Characteristics of the Faculty Involved.

One set of studies focused on the characteristics of faculty and universities who are involved in industry-university collaboration. Rahm (1994) addressed the issue of why some academics become involved in technology transfer and some do not. Are there aspects of academia that facilitate university-industry cooperation? Are there any barriers to this cooperation? Researchers from the top 100 research universities were surveyed. Surveys were sent to the department heads in the departments of Biology, Chemistry, Computer Science, Electrical Engineering, and Physics for each of the universities. The department head was asked to complete the survey and select two other faculty members in the department to also complete the survey. This may have introduced some sampling bias as department heads may have picked faculty members that they felt would be good examples for the department.

The surveys sent to the researchers inquired about concerns a faculty member might have or have had about industry-university collaboration. Two types of academic researchers were defined with respect to technology transfer activity. Spanning researchers were those faculty "who have interacted with firms in an effort to transfer knowledge, know-how, or a technology" (p. 270). University-bound researchers had no experience in technology transfer activity with industry. A total of 1013 researchers completed the survey, 254 of these were university-bound researchers and 759 were spanning researchers. Eighty percent of the sample was either tenured associate or full professors (This may be due to the fact that the sample was not drawn randomly.). The main objective of the study was to see if there were any differences between spanning researchers and university-bound researchers (Rahm, 1994).

A comparison between the two types of researchers showed that there were differences in four major areas. The results were primarily descriptive, with Chi-Square tests run to test the significance of results between the two groups.

1. *Firm Contacts.* As one would expect, spanning researchers were significantly more likely than university-bound researchers to have contacts with firms outside of the university. This result is rather obvious considering the definition of a spanning researcher.
2. *Firm friendly class offerings.* Spanning researchers were significantly more likely to come from universities that were described as "firm friendly". These universities were significantly more likely to offer classes and workshops that were accessible to firm personnel (night and weekends). Internship opportunities at the firms were also available for students.
3. *Firm friendly university programs and organizations.* In addition to classes and internships, the firm friendly universities were significantly more likely to be involved in partnership activities with firms. Examples of the partnership activities are; research consortia, tech transfer conferences, industrial extension services, research parks, and spin-off companies.
4. *Personal program of research.* In terms of their personal research program, spanning researchers were significantly more likely university-bound researchers to describe their program as multidisciplinary in nature (77% versus 62%). University-bound researchers were significantly more likely to report that they were the sole principal investigator for their research projects (28% versus 20%). Spanning researchers were also significantly more likely to be conducting research that was affiliated with a research center (60% of spanning researchers versus 44% of bound researchers).

However, both spanning and university-bound researchers raised concerns about university-industry cooperation. The major concern was that involvement with industry would have a negative impact on the basic research mission of the university, although this was significantly more likely to be reported by university-bound researchers (54%) than spanning researchers (41%). About half (53%) of the spanning researchers surveyed also reported having restrictions placed on the sharing of research results because of potential commercial gains of the firm involved in the research. It was not stated how many university-bound researchers had similar restrictions placed on the sharing of research results (Rahm, 1994).

Rahm (1994) does a good job of describing the characteristics of the university and faculty research programs involved with industry. However, individual faculty characteristics such as rank and age were not considered in analysis. Another limitation to this study is the non-randomness of the sample. There is a huge probability that department heads engaged in some type of selection bias when choosing which two faculty members in their department to ask to complete the survey. Also, the data is descriptive in nature with the only statistical test done assessing differences between the two groups of researchers.

In a national sample of engineering faculty, Strickland, Kannakutty, and Morgan (1996) (see full description of methods above) differences were assessed between faculty with high support from industry and faculty with high support from federal sources. Researchers divided the sample into two “extreme case” groups: faculty whose research support was primarily from federal sources (50% or more from federal sources and less than 10% from industry, 36% of the sample) and faculty whose research was primarily supported by industry (30% or more funding from industry and 10% or less from federal sources, 8%). Faculty that did not meet either of these criteria were not included in this analysis, which was slightly over half (56%) of the sample. No reasoning was given for the uneven breakdown of the sample. In was also not clear whether all of the results from the analysis were statistically significant, specific statistical values were not given for some of the differences. High federal supported research is likely to be done by an individual researcher who receives a grant that is for anywhere from 19 months to two years in duration. While high federal supported faculty engaged in significantly more basic than applied research (38.2% vs. 16.8%), almost half (47%) also engaged in applied research, although this percentage was significantly less that high industry support researchers (47% vs. 54%). High industry supported research tends to be conducted by a group of collaborating investigators (defined as a research group of more than seven investigators), working with a grant that is between 6 to 12 months in length. This research is more applied and more focused on development than high federal supported research. In addition, high industrial research as compared to high federal research is significantly more: experimental than theoretical, concentrated on synthesis rather than analysis, oriented towards products and processes rather than publications, is less long term focused, and is pulled more by the market rather than pushed by science and technology. This was based on self-reporting of the faculty members. While the comparisons between the high industry and high federal funded groups are informative, it is important to remember that over half of the sample (56%) was left out of this part of the analysis. Also questions, which asked respondents to rate whether they felt there had been changes in the nature of industry involvement over time were based on the respondents retrospective assessments and may or may not be completely accurate (Strickland, et. al., 1996).

Outcomes

The final major topic to emerge out of this literature is the outcomes for faculty involved in industry-university research collaboration. Do faculty members obtain benefits from being involved in research collaboration with industry? Are there any consequences of being involved in this type of collaboration that were not intended? The studies in this category address three different measures of outcomes. The first are the measurement of outcomes that are perceived by the faculty member. An example of this is if involvement in this type of research has led to an increase in the perceived amount of applied research done at the university. The second are subjective assessments of outcomes that are received as a result of the research. An example of this may be the degree to which university-industry research has effected the satisfaction with the faculty member's research program. The third are objective outcomes such as the number of publications in the past year. Blumenthal (1986) surveyed faculty involved with industry in the field of biotechnology. These faculty feel that there are many benefits to this relationship, some of them being; increased use of basic research in applied settings, provide additional resources to faculty that might not be otherwise attainable, create opportunities for students that are involved in research, and an overall enhancement of scholarly productivity.

Gray, Johnson, & Gidley (1986) surveyed faculty and industry participants from two different programs of industry-university collaboration to ascertain what goals were important to both parties and what benefits were expected from this relationship. The two programs that data were collected from were the University-Industry Cooperative Research Projects Program (Projects program) and the Industry-University Cooperative Research Centers Program (Centers Program). Both programs were funded by the National Science

Foundation. Industry and university principal investigators were surveyed from the projects program, a total of 226 questionnaires were returned (a 96% response rate). From the centers program, center evaluators collected data from faculty members and the primary representative of each member company. A total of 65 faculty and 133 industry questionnaires were received (approximately a 90% response rate). The questionnaire obtained information on the participant characteristics, history of interaction between the participants, the perceptions of goal importance and the likelihood of expected benefits, and outcomes pertaining to stimulation of new research projects and satisfaction.

For perceptions of goal importance, there were differences between the two programs. Project program participants rated "patentable products" as most important followed by "commercialized products". For the centers program, "general expansion of knowledge" was most important followed by "enhanced student technical training" for faculty members and "enhanced research in industry" for the industry members. For the likelihood of realizing certain benefits, "better personnel recruitment" and "improved research projects in your lab" were the most likely to be realized. "Patentable products" and "commercialized products" were the least likely to be realized. All participants indicated relatively high levels of satisfaction (Gray, Johnson, & Gidley, 1986). It is important to remember that both industry and faculty members participated in this study and that the results are representative of both members of the collaboration. Also this survey was a subjective measure of outcomes, for example, it did not actually collect data on the number of patentable products that were created through the industry-university collaboration.

Besides helping to solve industry problems, university faculty may have their own agenda for becoming involved in research with industry. Lee (2000) assessed what faculty members feel they obtain from their collaboration with industry, a subjective measure of outcomes. The focus of the study was on the perceived benefits of faculty members. The author's premise was for faculty members to maintain the collaborative relationship with a firm they must realize significant benefits. The sample of faculty for the study were scientists and engineers from a stratified random sample of 40 research intensive universities that were on the National Science Foundation list of the top 100 research universities. The chair in each of the science and engineering departments at the universities were contacted and asked to identify five faculty members that were engaged in industry-sponsored research. Each of these faculty members were then contacted and invited to participate in the survey. A total of 671 faculty members were invited to participate, of which 427 completed the questionnaire (64% response rate). A list of possible reasons for academics collaborating with industry was identified. Participants were asked to rate the importance of each item on a five-point scale. (Lee, 2000).

Every faculty member in the sample was either currently or had previously collaborated with industry on research. About half (52%) of the faculty in the sample managed their projects through their department, one quarter (26%) through IURCs, and the last quarter (22%) through consulting type arrangements. About 10% managed their project in more than one way. Looking at the nature of the sponsorship, 65% of the projects were sponsored by one firm, the remaining projects by consortium of different sizes. These project had an average life span of approximately 3.6 years with the majority of projects (87.4%) lasting between one and six years (Lee, 2000).

The analysis of the responses showed the faculty are engaging in collaboration with industry primarily for the need to advance their own research agenda. The top four reasons or motivators for faculty collaboration with industry were: secure funds for research assistant and lab equipment (69.4% rated this response as "most important" or "very important"), gain insights into one's own research (68.5%), test application of theory (64.7%), and supplement funds for research (61.1%). The least important reason was to look for business opportunities (20.9%). When benefits experienced were examined, the top four benefits were: acquired funds for research assistant and lab equipment (67.1% rated this benefit as either "substantial" or "considerable"), gained insight's into one's own research (66.3%), supplemented funds for one's own academic research (57.6%), and field-tested one's own theory and research (56.1%). The benefit that was experienced the least was created business opportunities (18.7%) (Lee, 2000).

A bivariate correlational analysis was also done to determine how benefits received were related to the motivators to participate in collaborative research with industry. The motivations to collaborate with industry were: support academic research, enhance teaching mission, and create entrepreneurial opportunity. The benefits experienced were: support for academic research, enhanced teaching function, and opened entrepreneurial opportunity. The results of the analysis showed that there is a strong positive correlation between the independent variable of the motivation to participate in research with industry and the dependent variable of the actual benefits received. The specific correlation values were: support for academic research ($r = .61$), enhanced teaching function ($r =.62$,), and opened entrepreneurial opportunity ($r = .63$). For example, faculty who participate in collaborative research with the expectation to support their own academic research are likely to receive benefits from that research that support their own academic research. Also, the longer the time of the research project, the greater the benefits a faculty member receives in research support, teaching, and entrepreneurial opportunity. Finally, there were small positive correlations between the frequency of interaction between a faculty member and the firm and the benefits received in support for research (r = .138), teaching function (r = .243), and entrepreneurial opportunity (r = .195) (Lee, 2000).

This study does a good job of ascertaining the reasons why academics collaborate with industry. While the researchers addressed a number of different types of research collaboration with industry in their sample, differences between these different types of collaboration were not assessed. However, it is possible that by presenting a list of benefits for the participants to rate a suggestibility bias may have been created. Participants may not have rated the same benefits if they had been given the opportunity to simply list the benefits that they had received through research collaboration with industry.

Strickland, Kannakutty, and Morgan (1996) compared the outputs received from research for faculty with high industry support (30% or more funding from industry and 10% or less from federal sources) and faculty with high federal support (50% or more funding from federal sources and 10% or less from industry). This was more of an objective assessment of outputs than were mentioned in the previous two studies. The outputs from high industry funded research are more likely to be commercial products and processes, licenses, patents, and hardware. These outputs were reported significantly more for the high industry funded faculty than for the high federal funded faculty. The research for the high industry supported faculty is geared towards improving the manufacturing processes, developing applications of products and processes, and looking at quality and control methods. Almost half (45%) of the research performed by high industry supported faculty had led to a major development in either government or industry as compared to 33% by high federal supported faculty (Strickland, et. al., 1996).

A study by Blumenthal, Campbell, Anderson, Causino, and Louis (1997) addresses the issue of data withholding by faculty and the factors that increase the likelihood of this practice. Life science faculty from the top 50 universities received funding from the National Institutes of Health were mailed surveys. Completed surveys were received from 2167 faculty. Analysis was done via regression. Two dependent variables were measured: the extent to which faculty in the study withheld research results for longer than six months and whether the faculty refused to share research results with colleagues in the university in the past three years. Researchers also inquired as to the reasons for these actions. The independent variables in the study were personal characteristics (sex and academic rank), research context (total research funding, participation in an academic-industry research relationship, and participation in genetics as a field of research) and productivity (number of articles published in the last three years and whether the results of research have lead to patent applications, patents licensed, trade secrets, a product under regulatory review, a product or service that is currently being marketed, or a start-up company.

The percentage of the faculty who reported delaying publication for more than 6 months was 19.8%. The reasons for the delay were: allow time for patent applications (46%), to protect the proprietary value of the results in a way other than a patent (33%), to protect their scientific lead (31%), to slow dissemination of undesirable results (28%), to allow time for license agreements (26%), and to resolve disputes over intellectual property (17%). Only 8.9% of the faculty had refused to share results with a colleague in the university in the last three years. Some of the reasons for this action were to protect their scientific lead (46%), because of the limited supply or high cost of the materials requested (27%), and because of a previous informal agreement with a company (18%). Bivariate relationships were then examined. In terms of personal characteristics, males were significantly more likely to delay publication than females (21.1% vs. 14.2%) and higher academic ranks were also associated with significantly more delays (23.8% for professors, 18.5% for associate professors, and 14.0% for assistant professors). For research context, faculty who reported receiving funding from industry (28% of the sample), 27% reported delaying publication compared to 17% of other faculty. They were also significantly more likely to report denying colleagues access to results (11% vs. 8%). In terms of productivity, faculty who reported delays published an average of 14.9 articles in the last three years compared to an average of 11 articles for faculty who did not report delays. For faculty who reported some type of commercialization of their research, 31% reported a delay in publication compared to 11% for faculty who did have commercialization of their research (Blumenthal et. al., 1997).

Finally a multivariate analysis was done to see if any of the independent variables (personal characteristics, research context, or faculty productivity) predicted delays in publication or the denying of university colleagues access to research results. Only participation in an industry-university research relationship was predictive of a delay in publication. For denying access to results, participation in commercialization activities, a research focus in genetics, and a higher rate of publication were predictive. While these results shed some light on the issue of delaying publication, only 27% of the sample was involved with an industry-university research relationship (Blumenthal et. al., 1997).

Some researchers argue that increased involvement in industry research will lead to a decrease in the amount of publications for a faculty member. Landry, Traore, and Godin (1996) focused on the relationship between industry-university collaboration and academic productivity. Their study compared different collaboration relationships: university and university, university and industry, and university and government. The authors present two opposing views of this relationship: 1. That industry-university collaboration does not increase scientific productivity or change the mission of the university and 2. That collaboration will increase scientific productivity but may change the mission of the university. One criticism they make of past research on industry-university collaboration is its general focus on the motivation, benefits, and cost for those involved with a general lack of focus towards the impact of the collaboration on productivity. The main question the researchers sought to answer was; Do industry-university collaboration projects have any effect on the scientific productivity of a faculty member?

To answer this question, a questionnaire was sent to professors at Quebec universities (the names of specific universities and departments were not stated). Of the 1566 returned surveys (representing a low response rate of 17%), 95% of the respondents reported at least one instance of collaborative activity (the specific types of collaborative activities were not given) in the past 5 years. Forty percent of this collaboration was with industry. Other collaboration partners were other university faculty (83%) and areas of the government (60%). Productivity was defined as the number of outputs in each of 18 different categories and the percentage of each of these outputs that were produced with collaboration. Some examples of these outputs are new books, book chapters, journal articles, supervision of graduate students, and new university courses. Data analysis was done via regression with the dependent variable being overall productivity (measured as a standardized index of the number of outputs in 18 categories) (Landry, Traore, & Godin, 1996).

The results showed a mix of positive and negative relationships, the model proposed explained 22% of the variance in productivity. Overall, as percentage of work done in collaboration increased, productivity decreased but as the intensity of the collaboration increased, productivity also increased. This may suggest that merely being a part of collaborative activity does not guarantee outcomes, there needs to be a vested interest by those involved in the collaboration. With regards to the collaborative partner, relationships with industry, government, or other universities all resulted in an increase in productivity. However, when the researcher's main collaborating partner was industry, there was a negative effect on productivity (Landry, Traore, & Godin, 1996).

Blumenthal (1986) examined the possible negative consequences for university faculty that are involved in University-Industry Research Relationships (UIRR), in particular those faculty who are involved in relationships with biotechnology firms. More specifically, the study focused on the effects these relationships might have on different job outcomes for the faculty member. Some of the job outcomes that may be affected are; scholarly productivity, commitment to teaching, focus of research (applied versus basic), and research relationships with other scientists.

Faculty members were randomly selected from research universities that receive the largest amounts of federal research funds in the United States. Participants were either faculty members in the biotechnology fields (the article does not define which departments were considered "biotechnology" or other life sciences) or in the departments of chemistry and engineering (used as a comparison group to compare the percentage of faculty involved with industry). Surveys were administered to these participants through the mail. A total of 1238 faculty members (993 in the life sciences, a 69% response rate and 245 in chemistry and engineering, a 65% response rate) returned the survey. For the biotechnology faculty, 23% receive some sort of funding from industry compared to 17% for other life science faculty and 43% of the chemistry and engineering faculty. Participants (for the life sciences and biotechnology faculty) were divided into two groups, those that were involved with biotechnology firms and those that were not. Two-tailed *z* tests assessed differences in the means of the questionnaire responses between the two groups (Blumenthal, 1986).

Results were presented in the following areas:

Traditional University Activities: Faculty involved with industry in biotechnology showed a significantly greater amount of publications and involvement with professional activities than other faculty. For those faculty who received more than 50% of their research funding from industry, there was no difference in their publication rate, student contact, and hours of involvement from other faculty. There was no difference between the groups in time-spent teaching. The same results held even when controlling for variables such as academic rank and number of years since receiving their degree. These results show that involvement with industry in research does not have a negative effect on publication rate, interaction with students and faculty involvement in professional activities (Blumenthal, 1986).

Commercial Productivity: Faculty that were involved in UIRR's were twice as likely to report they had done research that resulted in patent applications, patents, or "trade secrets". These faculty also earned more in royalties than other faculty. These results are not surprising since it is logical that greater involvement with commercial organizations would lead to a greater number of commercial products. Also the major product of traditional university research is not commercial products rather it is the dissemination of knowledge through journal publications (Blumenthal, 1986).

Perceived Benefits: Faculty that were involved in UIRR's believed more strongly in the potential benefits of them than those who were not involved. These benefits are: less red tape than from federal funding, increase in the number of applications from basic research, provides resources not obtainable elsewhere, enhances career opportunities for students, and enhances scholarly productivity (Blumenthal, 1986).

Secrecy in the University: Forty-four percent of faculty involved with industry felt that UIRR's pose the risk of threatening intellectual exchange between colleagues compared with 68% of non-involved faculty. However, involved faculty were four times as likely to report that their research had resulted in "trade secrets" defined by the authors as "information kept secret to protect its proprietary value (p. 1364)." Clearly these results display a large difference of opinion between those involved with industry and those not involved (Blumenthal, 1986).

Equity holding in Biotechnology Companies: Eight percent of the faculty surveyed stated that they hold equity in a company whose products are based on their research. However, only 0.5% of the faculty hold equity in a company that they are currently receiving research funds from for their research. Holding equity in a company and simultaneously receiving research funds from it could pose a conflict of interest, however this does not appear to be a common practice for the faculty surveyed (Blumenthal, 1986).

In a later study by Blumenthal (1996), similar results were found as those for the earlier (1986) study. Faculty from the life sciences departments at the 50 US universities that received the most research support from the National Institutes of Health were mailed the survey. A total of 2052 faculty members completed the survey. The data was analyzed using multivariate linear and logistic regressions.

Results showed that faculty who received industrial funding for research had a greater number of published articles and participated in more services activities in their institutions or field of research. The rates of publication in the previous three years and the number of service activities the faculty member was involved in were highest for faculty members that received a minimal to moderate amount of industry funding. Faculty who received support from industry were also more likely to state that their research had a commercial outcome. However, these faculty were also more likely to state that restrictions had been placed on the communication of their research results. There was a slight increase in the percentage of faculty who reported that trade secrets had resulted from their research (12% in 1986 as compared to 17.2% in 1996), although it is not clear if this difference is significant. For the influence in choice of research topic, there was no difference, 30% of faculty members in 1986 and 1996 reported that their choice of research topic was affected by whether the results would have commercial applications (Blumenthal, Campbell, Causino, & Louis, 1996).

Summary

Three basic topics emerge from the articles on faculty and industry-university collaboration: the attitudes of faculty towards industry-university collaboration, the characteristics of faculty and universities involved in collaboration with industry, and the outcomes for the university and faculty member involved in this type of relationship. However, a quick summary on what is known will convey to the reader that only a limited amount of light has been shed on these topics.

Faculty Views of Industry-University Collaboration

An important variable to consider is faculty attitudes towards industry-university collaboration. In general, academic faculty are supportive of industry-university collaboration in research. This support has also shown an increase in the past decade (based on retrospective data), particularly from the engineering and applied science fields. There is also an overall increase in acceptance of applied research by faculty in the past decade (again, based on retrospective data) (Lee, 1996). A large percentage of engineering faculty would like to see more industry involvement in academic research (Strickland, et. al., 1996). Support for user oriented research was more likely to come from faculty in the applied sciences and faculty who feel that user-oriented research would not interfere with the basic research mission of the university. Support for the commercialization of university research was predicted by being in an applied science discipline and by the belief that industry-university collaboration is not a threat to academic values (Lee, 1996).

Academic faculty are also open-minded towards changes in the university norms that would facilitate an increase in the amount of collaboration with industry. This means a move from the belief that the university's mission is to produce basic research towards a belief that applied research has a purpose in the university. Faculty who are involved with industry seem to want more control of this relationship in terms of the amount of time they spend working on the collaborative activity, even if this means relinquishing traditional academic duties. These faculty also respond to potential conflict in a way that would foster the collaboration with industry. However, all groups felt that the faculty member's responsibilities towards students should remain the same regardless of industry involvement. Finally, faculty that are involved in collaborative activity want a greater opportunity to obtain financial rewards and more flexibility. Faculty that are not involved in collaborative activity were more negative in their view of financial gain from this type of collaboration (Campbell, 1997; Campbell & Slaughter, 1999).

Characteristics of the Faculty Involved

Rahm (1994) showed that the type of university in which a faculty member works is important. Faculty involved in industry-university collaboration tend to come from universities that are "firm friendly", that is, the university offers classes and workshops for firm employees, internship opportunities with firms are arranged for students, and the university is involved with companies in activities such as research consortiums. The type of research program of the faculty member is also important, faculty who are involved with industry tend to describe their research programs as multidisciplinary.

There are further differences in the research program of faculty who collaborate with industry. In addition to having been part of a multidisciplinary research program, this research is also likely to have the following characteristics: conducted by a group of collaborating investigators who are working with a grant that is relatively short in duration, and they have a more applied and product development focus than a basic research focus. When compared to research that is more federally support, faculty with high industry supported research are more likely to rate their research as more experimental, concentrated on synthesis, oriented towards products and processes, is less long-term focused, and is pulled more by the market rather than be pushed by science and technology (Strickland, et. al., 1996).

<u>Outcomes</u>

Three different types of outcomes are discussed in the studies presented in this review: perceived outcomes, subjective outcomes, and concrete outcomes. One type of outcome that is discussed are perceived benefits to being involved in this type of relationship. Lee (2000) studied motivators for faculty to become involved in industry-university research and their perceived benefits. The four motivators that faculty listed as important reasons for collaborating with industry are to secure funds for research assistant and lab equipment, gain insights into one's own research, test application of theory, and supplement funds for research. The four greatest benefits received were: acquired funds for research assistant and lab equipment, gained insight's into one's own research, supplemented funds for one's own academic research, and field tested one's own theory and research. There was also a strong correlation between the motivation to participate in research with industry and the benefit received.

Issues dealing with publications have primarily been studied in terms of delay of publications and the effect of this type of collaboration on productivity. Being involved in an industry-university research relationship is predictive of delaying publication; the primary reason for this delay is to allow time for patent applications. However, in this study only about a quarter of the respondents were involved in an industry-university research relationship so it is hard to predict whether data withholding is a huge problem (Blumenthal, et., al., 1997). In terms of productivity, there are conflicting results for industry and university collaboration. Landry, Traore, & Godin, (1996) report a negative effect on productivity when the main collaborator with the university was industry. However, Blumenthal (1986), reported that faculty involved in industry-university research relationships showed a greater amount of publications, however these faculty were four times as likely to report that their research had resulted in trade secrets that in order to protect the proprietary value needed to be kept secret. A later study by the same author produced similar results (Blumenthal, et. al., 1996).

Conclusion

The studies reviewed here have addressed a number of variables important to understanding industry-university research collaboration among faculty: characteristics of the university (Rahm, 1994), characteristics of the faculty member's research program (Strickland, et. al., 1996), attitudes of the faculty member towards industry-university collaboration (Campbell & Slaughter, 1999, Campbell, 1997; Lee, 1996), and the various types of outputs that are a result of the collaboration (Blumenthal et. al., 1997, 1996; Blumenthal, 1986; Landry, Traore, & Godin, 1996; Lee, 2000).

While the studies reviewed present some information about faculty and industry-university research collaboration, there are a few limitations. The main limitation is that the data presented in these studies is primarily descriptive. Only three of the studies provide regression analyses: Lee (1996) on the support of user oriented research and support for the commercialization of university research; Blumenthal et. al., (1997) on delay in publication and denying access to results and; Landry, Traore, & Godin (1996) on productivity. Another limitation of the present research is in the area of methodology. Many of the studies employed unrepesentative techniques for obtaining participants, making their results hard to generalize past that sample. Response rate was also a problem for a few of the studies. Few of the studies focused on a particular type of collaboration, instead faculty participating in any type of collaboration with industry were considered for analysis.

While this research describes generally who is supportive of industry-university, the characteristics of those involved in this type of collaboration, and the outcomes from it, there is clearly much more to be studied in this area. Further research may address the reasons for this support and the increase in its acceptance by academic faculty. Are there differences in the type of support based on academic discipline? Are there differences in the level of support based on the type of collaboration? Why are there differences in the characteristics in the research that is done in collaboration with industry versus other type of research?

This study will focus on the issue of outcomes. What is the effect of collaboration on the individual faculty member, what do they gain from it? There is little discussion in the current literature of what the potential gains may be for the faculty member who gets involved in industry-university collaboration. Obviously, as suggested by Lee (2000), there must be some positive outcomes for the faculty member or it would be unlikely that they would participate in these types of research relationships. However, a search of the literature provided limited outcome studies for faculty. While the studies on productivity (Blumenthal, 1986; Landry, Trace, & Godin, 1996) might be viewed as outcome studies, these studies tended to focus more on the negative aspects of the industry-university relationship. From the articles presented here, it is clear that the research needs to be expanded beyond the topic of general attitudes and into the area of outcomes. None of the studies touched upon what predicts different outcomes from this type of relationship.

One way of looking at outcomes is to examine what predicts a faculty member's satisfaction with being involved in an industry-university research relationship. If a faculty member is realizing benefits from their research work with industry it would be logical to assume that they would be more satisfied with the relationship. Unfortunately none of the literature touched upon the reasons for a faculty member's satisfaction with industry-university collaboration. Other outcomes that could be examined are that factors that contribute to increased publications and those that lead to outcomes focus on increased funding and career opportunities. Instead of doing comparisons between faculty who are involved in research with industry and those who are not involved with industry, this study will focus solely on the outcomes of faculty who are involved in research collaboration with industry.

A program that attempts to assess the types of outcomes mentioned above is the National Science Foundation's Industry-University Cooperative Research Centers (IUCRC) Program. This program is unique in that it engages in a yearly evaluation of its center industry and faculty members. The data obtained from this evaluation may be able to shed some light in the area of faculty outcomes. A more detailed description of the program appears below.

The NSF IUCRC Program and Evaluation

As discussed above, one type of research linkage the university can make with industry is an industry-university research center. There are many of these centers, which are funded through a number of different programs. One particular program is the National Science Foundation (NSF) Industry-University Cooperative Research Center (IUCRC). The IUCRC is a research center located in a university setting that brings together academic faculty and various industries to collaborate on cutting-edge research in various fields. While each individual center may vary slightly in terms of organizational structure most centers consist of an administrative core, faculty members, and industry affiliates. The majority of the research conducted in the centers is focused on applied science issues (versus basic science issues) (Gray & Walters, 1998).

A typical research center will be affiliated with the program for a period of five years. During this time, NSF will supply the center with a small amount of funding and industry members will pay a membership fee to belong to the center. At the end of the five years, the center may apply to NSF for a “no cost extension” in which the center would continue to be a part of the NSF IUCRC program but would no longer be receiving funding from NSF. The membership fee paid by industry members is used to fund research in the center. Members have the opportunity to voice which research projects they would like to see funded in the center through the presentation of research proposals at center meetings. The “industrial advisory board”, which consists of an industry representative from each of the member industries vote to determine which projects will be funded (Gray & Walters, 1998)

A required component of each research center is a center evaluator who oversees the evaluation of both the industry members and center researchers. The evaluator collects data on the structure, processes, and outcomes of the center and shares this information with the center director in order to improve center operations. This evaluation occurs every fiscal year that the center is in operation and is a member of the IUCRC program. Results from the industry data collection are included in a detailed evaluator’s report of the center each year. Faculty data is not typically included in this report; rather, it is aggregated with faculty responses from other centers to create a national report that summarizes the data. No further analysis is typically done on the faculty data (Gray &Walters, 1998).

The faculty process/outcome survey collects data relating both the effect the center has had on the research process for the faculty member as well as the outcomes that have been realized in the research. It is divided into five sections. The first section asks questions concerning the scope and time frame of center projects as compared to projects the faculty member has done outside of the center. This section also asks for the number of publications and presentations that the faculty member has made based on center research and the number of theses and dissertations he or she has advised. Finally, this section asks for the amount of time, the faculty member feels it should take a center research project to yield tangible results.

The next section inquires about benefits for the faculty member. Two types of benefits or outcomes are considered: Process outcomes, which reflect an improvement in the conducting of research and product outcomes which reflect funding and career enhancement opportunities that are created as a result of conducting center research. The third section inquires about areas in which the investigator feels his or her research has had an impact on industry. A brief satisfaction section asks how satisfied the investigator was concerning the quality of the research program; relevance to industry needs, and center administration and operations. Finally, the survey asks about the faculty member's rank and tenure. The complete survey is presented in Appendix B.

METHOD

Research Questions

This research addressed the following questions:

1. What type of research do faculty conduct and what benefits and outcomes do they receive from their involvement in an industry-university research center?
2. Do characteristics of the center, the university, the research, benefits received by faculty member, the faculty member's evaluation of industry, the faculty member's autonomy and the timeliness of research, or the technical benefits received by industry predict outcomes related to publications and satisfaction?
3. Do the combined effects of the characteristics of the center, the university, the research, the benefits received by the faculty member, the faculty member's autonomy and the timeliness of research, the faculty member's evaluation of industry, and the technical benefits received by industry lead to increases in the prediction of publication and satisfaction?
4. What technical benefits do faculty members feel the industry members are receiving and what improvements do they feel the centers need in terms of administration and operations?

Research Design

The research design is a cross sectional predictive analysis of a national data set of faculty involved in industry-university research centers in US universities.

Procedures

Data was collected from both Industry University Cooperative Research Centers (IUCRC) and research centers located at a large Research I university in the Southeast. IUCRC faculty data were collected by each of the national evaluators for his or her center(s) and then submitted to the evaluation team at North Carolina State University. All faculty members received a copy of the Process/Outcome Survey. Faculty data collection uses the following procedure. First, the center director or administrative assistant is contacted so that an updated list of the center faculty members and their contact information can be obtained. A faculty process outcome survey is mailed to each of these faculty members, either by regular post or via electronic mail. To ensure confidentiality, each faculty member is given an identification number. This is the only identifying information that appears on the survey. Respondents are typically given a two-week period in which to complete and return the survey to the evaluator. After this two-week period follow-up is done with non-respondents via electronic mail, reminder letters and phone calls. Once the data has been collected it is analyzed at the local center level and then submitted to NCSU where it is entered into the national database and used to create national baseline data.

In order to diversify the sample of centers used in this study, additional data were collected from other industry-university research consortia located at large Research I university in the Southeast. The office of centers was contacted to obtain a list of centers in the university. A total of 56 centers were identified. Of these centers, four were IUCRC centers and were already included in the data collection. Thirteen were membership centers not affiliated with the IUCRC program. These centers were similar in structure to the IUCRC centers: they consisted of a group of industry members and a group of faculty researchers. A minimum requirement of 5 members was established as a criterion for being included in the study. This brought the number of centers to seven. The directors of those centers were then contacted to determine if they might be interested in participating in the study. Of the seven centers contacted, four agreed to participate in the data collection. A list of faculty was obtained from each of the centers. Surveys were sent to the faculty members via email, following the above procedure. Data was received from three of the centers.

Setting and Population

In the 2000-2001 evaluation year, there were a total of 50 centers in the IUCRC program, representing 57 universities from across the United States. A total of 515 faculty were involved in these centers. Data were collected from 29 of the 50 centers in the program (a 58% center response rate); these centers had a total of 379 faculty. Possible reasons for centers not returning data included: center restructuring, the phasing out of the center from the IUCRC program (in each case, no data was collected), or the center evaluator was doing alternative methods of evaluation. From the sample of 29 centers that collected data, a total of 207 faculty surveys were received (a 54.62% response rate of surveyed universities). Table 1 summarizes the survey response rates.

Table 1

Response Rates for the Study

	Centers	Surveyed Faculty	Sample Received	Response Rate (%)
IUCRC Centers				
2000-2001	29	379	207	54.62
1999-2000	9	140	46	32.86
Non IUCRC Centers	4	55	22	40.00
Total Sample	42	574	275	47.91

For the centers that did not collect faculty data in the 2000-2001 evaluation year, an attempt was made to use data from the previous (1999-2000) evaluation year. This added data from an additional 9 centers (increasing the center response rate to 76%) and increased the number of faculty that received the survey to 519. A total of 46 faculty surveys were returned from these centers (a response rate of 32.86% and a decrease in the overall response rate to 48.75%). The total number of IUCRC faculty respondents was 253. From the non-IUCRC centers, data was received from a total of 22 faculty (a 40% response rate). This brought the total sample size to 275 faculty (an overall response rate of 47.91%).

In order to assess whether the 1999-2000 data differed on any variables from the 2000-2001 data, t-tests were run comparing data used from the two sets of data. Faculty from the additional data group were significantly more likely to come from centers that were smaller in size ($F= 51.53$, $p<.05$) and had less funding per principal investigator ($F=6.34$, $p<.05$). They also were significantly more likely to come from universities that received a smaller percentage of research funding from industry ($F=4.498$, $p<.05$). A number of factors may have contributed to these differences. The first is that evaluators are given the discretion to not collect data for a given year if the size of the center has grown so small that anonymity cannot be guaranteed in the data collection process. Thus, these centers might also represent a group of centers that are on a downward cycle so that if data had been collected in the next year, scores might have been lower than expected.

Table 2 summarizes the demographic characteristics of the whole sample. About fifty-three percent of the faculty came from multi-site university centers, the remaining from single-site centers (46.9%). In terms of tenure status, the majority of the sample were tenured (66.5%), the remaining were either on tenure-track (16%) or were non-tenure track faculty (16.4%). Close to half of the faculty in the sample (47.9%) were full professors, about a quarter (23.2%) were associate professors, and the remaining were either assistant professors (15.7%), or described their rank as “other” (13.1%). Finally, the majority of the sample came from public universities (87.7%).

Table 2

Demographic Characteristics of the Sample

Characteristic	N	%
Type of Center		
Single-site	129	46.9
Multi-university site	146	53.1
Tenure		
Tenured	177	66.5
Tenure-track	44	16.5
Non-tenure track	45	16.9
Rank		
Full Professor	128	47.9
Associate professor	62	23.2
Assistant professor	42	15.7
Other	35	13.1
University Type		
Public	236	87.7
Private	33	12.3

<u>Measures</u>

For the variables that were obtained from the Faculty Process/Outcome Questionnaire, the specific question number that pertains to that variable is indicated. A copy of the complete faculty questionnaire is located in Appendix B. Organizational characteristics of the centers were obtained from data provided by center directors to the IUCRC evaluation project at North Carolina State University. Univariate statistics for the continuous variables are presented below and appear in Appendix C.

<u>Characteristics of the University.</u>

As discussed by Rahm (1994), the type of university in which a faculty member is located is important for his or her work. Faculty who collaborate with industry tend to come from institutions which are more supportive of this type of research. Therefore, it would be useful to understand what university characteristics might be related to faculty outcomes. The following university characteristics were used in the analysis:

Type of university. Whether the university is considered a public or private institution. The majority of the faculty in the sample (87.7%) came from public universities.

Research Intensiveness. Research intensiveness was measured using the Carnegie Classification of the university. This measure of research intensiveness is based on the size of the university's baccalaureate and graduate degree programs, the amount of research funding they receive, and their selectivity (for baccalaureate colleges). There are 10 categories in the classification; Research I, Research II, Doctorate granting I, Doctorate granting II, Master's universities and colleges I, Master's Universities and colleges II, Baccalaureate I, Baccalaureate II, Associate of arts, Professional schools (National Science Foundation, 2000). Universities that are more research intensive may be more involved in research with industry and therefore show more outcomes from this research. Because only 18.3% of the sample came from non-research I institutions, these categories were combined to yield a variable with only two categories: research I institutions and non-research I institutions.

Size of the university. The size of the university was measured using the total research budget of the university, measured in thousands of dollars. A university with a larger research budget may be able to supply more funding and resources to faculty for their research, which may help facilitate outcomes. The mean budget in the sample was $197,426 million dollars. The range in the sample was $508, 225 million dollars with the minimum being $394 million and the maximum being $508,619 million. The median value was $213, 838 million.

Percent of the university budget that the university receives from industry. This information was obtained from the National Science Foundation Science and Engineering Indicators (National Science Foundation, 2000). It is possible that universities that receive a larger amount of funding from industry may be more supportive of faculty collaboration with industry, therefore making outcomes more likely. The universities represented in this sample received a mean of 11.5% of their total research dollars from industry. This is higher than the national average of approximately 7.1% (National Science Foundation, 2000). The median value of 9.49% was also higher than the national average. There was a large range in this variable of 42.64% with a minimum of .15% and a maximum of 42.79%.

Characteristics of the Center.

As characteristics of the university might have an effect of the research outcomes for faculty, characteristics of the center may also have an effect on these outcomes. Strickland, et. al. (1996) showed that there are differences in the characteristics of research that is primarily supported by industry versus research that is primarily federally supported. The following characteristics of the center were considered for analysis:

Size of the center. The size of the center was measured by the number of industry members. Larger centers may be able to provide more resources to faculty, increasing the likelihood of outcomes. The centers represented in the sample had a mean of 15.91 members, with a standard deviation of 6.98 members. The median number of members was 14.

Total operating budget of the center. Data for this variable were obtained from the 2000 Report of Center Structural Information (Gray & Rudolph, 2000). Centers with a larger operating budget may be able to provide more resources to faculty members, which may help facilitate outcomes. The centers in the sample had a mean operating budget of $1,487 million dollars with a standard deviation of $1,600 million dollars. The range was $5,705 million dollars with a minimum of $318 million dollars and a maximum of $6,023 million dollars.

Age of center. Number of years that the center had been in existence. This data was obtained from the 2000 Report of Center Structural Information (Gray & Rudolph, 2000). Centers that are older may be more established in their research programs. Faculty in these centers may report better outcomes. The mean age of the centers was 7.51 years with a standard deviation of 4.39 years. The centers ranged in age from 1 year to 18 years with a median age of 6 years.

Discipline of the center. An attempt was made to characterize the disciplinary composition of the research center. It is possible that faculty outcomes may be influenced by the discipline in which they do research. In order to obtain this information, emails were sent to each of the center evaluators for the IUCRC centers and center director were contacted in the non-IUCRC centers. They were asked to identify the primary discipline of the center according to four categories: engineering science, natural science, other science, or a combination of the previous three categories. Because only 5.1% of the centers were natural science, 14.1% of the centers were other science and 5.5% of the centers were a combination (compared with 72.7% of the centers being engineering science) the two major distinctions that was used in the analysis were centers whose primary research area was engineering (78.2% of the sample, including the combination centers who were both engineering and another discipline) and centers whose primary research area was another area of science (19.3% of the sample).

Center funding per faculty member. This variable was computed by dividing the number of faculty members for the center by the total funding for the center (measured in thousands of dollars). This information was obtained from the 2000 Report of Center Structural Information (Gray & Rudolph, 2000). Faculty that received greater amounts of funding may realize more outcomes. These faculty may in turn have a higher level of satisfaction with the center research program. The mean amount of funding for the faculty in the sample was $90.25 thousand dollars with a standard deviation of $69.98 thousand dollars. The range of funding was $343.79 thousand dollars with a minimum of $17.04 thousand dollars and a maximum of $360.83 thousand dollars.

<u>Faculty Characteristics.</u>

In addition to university and center characteristics, individual faculty characteristics may have an affect on outcomes. The following faculty characteristics were measured:

Academic Rank. The academic rank of the faculty member were measured using four categories: assistant professor, associate professor, full professor, and other rank (in most cases a non-tenure track position) (q. 9). This measure represents a number of underlying dimensions. As faculty are promoted in rank, there is an increase in the amount of their job security, job status, and their stability of appointment. In order to represent these dimensions, these items were scaled according to the following values: a score of one was given to faculty in the other category, as these were usually non-tenured positions, two for assistant professor, three for associate professor, and four for full professor. Faculty with higher rank may have more established research programs and may realize a greater amount of outcomes than lower ranked faculty.

Tenure. Tenure was measured by two yes or no questions, one which asks whether the faculty member is tenured (q. 10a) and if they are not tenured, whether or not they are in a tenure track position (q. 10b). As with rank, underlying dimensions of security, status, and job stability are also represented in tenure. Therefore, this item was scaled according to the following dimensions: a score of one was given to a respondent who was in a non-tenure track position, a score of two was given to a faculty member who did not have tenure but was in a tenure track position, and a score of three was given to a faculty member who had tenure.

<u>Self-Report Measures</u>

<u>Tangible Benefits</u>

Faculty Tangible Benefits. This variable is the amount of time, measured in months, the faculty member feels it should take a new center research project to yield tangible results (q. 3). The sample showed a mean of 18.19 months with a standard deviation of 9.06 months. The range of estimates was 57 months with a minimum estimate of 3 months and a maximum estimate of 60 months.

Difference in Subjective Estimates of Time till Tangible Benefit: I-U Difference Scores. This variable is the difference between industry and faculty for a given center on the following question: "How long, on average, do you feel that it should take for a new Center research project to yield tangible results (q. 3)?" The variable is measured in months. This question appears on both the faculty and industry questionnaires. A positive difference means that the faculty member responded with a great number of months than the average of the industry responses for the center. A negative difference means that the industry average for that center was larger than the faculty response. Centers in which the difference is small may have a greater amount of alignment between industry and faculty attitudes towards research. This may contribute to a higher level of satisfaction with the research program for faculty. Non-IUCRC faculty were not included in this analysis as there was no industry data for those centers. The mean difference in opinion of the time it should take center research projects to yield tangible benefits was 2.59 months, with a standard deviation of 2.33 months. This means that on average faculty feel that it should take an average of 2.59 months longer for center research projects to yield tangible results. The range in difference was 54.50 months, with the minimum being an 18 month shorter time frame than industry and the maximum being a 36.50 month longer time frame than industry.

<u>Faculty Report of Research</u>.

These variables are a self-report comparison of the research performed by the respondent in the center with research conducted outside of the center on three dimensions: basic/applied (q 1a), broad/narrow scope (q 1b), longer/shorter time frame (q1c). All three characteristics are presented on a five point Likert scale, with a score of one meaning more basic (q1a), broad (q1b), or longer time frame, (q.1c) and a score of five meaning more applied (q1a), narrow (q1b), or shorter time frame (q1c).

Technical Benefits

Two questions in the questionnaire asked about the benefits the faculty member believes industry has received in the areas of R&D efforts (q. 7a) and the commercialization of products, processes, and/or services (q. 7b). Reponses were given on a Likert scale with a score of one meaning no impact, a score of three meaning a moderate impact, and a score of five meaning a very high impact. The answers to these questions were summed and averaged to form a scale. A reliability analysis showed that the scale showed good reliability (Alpha= .83).

Benefits

In order to reduce the amount of data to be analyzed and to ascertain how some variables were related to each other, a principal components factor analysis was performed on the Investigator Outcomes section of the questionnaire (questions 4a-j). These questions inquired about the impact center involvement had on the outcomes for the faculty member. Responses were given on a 5 point Likert scale with a score of one meaning a very negative impact, a score of three meaning no impact, and a score of five meaning a very positive impact. A factor loading of .40 was used as the inclusion criterion for a factor. Results from the factor analysis showed three categories of variables: faculty academic freedom, faculty benefits, and faculty symmetry with industry (Table 3). Three variables loaded on two factors, for two of these variables (ability to publish research in a timely fashion and chances for promotion, tenure, and/or salary increases) they were included in the factor in which the loading was the strongest. For the third variable, the ability to support graduate students, loaded the strongest on the first factor, faculty academic freedom. However, conceptually, this variable fit better in the second factor, faculty benefits. Therefore it was included in the factor. The total variance explained by the factors was 58.8%. The results of the factor analysis are presented in Table 3.

Faculty Academic Freedom. This factor reflects the impact of center involvement on the *amount of autonomy in conducting research* and the *ability to publish research in a timely fashion*. The variance explained by this factor was 9.6%. The answers were summed and averaged to form a scale (coefficient alpha = .82).

Faculty Benefits. Faculty benefits included six benefits that the faculty member may receive because of their involvement in the center. These benefits include: *the ability to support graduate students, opportunities for consulting, opportunities for research contracts, access to equipment, chances for promotion and tenure, and amount of interaction with other faculty.* The variance explained by this factor was 38.5%. The answers to these questions were summed and averaged to form a scale (coefficient alpha = .71).

Faculty Symmetry with Industry. The second factor to emerge from the results of the factor analysis was faculty symmetry with industry. This factor reflects the impact the center has had on the faculty member's *trust and confidence in industry* and their *evaluation of the quality of industrial research*. The variance explained for this factor was 10.7%. The answers to these questions were summed and averaged to yield a score which measures the faculty member's evaluation of industry (coefficient alpha = .71).

Table 3

Factor Analysis Results for the Faculty Benefits Variables*

Item	Factor Loading 1	2	3	Communality
Amount of autonomy in conducting research	.843	.08	.223	.767
Ability to publish research in a timely fashion	.761	.00	.441	.774
Opportunities for consulting	.02	.702	.132	.510
Opportunities for research contracts	.05	.729	.312	.631
Access to equipment	.345	.400	.288	.362
Chances for promotion, tenure, and/or salary increases	.471	.515	.03	.488
Amount of interaction with other faculty	.329	.514	.120	.387
Ability to support graduate student thesis/dissertation research	.577	.410	.02	.502
Trust & Confidence in industry	.188	.248	.782	.708
My evaluation of the quality of industrial research	.165	.174	.835	.754
Eigenvalue	3.85	1.07	.96	Total Variance
Variance Explained	38.5	10.7	9.6	58.8

*Note: Minimum loading .40

Outcomes.

Number of Publications

Total number of publications and presentations. The first publications measure is the total number of publications and presentation that the faculty member had in the past year based on center research. This value was obtained by combining the total number of publications (q.2a) and the total number of presentations (q.2b).

Number of publications and presentations with member scientists. This variable was obtained by combining the number of publications with member scientists (q.2a) with the total number of presentations with member scientists (q. 2b).

Number of publications and presentations with students. This variable was obtained by combining the number of publications with students (q. 2a) with the number of presentations with students (q. 2b).

Number of theses and dissertations. This variable was obtained by combining the number of theses and dissertations completed or in progress that he or she has advised in the last year (q. 2c).

Satisfaction

Satisfaction is measured with three variables: *satisfaction with the quality of the research program, satisfaction with relevance to industry needs, and satisfaction with center administration and operations* (q. 7a-c). Answers are given via a five point Likert scale with a one meaning "not satisfied", a three meaning "somewhat satisfied" and a five meaning "very satisfied". A factor analysis of the data showed that all three variables constituted in one factor. The variance explained by this factor was 72.2%. Therefore the answers were summed and average to form a scale (coefficient alpha = .80).

Open-Ended Questions.

There are two open-ended questions on the faculty survey. The first question asks: "If you believe members benefited technically from your research, please describe what was transferred and/or how members benefited." The second question asks: "How can your Center improve its research and/or administrative operations?"

Data Analysis

Data analysis included a mix of univariate, bivariate and multivariate analysis techniques. The first research question, the benefits and outcomes that faculty members receive from their involvement in an industry-university cooperative research center, was answered primarily through a univariate analysis of the number of publications, faculty benefits variables, and satisfaction variables. The second research question, whether characteristics of the center, the university, the research, the benefits received by the faculty member, the faculty member's evaluation of industry, the faculty members' autonomy and timeliness of research, or the technical benefits received by industry predict outcomes related to publication and satisfaction, was answered through bivariate regression analyses. The third research question, whether the combined effects of the characteristics of the center, the university, the research, PI benefits, faculty symmetry with industry, technical benefits, and faculty academic freedom were predicative of publication and satisfaction was answered using multivariate regression analyses. Due to the exploratory nature of the research, a significance value of .10 was used for all analyses. This level was chosen in order to account for any multi-collinearity issues. Prior to conducting the regression analysis, a correlation matrix was run for all continuous variables. This matrix appears in Appendix C.

To make sure that models did not differ between groups, the regression analysis was run a second time using only the data from centers that were affiliated with the IUCRC program. The results showed no difference in the multivariate models. Another regression analysis was run using only data from the 1999-2000 evaluation year. The multivariate models for publications and presentations with students and publications and presentations with member scientists were the same as the multivariate models for the whole sample. The remaining multivariate models were the same except for the following: for total publications and presentations, the multi-university measure was not significant. For theses and dissertations, only the faculty symmetry with industry and faculty benefits variables were significant. For faculty satisfaction, university research budget was not significant, and the multi-university measure was significant.

The open-ended questions were analyzed by first transcribing all of the answers to the questions into one document. All identifying information for a person, center, or specific project was then removed from the comments. Comments expressing common ideas were then grouped together into common themes. To test whether the categories were reliable, a second researcher grouped the comments made for the second open-ended question (improvements for center administrative operations). These were compared to the categories of the first researcher. The inter-rater agreement was 82.13%.

RESULTS

Research Questions

The analysis of the data sought to answer the first three research questions of the study. The questions are:

1. What type of research do faculty conduct and what benefits and outcomes do they receive from their involvement in an industry-university cooperative research center?
2. Do characteristics of the center, the university, the research, benefits received by faculty member, the faculty member's evaluation of industry, the faculty member's autonomy and the timeliness of research, or the technical benefits received by industry predict outcomes related to publications and satisfaction?
3. Do the combined effects of the characteristics of the center, the university, the research, the benefits received by the faculty member, the faculty member's autonomy and the timeliness of research, the faculty member's evaluation of industry, and the technical benefits received by industry lead to increases in the prediction of publication and satisfaction?

Univariate Analysis

The univariate statistics for the sample and frequency histograms appear in Appendix C.

Faculty Report of Research

Faculty in this sample rated the center research as being slightly more applied than basic (mean= 3.36, SD= .75). More than a third of the faculty (39.7%) rated the research as more applied or much more applied than research they had done outside of the center. They also rated the research as slightly narrower in scope (mean= 3.14, SD= .81), and shorter in time frame (mean= 3.29, SD= .83) than non-center research that they have done. Again, over a third of the faculty (34.5%) rated the research as narrower or much more narrower in scope as well as shorter or much shorter in time frame (40.4%) than their non-center research. However, there was a small percentage faculty that rated their center research as being more basic (9.8%), broader in scope (21.6%), and longer in time frame (15.8%) than their non-center research, indicating the diversity of the research among the centers.

Industry Technical Benefits

Faculty rated the research as having a moderate impact on industry's research and development efforts (mean= 3.11, SD= 1.02), with three-fourths of the sample (74.9%) reporting at least a moderate impact. For the commercialization of products, processes, or services, there was a less than moderate impact (mean= 2.42, SD= 1.15), with close to half of the sample (48.4%) reporting at least a moderate impact. The medians for each variable showed a moderate impact for R&D efforts (median= 3.00) and a slight impact for commercialization (median= 2.00). In subsequent analyses, the two technical benefits variables were combined to form a scale. The overall scale value showed a mean of 2.76, meaning a slightly below moderate impact (SD= 1.01).

Benefits

Faculty Benefits

Participation in the center had a moderately positive impact on the faculty member's ability to support graduate students (mean= 4.12, SD= .69, median= 4.00) with 80% of the faculty reporting a moderately positive impact or very positive impact. There was a slightly positive impact on opportunities for research contracts (mean= 3.49, SD= .69, median=

4.00). and opportunities for consulting (mean= 3.49, SD= .68) with three-fourths of respondents reporting a moderately or very positive impact for research contracts and close to half (44.5%) of the respondents for consulting. There was also a positive impact for chances for promotion (mean= 3.59, SD= .72) and access to equipment (mean= 3.78, median= 4.00) with close to half (47.5%) of respondents reporting a moderately positive impact on promotion and close to two-thirds of respondents (59%) reporting at least a moderately positive impact for equipment. The scale for faculty benefits showed a mean of 3.83 and a standard deviation of .46 indicating an overall positive impact for center involvement on faculty benefits.

Faculty Symmetry with Industry

There was a slightly positive impact for both the faculty member's trust and confidence in industry (mean= 3.58, SD= .77, median= 4.00) and their evaluation of the quality of industrial research (mean= 3.68, SD= .78, median= 4.00). Over two-thirds (69.3%) of respondents rated the impact as at least moderately positive for trust and confidence, and two-thirds (59.1%) of respondents rated the compact as at least moderately positive for the quality of industry research. The scale value showed an overall mean of 3.76 with a standard deviation of .68 indicating a positive impact on the faculty member's evaluation of industry.

Faculty Academic Freedom

There was a slight positive impact on the faculty member's amount of autonomy in conducting research (mean= 3.44, SD= .77, median= 4.00) and the ability to publish research in a timely fashion (mean= 3.44, SD= .78, median= 4.00). About 40% of respondents reported at least a high impact on each of these measures (42.9% for autonomy and 40.6% for publishing). Only about 10% reported a negative impact on academic freedom (9.9% for autonomy and 9.2% for research publishing). The scale value showed a mean of 3.77 and standard deviation of .68, indicating that faculty reported a slightly positive impact on academic freedom.

Outcomes

Faculty Satisfaction

Faculty were quite satisfied with the quality of the research program (mean= 3.93, SD= .86, median= 4.00), satisfaction with the relevance to industry's needs (mean= 4.10, SD= .84, median= 4.00), and satisfaction with center administration and operations (mean= 3.98, SD= .99, median= 4.00). About three-fourths of respondents answered that they were at least "quite satisfied" with each of these center features (73.3% for the research program, 77.2% for industry's needs, and 76.2% for center administration and operations. The scale value showed a mean of 4.00 and a standard deviation of .76, indicating that faculty were quite satisfied with the centers.

Theses and Dissertations

The mean number of theses and dissertations for the last year was 2.03 (SD= 2.32, median= 1.00). The distribution of this variable (see Appendix C) showed a large skew to the right (skewness= 2.58).

Publications and Presentations

Three variables measured publications and presentations: the total number of publications and presentations, the number of publications and presentations with students, and the number of publications and presentations with member scientists. The mean total number of publications and presentations was 5.97 (SD= 7.03, median= 4.00), with students was 4.35 (SD= 4.41, median= 0), and with member scientists was 2.27 (SD=4.41, median=

0). All of these variables showed a very large range, there was also a large right skew for each variable (skewness= 2.79, 3.31, and 3.60, respectively, see Appendix C). For total publications and presentations and the number with students, the natural log of the variables were used in further analysis. For the number of publications and presentations with member scientist, over half of the sample (56.2%) reported no publications, therefore, this variable was recoded into two categories: those faculty who had no publications or presentations with member scientists and those faculty who had at least one publication or presentation with member scientists.

Faculty Satisfaction

Bivariate Regression

The results of the bivariate linear regression analyses for faculty satisfaction are shown in Appendix C. Significant variables ($p<.10$) from these analyses were included in further regressions. A total of twenty independent variables were tested, of these thirteen were significant; center size, center age, engineering/non-engineering discipline, center funding per faculty member, public/private university, research I/non-research I university, university research budget, faculty symmetry with industry, faculty benefits, faculty academic freedom, broad/narrow scope of research, longer/shorter time frame of research, and industry technical benefits.

Multivariate Regression

The first round of multivariate analyses for faculty satisfaction examined the predictor variables by the variable domains: center characteristics, university characteristics, benefits, research characteristics, and industry technical benefits. The results for each model are presented in Table 4.

Table 4

Summary of Multiple Regressions of Faculty Satisfaction on the Predictor Variables by Variable Domain

Variable	B	*B*	P
Center Characteristics (n= 249, df=4)			
Center Size	.00	.05	.48
Center age	.02	.11	.11
Center discipline	.42	.22	.00
Center funding per faculty member	.00	.14	.06
R^2	.075		
University Characteristics (n= 246, df= 3)			
Public/Private	-.40	-.17	.01
Research I	.08	.04	.58
University Research Budget	.00	.22	.01
R^2	.09		
Benefits (n= 242, df= 3)			
Faculty symmetry with industry	.39	.35	.00
Faculty Benefits	.37	.22	.00
Faculty Academic Freedom	-.00	-.01	.94
R^2	.24		
Faculty Report of Research (n= 247, df= 2)			
Broad/Narrow	-.16	-.18	.01
Longer/Shorter Time Frame	-.04	-.05	.51
R^2	.040		
Industry Technical Benefits (n= 245, df= 1)			
Industry Technical Benefits	.20	.25	.00
R^2	.06		

For center characteristics, three variables were present in the model: center size (number of industry members), center age (measured in years), center discipline (whether the center had an engineering discipline or other science discipline), and the amount of center funding per faculty member (measured in thousands of dollars). The model explained 7.5% of the variance in faculty satisfaction. Center funding per faculty member and center discipline were both significant ($p<.10$) and had a positive effect meaning that faculty from centers that were larger in size and had a non-engineering focus were more satisfied with their work in the center. Looking at the standardized coefficients, center discipline had the larger effect on satisfaction.

For university characteristics, three variables were in the model; whether the university the faculty member was from was public or private, whether or not the university was a Research I university, and the university research budget. The public/private measure and the university research budget significantly contributed to the model, explaining 9% of the variance. There was a negative effect for public/private, meaning that faculty from public universities were in general more satisfied than faculty from private universities. The university research budget had a positive effect on satisfaction meaning that faculty from universities with larger research budgets were more satisfied than those from institutions with smaller research budgets. The standardized coefficients show that the university research budget had a larger effect on satisfaction than the public/private university measure.

The benefits model included three variables: faculty symmetry with industry, faculty benefits, and faculty academic freedom. Faculty symmetry with industry and faculty benefits contributed significantly to the model explaining 24% of the variance in the satisfaction measure. Both variables had a positive effect on the dependent variable, meaning that faculty who feel that participation in the center has a more positive impact on the receipt of benefits and their evaluation of industry were more likely to be satisfied with the center. The effect size of both independent variables were similar, with faculty symmetry with industry being slightly larger than faculty benefits.

The research characteristics model included two variables; whether center research was more broad or narrow than research outside of the center and whether center research has a longer or shorter time frame than non-center research. Only the broad/narrow measure significantly contributed to the model, explaining 4% of the variance. There was a negative effect meaning that faculty who rated their center research as more broad than research outside of the center were more likely to be satisfied with the center.

The final predictor model was industry technical benefits. This model included only one variable, industry technical benefits; which significantly predicted 6% of the variance in satisfaction. This was a positive effect meaning that faculty who felt that their research had a high impact on the technical benefits for center members were more likely to be more satisfied with the center.

Significant variables from each of the predictor variable models were included in the overall multivariate model. In all, eight independent variables were in the model; center size, center discipline, public/private university, university research budget, faculty symmetry with industry, faculty benefits, broad/narrow scope, and technical benefits. The results for this model are presented in Table 5. Four of the eight variables significantly contributed to the model; center discipline, university research budget, faculty symmetry with industry, and faculty benefits. The model explained 35% of the variance in the satisfaction measure. Each variable had a positive effect on satisfaction, faculty symmetry with industry having the strongest effect, followed by faculty benefits, then center discipline and finally university research budget. The results of this model imply that faculty who come from a non-engineering or mixed discipline center, universities with a larger research budget, and faculty that believe that involvement in the center has had a positive impact on their evaluation of industry and that report more benefits are more likely to be satisfied with the center.

Additional Faculty Satisfaction Analysis

An additional multivariate linear regression analysis was conducted to determine if any of the individual benefits items significantly contributed to faculty satisfaction. The regression model contained the significant variables from the domain level regressions (center discipline, center funding per faculty member, public/private university, university research budget, broad/narrow scope of research, and industry technical benefits). Benefit items were entered into the model in a stepwise format. The final model contained the significant variables from the domain groups plus the following benefits items: trust and confidence in industry, amount if interaction with other faculty and access to equipment. All of these benefits variables significantly contributed to the model, in addition to center discipline, university research budget and industry technical benefits. All effects were positive, trust and confidence in industrial had the largest effect, followed by the amount of interaction with other faculty. A total of 37% of the variance was explained in faculty satisfaction by the final model. The results for this analysis are presented in Table 6.

Table 5

Summary of Overall Multiple Regression of Faculty Satisfaction on the Predictor Variables

Variable	B	*B*	P
Center Characteristics			
Center Discipline	.30	.16	.02
Center funding per faculty member	.00	.09	.16
University Characteristics			
Public/Private University	-.12	-.05	.45
University Research Budget	.00	.12	.06
Benefits			
Faculty Symmetry with Industry	.37	.34	.00
Faculty Benefits	.38	.23	.00
Faculty Report of Research			
Research is broad/narrow in scope	-.05	-.03	.60
Industry Technical Benefits			
Technical Benefits	.04	.05	.40
R^2	.35		

Note: n= 210, df= 8

Table 6

Summary of Additional Multiple Regression of Faculty Satisfaction on the Predictor Variables and Individual Benefits Variables

Variable	B	*B*	p
Step 1 (n= 209, df=6)			
Center Characteristics			
Center Discipline	.28	.15	.02
Center funding per faculty member	.00	.09	.16
University Characteristics			
Public/Private University	-.15	-.06	.32
University Research Budget	.00	.13	.05
Faculty Report of Research			
Research is broad/narrow in scope	-.01	-.02	.82
Industry Technical Benefits			
Industry Technical Benefits	.08	.10	.10
R^2	.16		
Step 2 (n=209, df=7)			
Benefits Variables			
Amount of interaction with other faculty	.25	.22	.00
R^2 (ΔR^2)	.29(.13)		
Step 3 (n=209, df=8)			
Access to equipment	.15	.15	.02
R^2 (ΔR^2)	.36(.07)		
Step 4 (n=209, df=9)			
Trust and Confidence in industry	.31	.31	.00
R^2 (ΔR^2)	.37(.01)		

Another exploratory analysis was done to see if tenure interacted with either the faculty symmetry with industry variable or the faculty benefits variables for faculty satisfaction. Interaction terms were created and then presented in a model with the significant predictor variables from the variable domain regressions (center discipline, center funding per faculty member, public/private university, university research budget, broad/narrow scope of research, and industry technical benefits). The interaction terms did not significantly contribute to the model.

Number of Theses and Dissertations

Bivariate Regression

Appendix C shows the results of the bivariate linear regression analyses for the number of theses and dissertations. Significant variables ($p<.10$) from these analyses were included in further regressions. A total of twenty independent variables were tested, of these nine were significant; center discipline (engineering/non-engineering center), center funding per principal investigator, multi-university center, rank, tenure, faculty symmetry with industry, faculty benefits, faculty academic freedom, and industry technical benefits.

Mulivariate Regression

As with satisfaction, the first step in the linear multivariate regression analysis for theses and dissertations was an examination of the predictor variables grouped into variable domains. Four variable domains were included, based on the results of the bivariate analysis; center characteristics, faculty rank and tenure, Benefits, and industry technical benefits. The results for each model are presented in Table 7.

Table 7

Summary of Multiple Regressions of the Number of Theses and Dissertations on the Predictor Variables by Variable Domain

Variable	B	*B*	p
Center Characteristics (n= 264, df= 3)			
Center discipline	-.72	-.12	.06
Center funding per faculty member	.00	.10	.14
Multi-university center	-.83	-.18	.00
R^2	.07		
Faculty Rank and Tenure (n= 261, df= 2)			
Rank	.23	.11	.32
Tenure	.74	.15	.16
R^2	.06		
Benefits (n= 255, df= 3)			
Faculty Symmetry with Industry	.42	.12	.09
Faculty Benefits	1.08	.22	.00
Faculty Academic Freedom	.04	.02	.82
R^2	.10		
Industry Technical Benefits (n= 255, df= 1)			
Industry Technical Benefits	.52	.24	.00
R^2	.06		

Three variables were present in the center characteristics model; center discipline, center funding per faculty member, and whether the center was a multi-university center. Center discipline and multi-university center significantly contributed to the model, explaining 7% of the variance in theses and dissertations. Both variables had a negative effect on the dependent variable, meaning that centers that were engineering focused and were single-university centers were more likely to have more theses and dissertations than multi-site, non engineering focused centers. The largest effect was for the multi-university center measure.

The faculty rank and tenure model included both a measure of the faculty member's rank and a measure of their tenure status. Neither variable significantly contributed to the model.

The benefits model included three variables; faculty symmetry with industry, faculty benefits, and faculty academic freedom. Two of the independent variables significantly contributed to the model, faculty symmetry with industry and faculty benefits, explaining 10% of the variance in the number of theses and dissertations. Both variables had a positive effect on the dependent variable meaning that faculty who felt that their involvement in the center had a more positive impact on their evaluation of industry and their receipt of benefits were more likely to have more theses and dissertations underway or completed and their direction. Faculty benefits had the larger effect on the dependent variable.

The final variable domain model was technical benefits, which included one variable, technical benefits. This variable significantly contributed to the model, explaining 6% of the variance in the dependent variable. The effect on the dependent variable was positive meaning that faculty who felt their center research had a more positive effect on the center members' technical benefits were more likely to have more theses and dissertations under their direction.

Significant predictor variables ($p<.10$) from each of the variable domain models were included in the final overall multivariate model. Five variables were included in the model; center discipline, whether the center was a multi-university center, faculty symmetry industry, faculty benefits, and technical benefits. The results for this model are presented in Table 8. All of the independent variables significantly contributed to the model, explaining 17% of the variance in the dependent variable. Center discipline and the multi-university center measure had a negative effect on the dependent variable, meaning that faculty from engineering focused centers and single university centers in general had more theses and dissertations under their direction, completed or ongoing, than faculty from non-engineering focused or multi-university centers. The remaining three variables, faculty symmetry with industry, faculty benefits, and industry technical benefits, had a positive effect on the dependent variable. This implies that faculty who felt that their involvement in the center had a more positive effect on their evaluation of industry, the receipt of benefits, or a positive impact of technical benefits for industry tended to have a greater number of theses and dissertations under their direction. The independent variable with the largest effect on the dependent variable was the multi-university center measure, followed by faculty benefits.

Table 8

Summary of Overall Multiple Regression of the Number of Theses and Dissertations on the Predictor Variables

Variable	B	*B*	p
Center Characteristics			
Center Discipline	-.71	-.13	.05
Multi-university center	-.84	-.19	.00
Benefits			
Faculty Symmetry with Industry	.46	.14	.05
Faculty Benefit	.81	.16	.03
Industry Technical Benefits			
Industry Technical Benefits	.31	.14	.04
R^2	.17		

Note: n= 223, df= 5

Total Number of Publications and Presentations

Bivariate Analysis

Appendix C shows the results of the bivariate linear regression analyses for the total number of publications and presentations. Significant variables ($p<.10$) from these analyses were included in further regressions. A total of twenty independent variables were tested, of these eight were significant; center funding per faculty member, multi-university center, rank, tenure, faculty symmetry with industry industry, faculty benefits, faculty academic freedom, and industry technical benefits.

Multivariate Analysis

The multivariate linear regressions of the total number of publications and presentations on the predictor variables by variable domain included four variable domains; center characteristics, faculty rank and tenure, faculty outcomes, and industry technical benefits. The results for the each of the models are presented in Table 9. Due to the right skew of the variable (skewness= 2.79), the natural log of the dependent variable was used in this analysis. This produced a more normal distribution.

Table 9

Summary of Multiple Regressions of the Total Number of Publications and Presentations (natural log) on the Predictor Variables by Variable Domain

Variable	B	*B*	p
Center Characteristics (n= 259, df= 2)			
Center funding per faculty member	.00	.16	.01
Multi-university center	-.23	-.13	.04
R^2	.05		
Faculty Rank and Tenure (n= 249, df= 2)			
Rank	.09	.11	.32
Tenure	.06	.04	.76
R^2	.02		
Benefits (n= 244, df= 3)			
Faculty Symmetry with Industry	.21	.16	.02
Faculty Benefits	.59	.31	.00
Faculty Academic Freedom	.02	.02	.82
R^2	.18		
Industry Technical Benefits (n= 243, df=1)			
Industry Technical Benefits	.52	.24	.00
R^2	.11		

For the center characteristics model, two variables were included in the analysis; center funding per faculty member and whether the center was a multi-university center. Both variables contributed significantly to the model, explaining 5% of the variance in the dependent variable. Center funding per faculty member had a positive effect on the dependent variable meaning that faculty who received more funding in their center were more likely to report more publications and presentations. The multi-university measure had a negative effect on the dependent variable meaning that faculty from single-site centers were more likely to have more publications and presentations. Center funding per faculty member had the larger effect on the dependent variable.

The next variable domain model, faculty rank and tenure included the measure of faculty rank and the measure of tenure status. Neither variable contributed significantly to the model.

The benefits model contained three independent variables, faculty symmetry with industry, faculty benefits, and faculty academic freedom. Faculty symmetry with industry and faculty benefits significantly contributed to the model, explaining 18% of the variance in the dependent variable. Both had a positive effect on publications and presentations, meaning that faculty who felt that their involvement in the center had a positive impact on their evaluation of industry or their receipt of benefits in general had more publications and presentations. Faculty benefits had the larger effect on the dependent variable, about twice as large as the effect of faculty symmetry with industry.

The final variable domain model was industry technical benefits, which included one independent variable, the industry technical benefits measure. This variable significantly contributed to the model, explaining 11% of the variance. The was positive meaning that faculty who report that their center research had a positive impact on the receipt of technical benefits for industry members also reported more publications and presentations.

The results for the overall multivariate regression model of the total number of publications and presentations are presented in Table 10. Five independent variables are included in the analysis; center funding per faculty member, whether the center is a multi-university center, faculty symmetry with industry, faculty benefits, and industry technical benefits. Three of the independent variables significantly contributed to the model; the multi-university measure, faculty benefits, and industry technical benefits. The model explained 25% of the variance in the total number of publications and presentations. The multi-university measure had a negative effect on the dependent variable meaning that faculty from single-site centers reported more publications and presentations than faculty from multi-site centers. The remaining independent variables had a positive effect on the dependent variable. This means that faculty who feel that their involvement in the center had a positive impact on the receipt of benefits, or who believe that their research had a positive impact on the technical benefits for industry members reported more publications and presentations. The variables with the greatest effects were faculty benefits and industry technical benefits.

Table 10

Summary of Overall Multiple Regression of the Total Number of Publications and Presentations (natural log) on the Predictor Variables

Variable	B	*B*	P
Center Characteristics			
Center Funding per Faculty Member	.00	.07	.27
Multi-University Center	-.27	-.15	.01
Benefits			
Faculty Symmetry with Industry	.11	.09	.20
Faculty Benefits	.45	.23	.00
Industry Technical Benefits			
Industry Technical Benefits	.23	.26	.00
R^2	.25		

Note: n= 217, df= 5

Publications and Presentations with Students

Bivariate Analysis

Appendix C shows the results of the bivariate linear regression analyses for the number of publications and presentations with student. Significant variables ($p<.10$) from these analyses were included in further regressions. A total of twenty independent variables were tested, of these eight were significant; center discipline (engineering/non-engineering center), center funding per faculty member, rank, tenure, faculty symmetry with industry, faculty benefits, faculty academic freedom, and industry technical benefits.

Multivariate Analysis

The multivariate regressions of the number of publications and presentations with students on the predictor variables by variable domain included four variable domains; center characteristics, faculty rank and tenure, Benefits, and industry technical benefits. The results for each of the models is presented in Table 11. Due to the large right skew, (skewness= 3.31), the natural log of the dependent variable was used in this analysis. This produced a more normal distribution.

The first variable domain was center characteristics, which included two independent variables, center discipline and center funding per faculty member. Only center discipline significantly contributed to the model, explaining 3% of the variance in the dependent variable. The direction of the effect was negative meaning that faculty from centers with an engineering focus reported a greater number of publications and presentations with students.

The next variable domain was faculty rank and tenure, which included both the measure of rank as well as tenure. Neither variable significantly contributed to the model.

Table 11

Summary of Multiple Regression of the Number of Publications and Presentations with Students on the Predictor Variables by Variable Domain

Variable	B	*B*	P
Center Characteristics (n= 256, df= 2)			
Center Discipline	-.35	-.14	.03
Center Dunding per Faculty Member	1.07	.08	.25
R^2	.03		
Faculty Rank and Tenure (n= 253, df= 2)			
Rank	.12	.13	.24
Tenure	.24	.12	.28
R^2	.06		
Benefits (n= 248, df= 3)			
Faculty Symmetry with Industry	.10	.07	.31
Faculty Benefits	.63	.31	.00
Faculty Academic Freedom	-.01	-.01	.87
R^2	.12		
Industry Technical Benefits (n= 247, df=1)			
Industry Technical Benefits	.31	.36	.00
R^2	.13		

For the benefits domain, three independent variables were included in the model; faculty symmetry with industry, faculty benefits, and faculty academic freedom. Only faculty benefits significantly contributed to the model, explaining 12% of the variance in the dependent variable. The direction of the effect was positive meaning that faculty who reported that involvement the center had a positive impact on their receipt of benefits also reported more publications and presentations with students.

The final variable domain was industry technical benefits, which included one independent variable; the industry technical benefits measure. The variable significantly contributed to the model, explaining 13% of the variance. The direction of the effect was positive meaning that faculty who reported that their center research had a positive impact on the industry members receipt of technical benefits were also more likely to report a greater number of publications and presentations with students.

Table 12 presents the overall multivariate regression of the number of publications and presentations with students on the predictor variables. Three variables were included in the model; center discipline, faculty benefits, and industry technical benefits. Two variables significantly contributed to the model, faculty benefits and industry technical benefits explaining 17% of the variance in the dependent variable. Faculty benefits and industry technical benefits had a positive effect on the dependent variable meaning that faculty who reported that center involvement had a positive impact on their receipt of benefits and faculty who reported that their research had a positive impact on the receipt of technical benefits for center members were more likely to report a great number of publications and presentations with students. The variable with the greatest effect was the industry technical benefits, followed by faculty benefits.

Table 12

Summary of Overall Multivariate Regression of the Number of Publications and Presentations with Students on the Predictor Variables

Variable	B	*B*	p
Center Characteristics			
Center Discipline	-.20	-.09	.17
Benefits			
Faculty Benefits	.49	.23	.00
Industry Technical Benefits			
Industry Technical Benefits	.25	.26	.00
R^2	.18		

Note: n= 218, df= 3

Publications and Presentations with Member Scientists

Bivariate Analysis

Appendix C shows the bivariate logistic regression results for publication and presentations with member scientists. Significance for each model was determined using the Chi-Square statistic, significant variables ($p<.10$) were used in further analyses. A total of twenty variables were tested, six of these were significant; center size, center age, faculty symmetry with industry, faculty benefits, faculty academic freedom, and industry technical benefits.

Multivariate Analysis

Table 13 presents the results of the multivariate logistic regression of publications and presentations with member scientists on the predictor variables by variable domain. Since the dependent variable was a dichotomous variable, a logistic regression technique was employed. Three variable domains were present in the analysis; center characteristics, faculty outcomes, and industry technical benefits.

For center characteristics, two independent variables were included in the analysis; center size and center age. Center age significantly contributed to the model. The odds ratio for the variable shows that for a one unit increase in center age, the odds of having a publication or presentation with a member scientist decreases. The analog R^2 for the model is .023, meaning that the predictor variables reduce the error of predicting the log odds by about 2.3%.

Table 13

Summary of Multivariate Logistic Regressions of Publications and Presentations with Member Scientists on the Predictor Variables by Variable Domain

Variable	B	Odd Ratio	X^2	df
Center Characteristics (n=260)			6.00**	2
Center Size	-.02	.98		
Center Age	-.05*	.95		
Analog R^2	.02			
Benefits (n= 245)			29.95***	3
Faculty Symmetry with Industry	.49**	1.64		
Faculty Benefits	1.07***	2.93		
Faculty Academic Freedom	.10	1.11		
Analog R^2	.11			
Industry Technical Benefits (n= 244)			11.54***	1
Industry Technical Benefits	.46***	1.59		
Analog R^2	.048			

*p<.10 **p<.05 ***p<.01

The benefits domain included three independent variables; faculty symmetry with industry, faculty benefits, and faculty research. Faculty symmetry with industry and faculty benefits significantly contributed to the model. Both odds ratios were above one, for faculty benefits, a one-unit increase in the scale increases the odds of having a publication with a member scientist by almost three times. For faculty symmetry with industry, a one-unit increase increases the odds of having a publication with a member scientist by over 1.5 times. The analog R^2 for the model was .109 meaning that the predictor variables reduced the error in predicting the log odds by about 10.9%.

The final variable domain model was the industry technical benefits model, which included one independent variable, technical benefits. The independent variable significantly contributed to the model, the odds ratio was above one indicating that for every one unit increase on the technical benefits scale, the odds of having a publication with a member scientist increased by over .5 times. The analog R^2 for the model was .048 meaning that the predictor variable reduced the error of predicting the log odds by about 4.8%.

The results for the overall multivariate logistic regression of publications and presentations with member scientists on the predictor variables on are presented in Table 14. Four predictor variables were included in the model; center age, faculty symmetry with industry, faculty benefits, and industry technical benefits. All predictors significantly contributed to the model, the odds ratio for center age was below one, for all other predictors it was above one. For faculty benefits, a one unit increase in the variable leads to an increase in the odds of a having a publication with a member scientist by 2.63 times. The analog R^2 for the model was .16, meaning that the predictor variables reduce the error of predicting the log odds by about 16%.

Table 14

Summary of Overall Multivariate Logistic Regression of Publications and Presentations with Member Scientists on the Predictor Variables (n= 232)

	B	Odds Ratio	X^2	df
			42.16***	4
Center Characteristics				
Center Age	-.13***	.88		
Benefits				
Faculty Symmetry with Industry	.48*	1.61		
Faculty Benefits	1.29***	3.63		
Industry Technical Benefits				
Industry Technical Benefits	.33***	1.39		
Analog R^2	.16			

*p<.10 **p<.05 ***p<.01

<u>Open-Ended Analysis</u>

There were two open-ended questions in the survey, concerning the technical benefits that faculty members feel the industry members are receiving and improvements they feel the centers need in terms of administration and operations. Answers to these questions were subjected to content analyses. Table 15 shows a summary of the results from the content analysis of the open-ended questions. The actual comments for the questions are in Appendix E.

The first question asked the faculty member to indicate technical benefits that industry members received from their center research. A total of 147 faculty answered the question and a total of 157 individual comments were made. Nine themes were derived from the comments: data/data analysis/methods (36.73% of respondents), knowledge/understanding (23.81% of respondents), new/improved (9.52% of respondents), process (8.84% of respondents), new models (6.80% of respondents), patents (3.40% of respondents), hiring (1.36% of respondents), students (1.36% of respondents), and other (22 comments (14.97% of respondents) that could not be placed in one of the previous categories). The largest themes to emerge were the data/data analysis/methods themes and the knowledge/understanding. In the data/data analysis/methods theme respondents discussed how center research had allowed for the development of new data analysis techniques or new research methods of a discipline, process, or product ("Development of new design and analysis tools that provided market edge for the members."). In the knowledge/understanding theme, respondents discussed how their research helped industry to have an increased knowledge or fuller understanding of a discipline, product, or process ("Developed fundamental understanding.").

Table 15

Overview of the Open-Ended Analysis

Question	n	% (of respondents)
Question 6 If you believe member benefited technically from your research, please describe what was transferred and/or how members benefited?		
Total Faculty Sample	275	
Faculty who answered the question	147	53.45
Total Number of Comments	157	
Themes		
Data/Data Analysis/Methods	54	36.73
Knowledge/Understanding	35	23.81
New/Improved	14	9.52
Process	13	8.84
New Models	10	6.80
Patents	5	3.40
Hiring	2	1.36
Students	2	1.36
Other	22	14.97
Question 8 How can your Center improve its research and/or administrative operations?		
Total Faculty Sample	275	
Faculty who answered the question	97	35.27
Total Number of Comments	104	
Themes		
Money	19	19.59
Administration	17	17.53
Communication and Coordination	16	16.49
Research	13	13.40
Increase Membership	12	12.37
Increase Industrial Interaction	10	10.31

Table 15 (Continued)

Question	n	% (of respondents)
Director	6	6.19
Faculty and Students	6	6.19
Good things	5	5.16

The second question inquired as to how the center could improve its research and/or administrative operations. A total of 97 faculty answered the question and a total of 104 individual comments were made. Nine themes emerged from the comments; money (19.59% of respondents), administration (17.53% of respondents), communication and coordination (16.49% of respondents), research (13.40% of respondents), a need for increased industrial membership (12.37% of respondents), increase industrial interaction (10.31% of respondents), director (6.19% of respondents), faculty and students (6.19% of respondents), and good things about the center (5.16% of respondents).

In the communication and coordination theme, faculty made comments concerning how information flowed through the center ("The center needs more attention to information flow to faculty.)" and how members, both faculty and industry, needed to improve communication with each other ("Develop an email and homepage system that researchers who are members can log on and keep in touch with each other."). The money theme discussed how money should be managed in the center ("More timely transfer of funds") and the need to increase center funding ("Center needs more funds to work with."). The director and administration themes discussed both positive aspects ("The director does a good job") and aspect that needed improvement ("Short handed!"). The research theme discussed the needs to change the research focus of the center ("Need more core research and fundamental work."). Faculty and students discussed various issues ("Recruit higher quality students and postdocs."). Increase industry membership ("Greater recruiting effort.") and increase industrial interaction ("More interactions with member companies.") discussed the need to improve the center in the area of membership and participation of current members. Finally, good things were mentioned about the centers ("I think our center is great!").

DISCUSSION

The United States spends a good deal of money on R&D, a large portion of which takes place in a university setting. A portion of this funding is provided by industry. Industry currently provides 7% of funding towards university R&D and is the fastest growing source of R&D funding to academic institutions (National Science Foundation, 2000). Reasons for the increase in spending include corporate downsizing, the broadening scope of research, and public policy changes that have promoted collaboration between industry and the university. Faculty have reported that they would like to see more industry involvement in academic research (Strickland, Kannankutty, & Morgan, 1996).

Many types of linkages are made between the university and industry. One of these is the industry-university research center. This type of linkage has shown a number of benefits such as the introduction of new products and processes and the improvement of existing products and processes (Cohen, Florida, & Goe, 1994). Although there has been a large amount of research done on industry-university research collaboration and I-U centers, most of this research has focused on the industry side of the relationship. University faculty have been relatively neglected in research. A literature review conducted for this study found only eleven studies on faculty and I-U relationships published since 1986. Though the studies do present information on a number of variables important to I-U collaboration such as characteristics of the faculty member's research program and attitudes of the faculty member towards I-U collaboration, there are limitations to this research. The main limitation is that the data is primarily descriptive. Other limitations are in the area of methodology. There is a clear need for an increase in the amount of research in this area.

Despite the limitations of the current literature, each of the studies does identify significant variables on a number of organizational levels important to the I-U relationship. There are variables on the institutional level such as the idea of a "firm friendly" university presented by Rahm (1994). There are also variables at the level of the partnership such as the characteristics of the research program (multidisciplinary, oriented towards products and processes, less long-term focused) of industry-funded research. Finally, there are individual level characteristics such as the faculty member's level of support for I-U research.

The present study sought to address issues concerning the relationship between various variables and faculty outcomes in the context of industry-university cooperative research centers. More specifically the study sought to examine what predicted outcomes related to satisfaction and publications (theses and dissertations, publications and presentations) for the faculty member. A number of independent variables at different organizational levels were proposed: characteristics of the university, the center, and the individual. There was also an analysis of open-ended questions that inquired about the technical benefits that faculty feel the industry members are receiving and what improvements they feel the center needs in terms of administration and operations. The results of the study showed that different organizational levels do make a difference in the prediction of outcomes. Variables at the institutional, the center, and the individual level predicted outcomes for faculty members in satisfaction and scholarly productivity.

Limitations

There are limitations to this study. One of these is that the focus was on a specific type of I/U collaboration: the industry-university research center. These results may or may not generalize to other areas of collaboration. It is also important to remember that the majority of the sample came from a specific centers program; the results obtained may be specific to faculty in that program. However, because of the large number of IURCs in the US, there is a need to identify what is important for faculty involved with industry-university centers, regardless of program.

Another limitation is that the research was restricted to the construct and items included in a preexisting survey, already in use by the IUCRC program to evaluate center faculty. Though the scales do show a good deal of reliability, there are additional items that could be added to make them more complete. For example, the faculty satisfaction scale inquires about the faculty member's satisfaction with the quality of the research program, the relevance of the research program to industry's needs, and center administration and operations. A beneficial addition to the scale would be a variable that asks the faculty member what their satisfaction is for the relevance to the research program to their own needs or what is their overall center satisfaction. Another possible limitation concerning the survey is the self-report nature of many of the items on the survey. Faculty are asked to report their number of publications and presentations however, there is no precise description of what is meant by a publication or presentation. Therefore, faculty responses are likely to be an aggregated response that includes things such as articles that have been submitted to a journal but not yet accepted, in press articles, actual printed articles, articles with multiple authors, poster presentations, short papers given at conferences, etc… While some of these might be acceptable to count as publications and presentations the imprecise definition, may cause some faculty to use a narrower definition thereby leaving out publications or presentations that they do not feel count and other faculty to use a broader definition and therefore include every type of publication and presentation they can think of.

A final limitation to consider is response rate. Though adding data from the previous evaluation year increased the total number of respondents, the effect on the response rate was negative. The overall response rate for the study was 47.91%, which is slightly lower than the traditional average return rate of 50% for a paper survey. Taking into consideration that the for the IUCRC centers, the evaluation process is an integral part of the centers, a higher return rate would be expected. However, the response rate may reflect the fact that IUCRC center faculty receive the same survey on a yearly basis, creating a possible feeling of repetition. Also, attention is traditionally focused on the industry survey results rather than the faculty survey results.

Major Results

The results of the study show that faculty are receiving positive benefits from their participation in I/U research centers. While all of the individual benefits variable means reflected a positive mean impact for faculty, the variables with the highest means were the faculty member's ability to support graduate students, amount of interaction with other faculty, and access to equipment. These are benefits that allow the faculty member to improve their research program and promote collaboration. The mean for faculty member's academic freedom, also reflected a positive impact for faculty. This was measured in terms of their perceived amount of autonomy in conducting research and the ability to publish research in a timely fashion. However, there was no relationship between academic freedom and satisfaction or scholarly productivity. These findings contradict some of the cautions raised in the literature concerning unintended consequences of industry-university collaboration, which predict that faculty involvement in industry-university research would have a negative impact on academic freedom and scholarly productivity. This may reflect the fact that although there are controls in place in many centers concerning faculty's ability to publish research (for example, a delay period for patents), they are rarely exercised.

Involvement in the center also had a positive impact on the faculty member's level of symmetry with industry. The average score for the scale showed an impact that was slightly below "moderately positive". This level of symmetry was measured in terms of their trust and confidence in industry and their evaluation of the quality of industrial research. It is possible that through their interactions with center members, faculty come to view industry as their peers in research. They may realize that industry is interested in the quality of the research it produces just as much the university is interested. Faculty also report that the characteristics of the research they conduct in centers is in general slight more applied and shorter in time frame than research done outside of the center. The scope of the center research was about the same outside research. However, it is important to remember the diversity in the research that is done across centers, as there were a small percentage of faculty that reported their center research to be more basic, longer in time frame, and broader in scope than their non-center research.

Overall, faculty are satisfied with their involvement in the centers. The mean for the satisfaction scale was at the level of "quite satisfied". Each of the means for the individual satisfaction items (quality of the research program, relevance of the research program to industry's needs, and center administration and operations) were also at the same level.

Due to the exploratory nature of the research, a significance level of $p<.10$ was chosen. This was done in order to account for any multi-collinearity between variables. However, when the overall multivariate models for each dependent variable are examined, it is shown that, with the exception of the faculty symmetry with industry scale for the publications and presentations with member scientists, all significant predictor variables were significant at the p=.05 level or below.

The results from the multivariate analysis show that faculty satisfaction is predicted by variables at three organizational levels: the university, the center, and the faculty member. At the university level, faculty were more satisfied when they came from universities with larger research budgets. The positive effect of the university research budget on satisfaction is not a surprising result. Larger research budgets mean more money that is available to individual faculty members, making it easier to fund their research programs without having to endure the stress of seeking external funding sources. More money from the university also means less grant money that needs to be spent on things such as equipment or overhead and more money that can be spent on the actual research. This is good for the IUCRC faculty from universities with larger research budgets, as many of the IUCRC centers receive very little funding. Therefore, faculty involved in the centers are working on a tighter budget. Faculty from universities with a larger research funding base are probably better able to cope with the marginal support than faculty at universities with a smaller funding base. It is surprising however, that center funding per faculty member did not predict satisfaction as this measure is closer to the faculty member level.

It is interesting to note that the universities in this sample received 11.5% of their research budget from industry, which is higher than the national average of 7%. The median value was also above the national average. These universities may be more “firm friendly” than universities in general (Rahm, 1994). This might explain why the percentage of money that the university receives from industry did not significantly predict satisfaction. The universities in this sample appear to be on the upper end of the distribution, creating a possible restriction of range.

At the level of the center, faculty were more satisfied when they came from a center with a non-engineering discipline. Upon examination of the disciplines of these centers, it was shown that they represented multidisciplinary fields such textiles, health science and management, and computer software. In comparison to the applied nature of the field of engineering, these fields are of the opposite extreme than was expected, they are even more applied than engineering. Because of the extreme applied nature of these fields, an even tighter coupling with industry is required than is needed in engineering. Therefore, faculty from these centers may express a higher level of satisfaction with being involved in these centers because it brings them in close contact with industry.

At the level of the faculty member, there was more satisfaction among faculty who reported that participation in the center had a positive impact on their receipt of benefits and on the level of symmetry they felt with industry. As explained above, the positive effect of the symmetry with industry variable further reflects the concept that faculty who feel that industry is their peer in research are likely to be more satisfied with the center. This would be a critical variable for a center to be aware of as centers with a mismatch between faculty and industry members might be less successful in their research program than those centers with a closer match.

An additional regression analysis showed that among the faculty benefits, the most important items are increased interactions with other faculty and access to equipment. This is important, as these are benefits that do not lead to personal gain for the faculty member. Rather, these benefits promote both collaboration and the research program of the individual faculty member. The results of the present study are in agreement with the work of Lee (2000), who suggests that faculty become involved in industry-university research to advance their own research program. This also complements the results of Gray, Johnson, and Gidley (1986) who state that faculty and industry participants from center programs have a primary goal of a general expansion of knowledge rather than patentable products.

Though faculty do report a positive level of satisfaction with the centers, they do list areas of improvement. One of these topics is in the area of membership, particularly the need to increase center membership (and therefore center funding) and improve interactions with center members. Another area is the improvement of communication and coordination among industry and faculty members. These suggested improvements would have a primary impact on collaboration efforts in the center, again, emphasizing that faculty view the interactions between faculty members and between faculty and industry as being important.

Another area of study was on scholarly productivity. The results show that faculty are reporting scholarly productivity as a result of their center involvement. There were four measures of scholarly productivity; number of theses and dissertations, total number of publications and presentations, publications and presentations with students, and publications and presentations with member scientists. The univariate statistics for scholarly productivity also show that faculty from IURCs are publishing at a high rate. Faculty in this sample published a total of 1,545 publications and presentations based on center research. The average number of total publications and presentations per faculty member was about 6. In addition, almost 50% of the faculty reported a publication or presentations with a member scientist and about 70% reported a publication or presentation with a student. An average of 2 theses or dissertations per faculty member were completed or in progress during the 1999-

2000 academic year. These results show that faculty are actively involved in publishing and presenting their center research.

As much of the studies on publications and I/U collaboration focus on possible unintended consequences (Blumenthol, 1986, Blumenthol et. al, 1997, Landry, et. al., 1996) this article adds to the literature by attempting to explain what predicts scholarly productivity in this relationship. All of these variables were predicted by independent variables at two levels: center level characteristics and individual level benefits. There were no university level predictors of scholarly productivity, indicating that publishing is dependent on factors at a level closer to the faculty member.

At the center level, there were a mix of characteristics that were significant predictors. Faculty from non-engineering centers were less likely to report theses and dissertations as well as publications and presentations with students. As mentioned above, this may be due to the fact that these non-engineering centers represent disciplines that are very closely aligned with industry. Faculty from multi-university centers were more likely to report theses and dissertations and a larger number of publications and presentations. Often, single university centers in the IUCRC program that are in danger of folding are made into multi-site centers in order to attempt to bring in more members and funding and therefore save the center. This may be the reason that single site centers seem to be producing more scholarly productivity, as they may be more stable than some multi-site centers. Finally, faculty from younger centers were more likely to report a publication or presentation with a member scientist. This may be due to the "gusto" of starting up a new center. There may be a push to produce research in collaboration with member scientists in the first few years of operation. The importance of this may decline as a center gets older.

At the individual level, faculty benefit predictors held across most of the scholarly productivity variables. Faculty symmetry with industry was predicative of both theses and dissertations and the reporting of a publication or presentation with a member scientist. Again, as mentioned above, symmetry with industry might make the research process smoother and faculty might be more likely to work with an industry member towards a publication. Faculty personal benefits and the receipt of technical benefits by industry significantly predicted all four scholarly productivity variables. An analysis of the second open-ended question gave some specific areas where faculty feel that industry is receiving technical benefits. The largest area is in the area of methods and data analysis followed by the knowledge and understanding of information. This suggests that the industry members are interested in receiving the knowledge and analytical tools necessary for them to create patentable products. These results compliment previous research comparing center programs to individual contract research which showed that the center program faculty sought a general expansion of knowledge as a viable outcome (Gray, Johnson, & Gidley, 1986). The relationship between scholarly productivity and the receipt of technical benefits by industry, as perceived by the faculty member may be due to inferences on the part of the faculty member. Faculty who are producing publications and presentations from center research may feel that centers members should be receiving benefits as a result of their production.

Compared with satisfaction model, the models for predicting scholarly productivity explained a smaller amount of the variance in the dependent variables. This may be due to the fact that the majority of the independent and all of dependent variables in the satisfaction model require a subjective response, whereas for scholarly productivity, the dependent variables were objective measures. Also, because of the format of the survey, the satisfaction questions appear at the end, which may have created a priming effect as faculty answer the benefits questions before answering the satisfaction questions.

<u>Conclusion</u>

The purpose of this study was to predict outcomes in the area of satisfaction and scholarly productivity for faculty involved in IURCs. It is clear from these results that factors at different organizational levels (university, center, individual) are important in the prediction of faculty outcomes.

Faculty are receiving benefits from their involvement in IURCs and these benefits are predicative of satisfaction. The most important benefits are in the areas of interaction with other faculty and access to equipment. These benefits help to promote their own research program as well as foster collaboration. Faculty member's level of symmetry with industry is also important, particularly for the prediction of satisfaction with the center. Faculty report a positive level of satisfaction with their centers. In all variables at three organizational levels predicted satisfaction: the university, the center, and the individual.

The results of this study also show that faculty in IURCs are publishing from the results of their center research. Factors at two levels are predicative of scholarly productivity: the center level and the individual level. Again, as with satisfaction, faculty receipt of benefits and the level of symmetry with industry as well as the receipt of technical benefits by industry were predictors of scholarly productivity.

<u>Future Directions</u>

Although the present study does shed some light on faculty involvement in industry-university relationships and IURCs in particular, there is still a great need for continued research in this area. There are two areas where this research could head: areas that expand the results of the present study or areas that address other issues mentioned in the literature review.

In terms of areas that would expand the present study, one possibility is the revision of the survey instrument that was used. Two areas that need improvement in the survey are an expanded satisfaction scale, which could pull from some of the literature on job satisfaction for academic faculty. In this literature, many aspects of a faculty member's job leads to satisfaction or dissatisfaction such as the level of institutional support they feel they receive (Johnsrund & Heck, 1998) or the characteristics of the environment in with they work (Matier, 1990). These same aspects might be present in the centers as well and have an effect of satisfaction.

Another improvement that could be made to the survey is more precise criteria for reporting publications and presentations. As was stated earlier, the current survey has no precise criteria of what is a publication or presentation. This area could also be expanded so that faculty would report on different kinds of publications and presentations. In general, more research is needed in that area of scholarly productivity, particularly longitudinally to ascertain what effect center involvement has on publications over time. It would be interesting to compare publishing activities before center involvement with publishing during center involvement.

Another area of focus for future research could also be the topic of the level of symmetry with industry for a faculty member individually with center members or for the faculty members as a whole in the center. As was mentioned previously a mismatch between faculty and industry could be detrimental to the success of the center. What effect does symmetry with industry have on the faculty member's research program?

In the broad area of faculty and industry-university collaboration, there is also a great need for additional research, particularly in the area of multivariate studies. Three major categories of research were covered in the literature review: faculty views of industry university collaboration, characteristics of the faculty involved, and outcomes. The present study added to the outcome literature, however more research is still needed in every category. Some questions that could be addressed are: what factors predict a faculty member's decision to become involved in an IURC? Are there differences in the level of support for industry-university research between involved and uninvolved faculty and does support differ by the type of collaboration? Are there differences in the type of support based on academic discipline? There is also a great need for research in the area of unintended consequences; does industry-university research have a negative effect on scholarly productivity, the research program of the university, or educational support for students? It is clear that research on the faculty side of industry-university collaboration needs to be given the same important as has been given for industry side. Understanding both sides of this increasing popular type of research collaboration with help to make it a more effective and beneficial relationship.

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APPENDIX A

Table A1

Literature Review Table

Authors	Year of Publication	Purpose of the Study	Participants	Analysis	Major Results
Blumenthal, Gluck, Louis, Stoto, & Wise	1986	To examine the effect of collaboration between faculty and industry on productivity, traditional academic activities, secrecy, and direction of research.	N= 1238 Faculty from life sciences (993) and faculty from chemistry and engineering (245)	Descriptive data, statistical method used to assess differences between groups not specified.	Faculty involved in research relationships with industry: • Reported more publications and involvement in professional activities. • Were twice as likely to report that they had done research that had resulted in patent applications, patents, or trade secrets. • Believed more strongly in the benefits from industry-university relationships.
Blumenthal, Campbell, Causino, & Louis	1996	To collect information on university-industry research from the standpoint of faculty members that are participating in them.	N= 2052 Faculty from life science departments	Multivariate and logistic regression.	• Faculty members with industrial funding had a greater amount of published articles and had greater participation in service activities. • They were more likely to report commercial outcomes of their research. • These faculty also reported restrictions has been placed on the communication of the results of their research.
Blumenthal, Campbell, Anderson, Causino, & Louis	1997	To examine the extent of data withholding among university faculty and the factors that would increase the likelihood of this happening.	N= 2167 Life-science faculty	Descriptive data, statistical method used to assess differences between groups not specified. Logistic regression to predict measures of withholding.	• Faculty involved in industry-university relationships were more likely to report delaying publications and the refusal to share research results. • Delaying publication was

Table A1 (Continued)

					predicted by participation in industry-university relationships and commercialization activities. • Refusal to share research results was predicted by commercialization activities, engaging in genetics research, and higher publications rates.
Campbell	1997	Investigate the views of university and industry toward three potential conflicts: Conflict of interest, conflict of commitment, and conflict over internal equity.	N= 370 University administrators (95) and faculty members (275) from the social sciences, fine arts, science and engineering, and business.	Factor analysis to create three conflict scales (conflict, commitment, and internal equity). ANOVA's to assess differences for each of the scales for faculty involved with industry and those not involved with industry.	• Faculty are open-minded towards changes in academic norms that would lead to increased collaborative activity with industry. • Those involved in collaboration want greater flexibility and more opportunities to obtain financial rewards.
Campbell & Slaughter	1999	To examine areas of tension between faculty and administrators involved in industry-university activity in terms of three potential conflicts: conflict of interest, conflict of commitment, and conflict over internal equity.	N= 407 University administrators (127) and faculty members (280) from social science, fine arts, science and engineering, and business.	ANOVA to assess views towards potential conflicts between faculty involved in industry relationships and those not involved in industry relationships.	• Faculty who are involved with industry want more control over this relationship in terms of the time they spend working on collaborative activity. • Faculty involved with industry respond to potential conflicts in a way that would foster the collaboration with industry.
Gray, Johnson, & Gidley	1986	To compare potential goals and outcomes of two federally funded programs of industry-university collaboration: the I-U Cooperative Research Projects Program and the I-U Cooperative Research Centers Program.	Projects Program: n= 226 Industry and University PI's Centers Program: n= 65 Faculty Members n= 133 Industry Members	t-tests and chi-square to assess differences between the two programs	• For the projects program, the most important goals were "patentable products" and "commercialized products". • For the centers program, the most important goals were "general expansion of knowledge", "enhanced student technical training" (faculty), and "enhanced research in

Table A1 (Continued)

					industry" (industry). • For benefits realized: "better personnel recruitment" and "improved research projects in your lab" (most likely); "patentable products" and "commercialized products" (least likely).
Landry, Traore, & Godin	1996	To examine the effect of collaboration on the productivity of university faculty.	N= 1566 Faculty from a Quebec University	Multivariate Regression with dependent variable being overall productivity (measured as a standardized index of the number of outputs in 18 categories).	• As the percentage of work done in collaboration increase, productivity decreased. • As the intensity of the collaboration increased, productivity increased. • Relationships with industry, government, or other universities all resulted in an increase in productivity. However, when the researcher's main collaborating partner was industry, there was negative effect on productivity.
Lee	1996	How US academics feel concerning institutional transfer-oriented policy and where they believe the boundaries of industry-university collaboration should be.	N= 986 Faculty from basic science, engineering applied science, and social sciences.	Descriptive data, Chi-square used to assess differences. Logistic regression to determine predictors of faculty support of user-oriented applied research.	• More approval now of applied research and industry supported research than in the 1980's. • Faculty support is a function of three variables: whether the faculty member is from a basic, applied, or social science discipline; whether the university encourages research with industry; and whether close industry-university collaboration is perceived by the faculty member to be a threat to academic values.
Lee	2000	To determine what benefits	N= 427 Faculty members	Descriptive data, correlation	• Faculty have their own agenda

		industry and university (particularly faculty) receive from their collaboration with each other.	from science and engineering fields from research intensive universities..	analysis of motivator variables and benefits variables, Chi-square analysis of the relationship between firm type and the faculty benefit experienced.	in their collaboration with industry. • The top four faculty motivators for collaborating with industry are: secure funds for graduate assistants and lab equipment, gain insight into one's own research, field test application of theory, and supplement funds for research.
Rahm	1994	Attempts to answer the following questions: Why do some academics engage in technology transfer while others do not? What facilitates technology transfer? What inhibits it?	N= 1013 Faculty from biology chemistry, Computer Science, Electrical engineering, and physics	Chi-square to assess differences between spanning and non-spanning researchers. Descriptive data.	• "Spanning researchers" (those who are involved with industry) tend to come from more "firm friendly" universities. • Spanning researchers have research that is more multidisciplinary. • Spanning researchers were less likely to feel that collaboration with industry had a negative impact on the basic research mission of the university.
Strickland, Kannakutty, & Morgan	1996	Present the results of a national survey of engineering faculty on four aspects of industry involvement in academia.	N= 1727 Full-time tenure track faculty whose principal appointment was in engineering and had been involved in university-based engineering research.	Descriptive data, differences between faculty with high industry support and faculty with high federal support were assessed. Specific statistical method used not stated.	• Faculty with high industry support for their research have research that is likely to: be done with collaborating investigators, have a grant that is 0 to 12 months in length, focused on applied issues, and have more commercial outputs.

APPENDIX B

NATIONAL SCIENCE FOUNDATION

INDUSTRY-UNIVERSITY COOPERATIVE RESEARCH CENTERS EVALUATION PROJECT

Faculty Questionnaire

Center:

INSTRUCTIONS: **Please answer all questions. For multiple choice questions please CIRCLE the number that corresponds with your response. For the remaining questions, please FILL IN the blanks as indicated. Attach additional sheets as necessary.**

Return by:

Return to:

Phone:
Fax:
Email:

I YOUR RESEARCH EFFORT

1) Compared to the research projects which you typically conduct outside the Center, would you describe your Center-funded research as:

	Much more basic	*More basic*	*Same*	*More applied*	*Much more applied*	
a)	*1*	*2*	*3*	*4*	*5*	[7]

	Much broader in scope	*Broader*	*Same*	*Narrower*	*Much narrower in scope*	
b)	*1*	*2*	*3*	*4*	*5*	[8]

	Much longer time frame	*Longer*	*Same*	*Shorter*	*Much shorter time frame*	
c)	*1*	*2*	*3*	*4*	*5*	[9]

I YOUR RESEARCH EFFORT-continued

2) During the past year:

	Total number	Number with member scientists	Number with students	
a) How many **publications** in the open literature have you had based on Center research?				[10-11]T# [12-13]M# [14-15]S#
b) How many **presentations** have you made at conferences or professional meetings based on Center research?				[16-17]T# [18-19]M# [20-21]S#

[Coder: "0" for total number = "0" for number with member scientists/students].

	Number completed during last year	Number still in progress	
c) How many **theses/dissertations** based on Center research are under your supervision?			[22]C# [23]P#

3) How long, on average, do you feel that it should take for a new Center research project to yield tangible results? **number of months:** ___ ___ [24-25]

II INVESTIGATOR OUTCOMES

4) What impact has participation in the Center had for YOU in the following areas?

		Very negative impact	Moderately negative impact	No impact	Moderately positive impact	Very positive impact	
a	Opportunities for consulting	1	2	3	4	5	[26]
b	Opportunities for research contracts	1	2	3	4	5	[27]
c	Access to equipment	1	2	3	4	5	[28]
d	Trust & confidence in industry	1	2	3	4	5	[29]
e	My evaluation of the quality of industrial research	1	2	3	4	5	[30]
f	Chances for promotion, tenure, and/or salary increases	1	2	3	4	5	[31]
g	Amount of interaction with other faculty	1	2	3	4	5	[32]
h	Ability to support graduate student thesis/dissertation research	1	2	3	4	5	[33]
i	Amount of autonomy in conducting research	1	2	3	4	5	[34]
j	Ability to publish research in a timely fashion	1	2	3	4	5	[35]

III INDUSTRY BENEFITS

5) During the past year, how much of an impact do you Believe YOUR RESEARCH had on the following technical benefits for Center members?

		No Impact	Slight Impact	Moderate Impact	High Impact	Very High Impact	Not Applicable	
a	Research and development efforts	1	2	3	4	5	9	[36]
b	Commercialization of products, processes, and/or services	1	2	3	4	5	9	[37]

III INDUSTRY BENEFITS-continued

Comments for Question 5

6) If you believe members benefited *technically* from your research, please describe what was transferred and/or how members benefited. [38]
Note: This information is helpful for member recruitment and continuing government sponsorship.

[Coder: 0 = no comment, 1 = comment].

IV SATISFACTION

7) During the past year, how *satisfied* were you with the following features of the Center?

		Not Satisfied	Slightly Satisfied	Somewhat Satisfied	Quite Satisfied	Very Satisfied	
a	Quality of the research program	*1*	*2*	*3*	*4*	*5*	[39]
b	Relevance of the research program to industry's needs	*1*	*2*	*3*	*4*	*5*	[40]
c	Center administration and operations	*1*	*2*	*3*	*4*	*5*	[41]

Comments for Question 7

8) How can your Center improve its research and/or administrative operations? Comments on items a-c rated "1" or "2" are particularly valuable. [42]

[Coder: 0 = no comment, 1 = comment].

IV BACKGROUND

9) What is your academic rank? [43]
- ❒ Assistant Professor (1)
- ❒ Associate Professor (2)
- ❒ Full Professor (3)
- ❒ Other (please state) (4): ________________

10a) Are you tenured? ❒ Yes (1) ❒ No (2) [44]
10b) If NO, are you in a tenure track position? ❒ Yes (1) ❒ No (2) [45]

THANK YOU FOR YOUR COOPERATION!

APPENDIX C

Table C1

Univariate Statistics of Continuous Variables*

Variable	M	Median	SD	Range	Min	Max	Skewness	Kurtosis
Independent Variables								
Characteristics of the University								
Total research budget (thousands of dollars)	197,426	213,838	136,463	508,225	394	508,619	-.01	-1.03
% of budget the university receives from industry	11.5	9.49	9.37	42.64	.15	42.79	1.62	2.85
Characteristics of the Center								
Size of the center (# of industry members)	15.91	14.00	6.98	27.00	5.00	32.00	.67	-.50
Total operating budget of the center (thousands of dollars)	1,487	700	1,600	5705	318	6,023	1.98	2.77
Age of the center	7.51	6.00	4.39	17.00	1.00	18.00	.74	-.28
Average funding per faculty member (thousands of dollars)	90.25	63.64	69.98	343.79	17.04	360.83	1.70	3.66
Faculty Characteristics								
Faculty tangible benefits	18.19	18.00	9.06	57.00	3.00	60.00	.90	1.37
Tangible benefits difference	2.59	2.33	9.29	54.50	-18.0	36.50	.48	.22

Table C1 (Continued)

Variable	M	Median	SD	Range	Min	Max	Skewness	Kurtosis
Faculty Report of Research								
More basic (1)/applied (5)	3.36	3.00	.75	3.00	2.00	5.00	.23	-.13
More broad (1)/narrow (5) in scope	3.14	3.00	.81	4.00	1.00	5.00	-.17	-.42
Longer (1)/Shorter (5) time frame	3.29	3.00	.83	4.00	1.00	5.00	-.99	-.19
Industry Technical Benefits (1= no impact, 5= Very High Impact)								
R&D efforts	3.11	3.00	1.02	4.00	1.00	5.00	-.21	-.36
Commercialization of products, processes or services	2.42	2.00	1.15	4.00	1.00	5.00	.34	-.71
Industry Technical Benefits (scale)	2.76	3.00	1.00	4.00	1.00	5.00	.14	-.60
Faculty Benefits (1= Very Negative Impact, 5= Very Positive Impact)								
Opportunities for consulting	3.49	3.00	.68	4.00	1.00	4.00	.23	-.19
Opportunities for research contracts	3.99	4.00	.73	3.00	2.00	5.00	-.26	-.39
Access to equipment	3.78	4.00	.79	3.00	2.00	5.00	.22	-1.01
Chances for promotion and tenure	3.59	3.00	.72	3.00	2.00	5.00	.62	-.60
Amount of interaction with other faculty	4.09	4.00	.69	3.00	2.00	5.00	-.39	.10
Ability to support graduate students	4.12	4.00	.73	3.00	2.00	5.00	-.25	-.87

Table C1 (Continued)

Variable	M	Median	SD	Range	Min	Max	Skewness	Kurtosis
Faculty Benefits (scale)	3.84	3.83	.46	2.67	2.33	5.00	.22	.47
Faculty Academic Freedom (1= Very Negative Impact, 5= Very Positive Impact)								
Amount of autonomy in conducting research	3.44	3.00	.85	4.00	1.00	5.00	.14	-.22
Ability to publish research in a timely fashion	3.44	3.00	.87	4.00	1.00	5.00	.19	-.13
Faculty Academic Freedom (scale)	3.44	3.00	.79	4.00	1.00	5.00	.25	-.26
Faculty symmetry with industry (1= Very Negative Impact, 5= Very Positive Impact)								
Trust & confidence in industry	3.58	4.00	.77	4.00	1.00	5.00	-.28	-.01
My evaluation of the quality of industrial research	3.68	4.00	.78	4.00	1.00	5.00	-.12	.10
Faculty symmetry with industry (scale)	3.77	4.00	.68	4.00	1.00	5.00	-.77	.40
Dependent Variables								
Number of Publications and Presentations								
Total number	5.97	4.00	7.03	45.00	0	45.00	2.79	10.42
Number with member scientists	2.27	0	4.41	33.00	0	33.00	3.60	17.01
Number with students	4.35	3.00	6.25	45.00	0	45.00	3.31	15.47
Number of theses and dissertations	2.03	1.00	2.32	16.00	0	16.00	2.58	9.63

Table C1 (Continued)

Variable	M	Median	SD	Range	Min	Max	Skewness	Kurtosis
Satisfaction (1= Not Satisfied, 5= Very Satisfied)								
Satisfaction with the quality of the research program	3.93	4.00	.86	4.00	1.00	5.00	-.64	.25
Satisfaction with relevance to industry's needs	4.10	4.00	.84	4.00	1.00	5.00	-.66	.02
Satisfaction with center administration and operations	3.98	4.00	.99	4.00	1.00	5.00	-1.02	.80
Faculty Satisfaction (scale)	4.00	4.00	.76	3.67	1.33	5.00	-.77	.40

Table C2

Correlation Matrix of Independent and Predictor Variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
1. Public/Private	1.00																									
2. R1/non R1	.21**	1.00																								
3. U. Research. Budget	-.28**	-.58**	1.00																							
4. % U. Budget from Industry	.25**	.14*	-.27**	1.00																						
5. IUCRC	-.11	-.14*	.16**	.00	1.00																					
6. Multi-univ center	.04	-.15*	-.12*	.19**	-.31**	1.00																				
7. Ctr Size	-.12	-.12	-.07	.30**	.15**	.22**	1.00																			
8. Ctr Budget	-.11	.01	-.21**	.14*	-.11	.06	.38**	1.00																		
9. Ctr Age	-.14*	-.26**	.11	.05	.16**	-.07	.28**	.45**	1.00																	
10. Ctr. $/faculty	-.18**	-.06	.06	.10	-.14*	-.16	.26**	.61**	.40**	1.00																
11. Ctr Discipline	-.13*	-.21**	.27**	-.19**	.33**	-.11	-.10	-.23**	-.04	-.33**	1.00															
12. Rank	.07	.01	.06	-.05	.02	-.03	-.02	.04	.13*	-.03	-.10	1.00														
13. Tenure	.11	.08	-.02	-.01	.02	.00	-.03	-.03	.07	-.11	-.15*	.82**	1.00													
14. Faculty tangible Benefits	-.05	.04	-.07	-.06	-.15*	-.12	-.04	-.01	-.02	.09	-.11	-.02	-.10	1.00												
15. Tangible benefits difference	-.08	-.02	.01	.00	-.12	-.06	-.07	-.03	.01	.07	-.17*	.01	-.04	.90**	1.00											
16. Faculty Symmetry with Industry	-.16**	-.17**	.12	-.10	-.05	.05	.11	.01	.12	.10	.00	-.02	-.03	-.08	-.03	1.00										
17. Faculty Benefits	-.10	.06	-.03	.02	.01	-.01	.08	.11	.14*	.12	-.05	.06	.10	-.05	.04	.51**	1.00									
18. Faculty Academic. Freedom	.00	.09	-.03	-.04	-.08	.04	-.01	-.02	-.05	.06	-.06	.02	.03	-.00	.05	.45**	.49**	1.00								
19. Basic/applied	.06	.12	-.11	.03	-.11	-.02	-.08	-.05	-.04	.00	-.00	.06	.10	.03	.07	-.11	-.02	-.14*	1.00							
20. Broad/narrow	.19**	.20**	-.16*	.15*	-.10	.10	-.02	-.08	-.20**	-.11	-.10	-.07	.02	.00	-.08	-.22**	-.11	-.13*	.20**	1.00						
21. Longer/shorter	.07	.15*	-.11	.11	-.12*	.10	-.06	-.03	-.08	.04	-.13	-.02	.10	.06	.09	-.14*	.04	-.03	.37**	.41**	1.00					

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
22. Industry Tech. Benefits	-.06	.01	.02	-.08	.01	-.03	.03	.08	.10	.05	-.09	.05	.03	-.04	.02	.32**	.37**	.32*	-.08	-.11	-.08	1.00				
23. Faculty Satisfaction	-.22**	-.12	.22**	-.10	.14*	-.10	.09	.00	.17**	.12	.17**	.06	-.01	-.01	.04	.47**	.38**	.25*	-.03	-.19**	-.12	.25**	1.00			
24. Theses & Dissertations	-.09	-.00	.06	-.09	-.03	-.18**	.04	-.03	-.02	.16**	-.14*	.23**	.26	.01	.08	.23**	.29**	.17*	-.00	-.08	.07	.24**	.14*	1.00		
25. Total Pubs & Pres	-.01	.02	.02	-.05	.06	-.15*	.03	.12	.06	.19**	-.10	.14**	.14*	-.04	-.02	.30**	.37**	.24**	-.03	-.08	-.02	.36**	.12	.52**	1.00	
26. Pubs & Pres w/ students	.01	-.05	.04	-.03	-.00	-.06	.08	.08	.02	.13*	-.17**	.22**	.21*.*	.01	.03	.21**	.33**	.18**	-.02	-.04	-.02	.34**	.05	.54**	.79**	1.00
27. Pubs & Pres w/ member scientists.	-.05	.06	-.05	-.09	.04	-.08	-.11	-.01	-.13*	.07	.00	-.04	-.04	.04	.05	.27**	.30**	.20**	.01	.01	-.05	.22**	.18**	.23**	.43**	.38**

*= p<.05, **= p<.01

Table C3

Summary of Bivariate Regressions of the Continuous Dependent Variables on Predictor Variables (Standardized Coefficients)

	Faculty Satisfaction	Theses and Dissertations	Total Pubs & Presentations	Pubs & Presentations with Students
Center Characteristics				
Center Size	.09*	.04	.03	.08
Center Age	.17***	-.02	.06	.02
Non-engineering center	.17***	-.14**	-.10	-.17***
Center funding per faculty member	.12*	.16***	.19***	.13**
Multi-University Center	-.10	-.18***	-.15**	-.06
University Characteristics				
Public/Private University	-.22***	-.09	-.01	.01
Non-research I University	-.12*	-.00	.02	-.05
Univ. Research Budget	.22***	.06	.02	.04
Percent of research budget from industry	-.10	-.09	-.05	-.03
Faculty Characteristics				
Faculty Tangible Benefits	-.01	.01	.04	.01
Tangible benefits difference	.04	.08	-.02	.03
Rank	.06	.23***	.14**	.22***

Table C3 (Continued)

	Faculty Satisfaction	Theses and Dissertations	Total Pubs & Presentations	Pubs & Presentations with Students
Tenure	.00	.24***	.13**	.22***
Benefits				
Faculty Symmetry with Industry	.47***	.23***	.30***	.21***
Faculty Benefits	.38***	.29***	.37***	.33***
Faculty Academic Freedom	.25***	.17***	.24***	.18***
Faculty Report of Research				
Basic/Applied	-.03	-.00	-.03	-.02
Broad/Narrow in Scope	-.19***	-.08	-.08	-.04
Longer/Shorter time frame	-.12*	.07	-.02	-.02
Industry Technical Benefits				
Industry Technical Benefits	.25***	.24***	.36***	.34***

Note: *= p<.10, **=p<.05, ***=p<.01

Table C4

Summary of Bivariate Logistic Regression of Publications and Presentations with Member Scientists on the Predictor Variables

Variable	B	Odds Ratio	X^2	df
Center Characteristics				
Center Size	-.03*	.97	.08*	1
Center Age	-.06**	.94	4.56**	1
Center Discipline	-.01	.99	0	1
Center Funding per Faculty Member	.00	1.00	1.33	1
Multi-University Center	.34	1.40	1.82	1
University Characteristics				
Public/Private	.30	1.36	.62	1
Research I	-.31	.74	.79	1
University Research Budget	-.00	1.00	.66	1
Percent Industry Funding	-.02	.98	2.10	1
Faculty Characteristics				
Rank	-.07	.93	.37	1
Tenure	-.11	.89	.18	1
Faculty Tangible Benefits	.01	1.01	.34	1
Tangible Benefits Difference	.01	1.01	.41	1
Benefits				
Faculty Symmetry with Industry	.88***	2.41	.20***	1
Faculty Benefits	1.40***	4.06	22.63***	1
Faculty Academic Freedom	.53***	1.69	10.36***	1
Research Characteristics				
Basic/applied	.02	1.02	.02	1
Broad/Narrow	.02	1.02	.02	1
Longer/Shorter Time Frame	-.13	.88	.63	1

Table C4 (Continued)

Variable	B	Odds Ratio	X^2	df
Industry Technical Benefits				
Industry Technical Benefits	.46***	1.59	11.54***	1

*p<.10 **p<.05 ***p<.01

APPENDIX D

Independent Variables

Faculty Report of Research
(1= much more, 3= same, 5= much more)

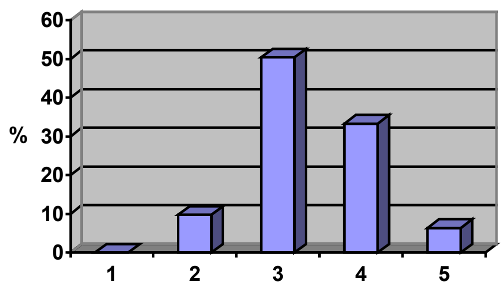

Figure D1: Basic(1)/Applied(5) Research

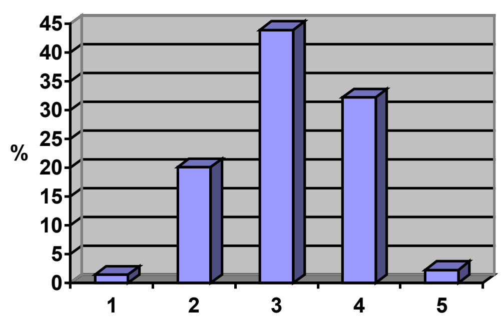

Figure D2: Broad(1) /Narrow(5) in Scope

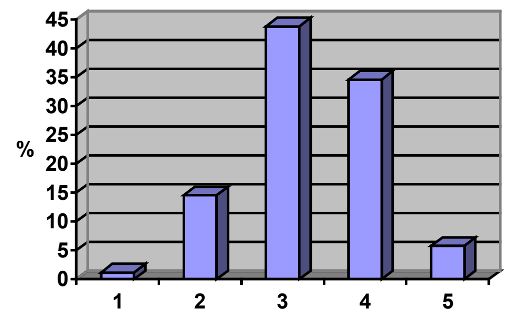

Figure D3: Longer(1) /Shorter(5) Time Frame

Benefits
(1= very negative impact, 3= no impact, 5= very positive impact)

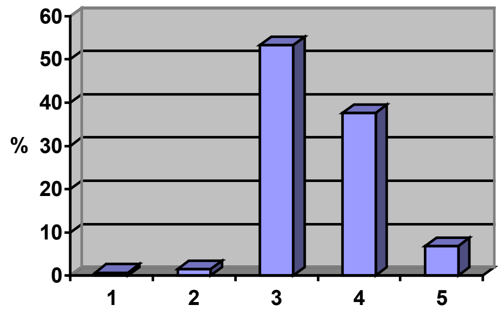

Figure D4: Opportunities for Consulting

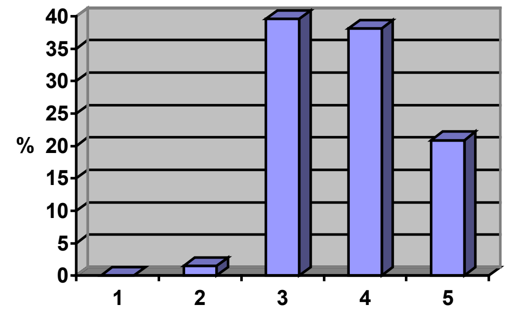

Figure D6: Access to Equipment

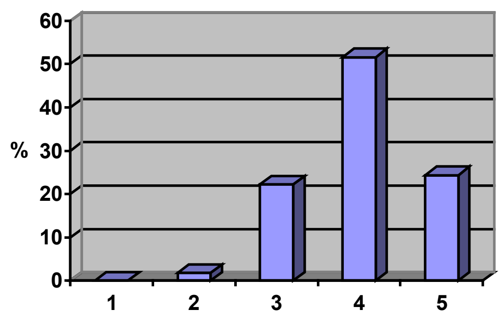

Figure D5: Opportunities for Research Contracts

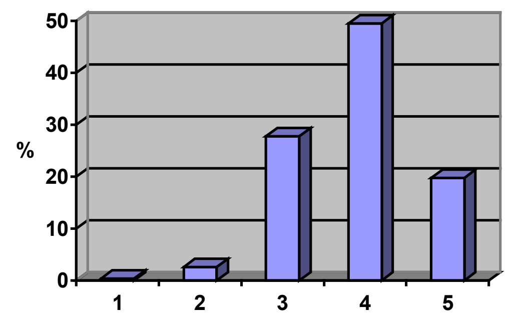

Figure D7: Trust and Confidence in Industry

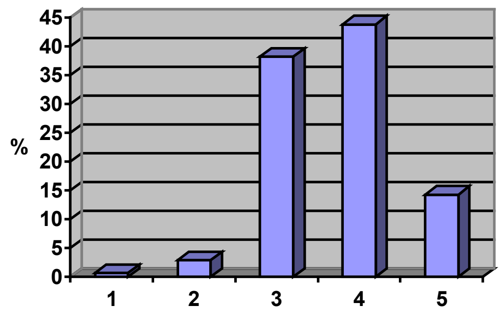

Figure D8: My evaluation of the quality of industrial research

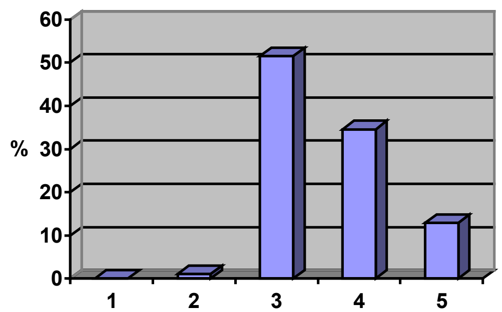

Figure D9: Chances for promotion, tenure, and/or salary increases

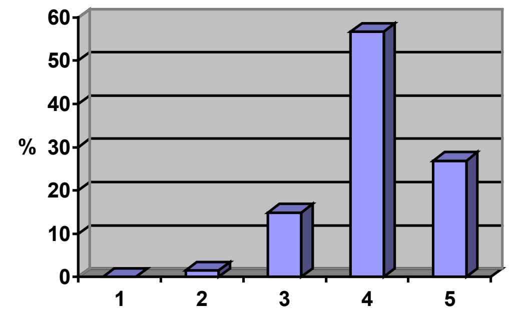

Figure D10: Amount of interaction with other faculty

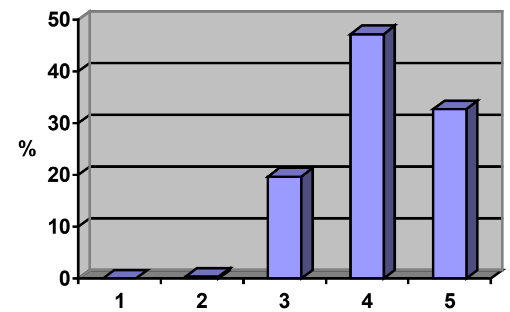

Figure D11: Ability to support graduate students

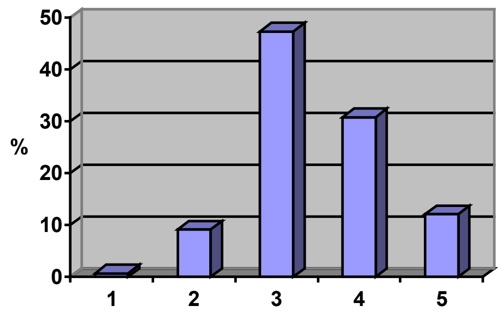

Figure D12: Amount of autonomy in conducting research

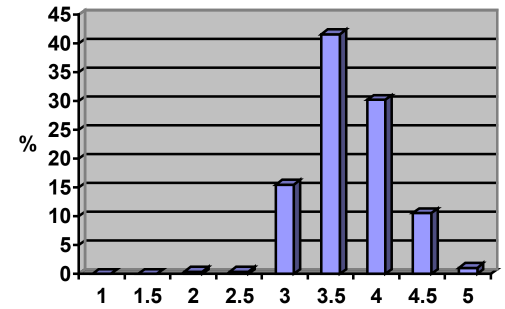

Figure D14: Faculty Benefits Scale

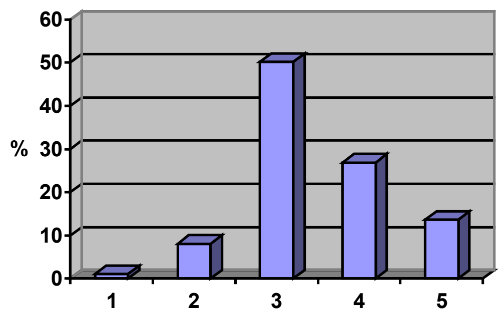

Figure D13: Ability to publish research in a timely fashion

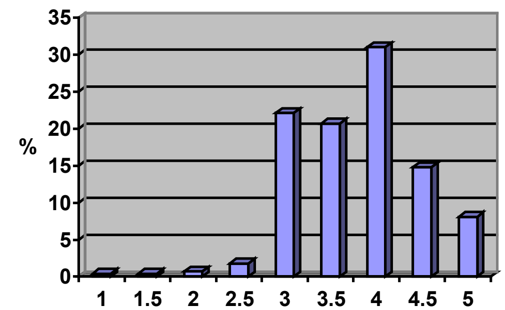

Figure D15: Faculty Symmetry with Industry Scale

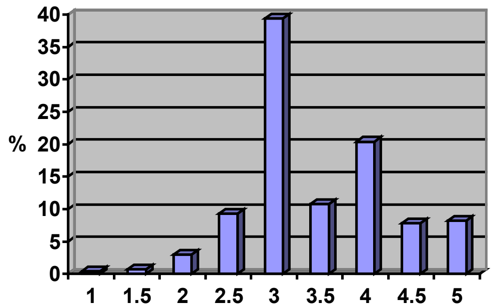

Figure D16: Faculty Academic Freedom Scale

<u>Industry Technical Benefits</u>
(1= no impact, 3= moderate impact, 5= very high impact)

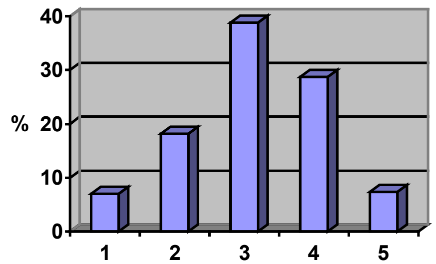

Figure D17: Industry's research and development efforts

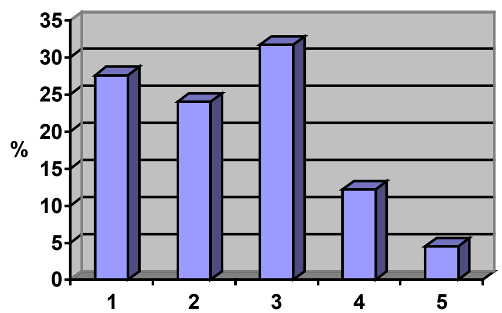

Figure D18: Industry's commercialization of products, processes or services

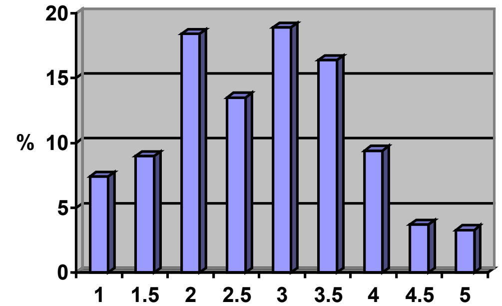

Figure D19: Industry Technical Benefits Scale

Dependent Variables

Satisfaction
(1= not satisfied, 3= somewhat satisfied, 5= very satisfied)

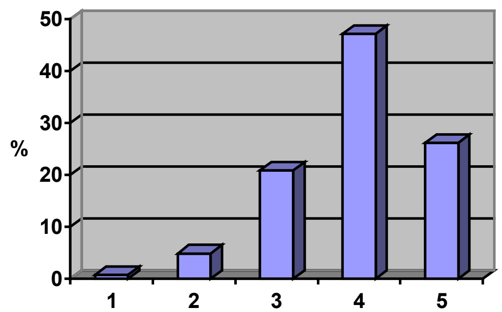

Figure D20: Satisfaction with the quality of the research program

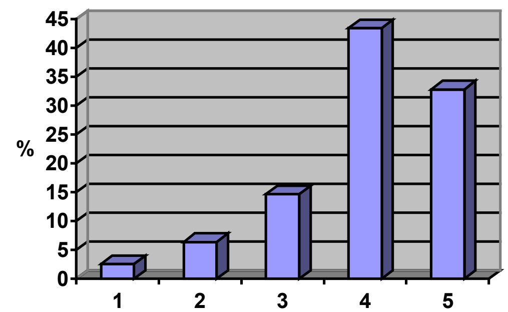

Figure D22: Satisfaction with center administration and operations

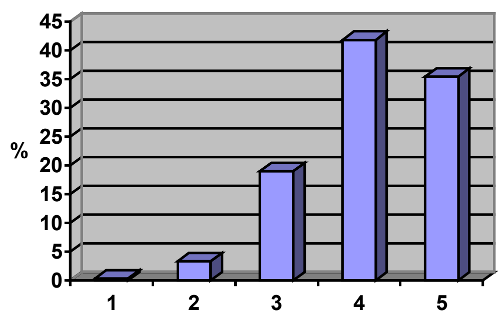

Figure D21: Satisfaction with the relevance of the research program to industry's needs.

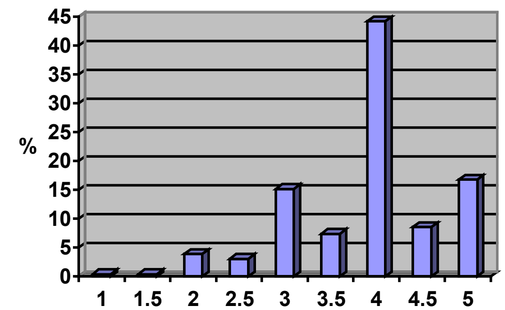

Figure D23: Faculty Satisfaction Scale

Scholarly Productivity

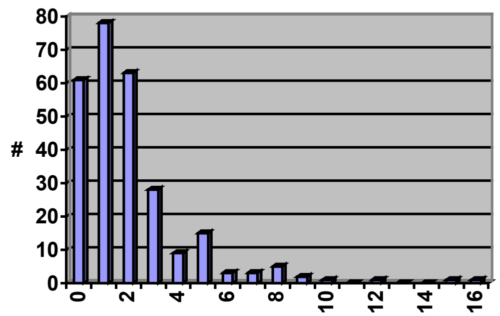

Figure D24: Number of theses and dissertations

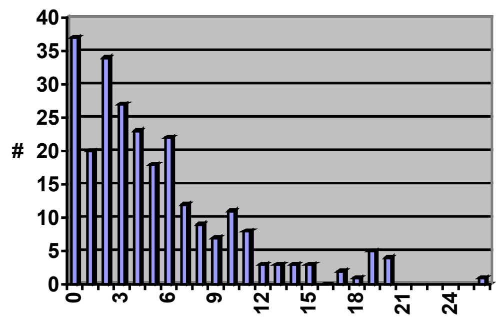

Figure D25: Total number of publications and presentations

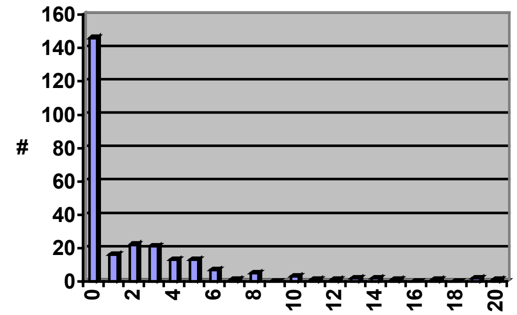

Figure D26: Number of publications and presentations with member scientists.

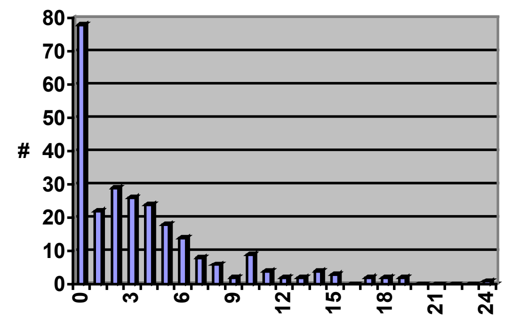

Figure D27: Number of publications and presentations with students.

APPENDIX E

<u>Question 6:</u> If you believe members benefited technically from your research, please describe what was transferred and/or how members benefited.

<u>Hiring</u>

1. One company member hired one of the center's research professors because of his center research on our project.
2. One company hired me as a consultant because of my center research.

<u>New/Improved</u>

1. Research under my direction led to improvements in software at a number of companies.
2. Developing new compositions
3. Research has lead to manufactures redesign.
4. New/improved technology
5. We developed new materials that will be used in industry.
6. Demonstrated use of … to make materials of commercial interest
7. Transfer of new formulation. For commercialization by members.
8. Software was delivered to members. One on one telephone support and email support for using the software was provided for 5 different members.
9. Equipment developed, used and characterized
10. Demonstrated feasibility of new applications of interest.
11. Technology has been transferred to a center member that will benefit the member
12. Introducing members to new technological areas for their in-house developments has been very valuable.
13. Two companies have adopted the approach we've formulated. Both have financially sponsored parts of the project.
14. Large scale implementation on factory floor

<u>Students</u>

1. 5 students on internship contributing/developing results that benefit companies and add to student's theses.
2. My expertise transferred through students

<u>Patents</u>

1. Produced several patents in which industry is interested
2. Numerous intellectual property disclosures, patents obtained, submitted and in preparation by attorney, and license agreements; research agreements.
3. Patent
4. Another company paid for the (non-exclusive rights) filing of a US patent on center technology, which they plan to commercialize.
5. IP generated very low cost to embers.

Knowledge/Understanding

1. Knowledge was transferred. Has allowed new processing methods at higher speed.
2. Basic understanding of issues
3. The center research provided the member companies with new technical information regarding recent advances. A number of companies provided feedback and oversight of the research program to guide the research towards systems they were interested in.
4. Information
5. Information
6. Transferred information
7. Design information
8. More understanding
9. More understanding
10. Basic knowledge is important to industry, science, and govt. Our information is allowing better decisions regarding the use of …by industry and govt.
11. General subject matter updating
12. Developed fundamental understanding.
13. Developed fundamental understanding.
14. I believe some of the research results have helped members understand. I don't know how this translated into product improvement, at least not in specific cases.
15. Knowledge gained
16. An understanding of a process.
17. I believe that members gained a fundamental understanding
18. Knowledge of different approaches to study.
19. Our research program continues to benefit ind. Members. Through improvements in methodology, improved process monitoring, and improved understanding
20. In general, a better understanding. More specifically, we have provided tools and methodology which can be applied.
21. Knowledge of ways to study…; also,
22. Companies now have information based on research conducted
23. We provided specific information
24. Our work has resulted in a better understanding of process variables, and our equipment has been made available to industrial sponsors for evaluation of the technology.
25. Providing member companies with basic principles addressing their problems in a broad sense.
26. Our research provided results to the member company that helped them understand the basic chemistry behind their products. This research will allow them to understand the uniqueness of their product and to make certain product claims.
27. This problem is important to understand better.
28. Understanding of fundamental problems and limitations.
29. New ideas
30. I organized a workshop on an issue most industrial reps had indicated was critical on which they claimed to have little basic understanding.
31. Discussions with researchers in the company may result in the implementation of ideas resulting from center-funded research.

32. Our technical reports, publications, and individualized training of resident visitor scientists had a noticeable impact on the member companies.
33. There is some possibility that we will be able to improve the member's quality control by providing a better understanding of the characteristics of their product.
34. Evaluation will help both supplier, users and information utilization.
35. Presentations made at 4 companies this year.

Process

1. A good understanding of an important process was developed, which is valuable to industry in improving productivity
2. Demonstrated technical feasibility of new process.
3. Improved process.
4. At least one project has tremendous potential for improving process
5. Understanding of process
6. Helped in optimizing the process.
7. Development of processing schemes has greatly aided both member companies as well as other faculty internally.
8. Models were developed of members' processes. We were able to help members improve their decision making about process changes and to develop a capability to help companies.
9. Evaluation of the process.
10. Developed processing techniques
11. Our sensors may be directly used in some member companies' processes. We're looking into these issues, especially seeking collaboration and funding for development of out projects.
12. Member used technical information and test information to bench mark and improve a new production process.
13. Priority research with one member company. Direct impact on operation of a large commercial process.

Data/Data Analysis/Methods

1. Data and program
2. Generated data
3. Generated lots of data
4. Priority data analysis with 2 member companies. This may lead to presentation of results in some format at IAB meetings. This may lead to separate contracts for focused research with these companies.
5. Discussions with 2 companies about data analysis and involvement with their problem processes.
6. Techniques for quantitative analysis are useful for member
7. Useful method for formulation and processing of any sensitive molecules.
8. New method. People from industry were interested in this new technology
9. An attempt to …without binding is being investigated. This could transfer to industry members using …
10. New methods

11. Methodology transfer to a number of companies
12. I was able to provide input and guidance on statistical methods and design of experiments.
13. Method to monitor individual components of a process
14. The main research output was measurement techniques and interpretation/understanding of these measurements.
15. My research developed new accurate techniques for measuring. This was used to do numerous studies and analyses
16. Development of new design and analysis tools that provided market edge for the members.
17. Developing new methods.
18. Helped two companies complete their own measurement system.
19. I believe the members will apply the new method we are developing.
20. For two companies, we are in the process of transferring analysis methods for application.
21. New analytical technique was demonstrated and proven useful for industry.
22. Made specific measurements for technologies
23. Techniques have been transferred
24. Companies have benefited from these techniques.
25. Several members contacted me for assistance employing a technique developed in the center
26. Companies made aware of new technique
27. New approach
28. Obtained tool for use in analysis and design
29. Development of new characterization techniques
30. We were able to introduce new techniques for
31. Introduced new approach
32. New ways of looking at
33. Development of simulation tools for sponsors.
34. I am collaborating on technology transfer of method. The goal is an additional integration method.
35. Method improvement applicable to a wide range of applications.
36. Identified treatment
37. Two versions of a tool were transferred to the center affiliates. As a result one affiliate has initiated with us joint research. Another affiliate formulated a new research problem based on our design.
38. Demonstration of the feasibility of certain approaches and the usefulness of solutions to certain problems.
39. Showed new technology, benefited by increasing understanding of analysis
40. Not relevant until commercial production begins
41. How to better design
42. Development of analysis
43. Algorithm enhancement
44. Design a system. The sponsor has obtained and is evaluating such a system.
45. Our successful system may be showing some members the way to proceed in this industrial timely area.
46. Simulation code was distributed
47. A member of the technical state of a member company showed that our method is crucial in the success of the particular implementation of a standard proposed by a (nonmember) company.

48. Expertise in using technique. Two member companies have asked for assistance in the area
49. Ability to formulate
50. Introducing members to new technological areas for their in-house developments has been very valuable.
51. Two companies have adopted the approach we've formulated. Both have financially sponsored parts of the project.
52. Characterization of industrial samples.
53. Real-time error compensation.

New Models

1. Develop model
2. Advanced model
3. Transfer of tools and models to a number of members.
4. Created simulation model.
5. General reliability prediction model.
6. New models and software have already begun used extensively by member companies leading to better reliability trend analysis and forecasting.
7. Model transferred to company
8. We delivered models to vendors. Students have had summer internships with companies, which provides technology transfer.
9. Concepts for future products and services.
10. Work in my group has directly benefited the development of engine at member company. This is just one example. There were a few other projects of similar nature.

Other

1. I got no sense whether the members paid attention. The research is first rate, but I think industry takes notice if something fits an immediate application. Otherwise, they might take interest in recruiting of students, although I have seen nothing concrete from our members. Right now, I am skeptical whether industry really wants research.
2. The members manifested their interest in the conducted research through their representatives participating at the center meeting, but afterwards no one responded to my contact attempts.
3. Work is in progress, technical benefits will appear within next year.
4. I was only minimally involved in the center last year.
5. This type of activity takes enormous time. The technical contacts are very busy (as we are) and initiatives advance slowly with out myself pestering them on a very frequent basis.
6. Same as past surveys
7. Open discussion at meetings
8. Access to unique lab resources
9. I found a very much outmoded operation that needed much current technical expertise. I believe that their entire operation was improved.
10. Our research is the only research in the country. Very wide circulation and demand.
11. Combination of lab and field trials brought great benefits in reducing replacement cost and proper management.

12. Our research is very basic. Most member companies do not do this type of work. Thus our results and conclusions are of value in that the companies have "paid" relatively little for needed research.
13. Studies have been important to member companies.
14. I showed member companies how my research is directly applicable to their work. I am also connecting them with other companies or members who can mutually benefit by the interest intersection of my research, the company I am helping and third party company.
15. From the initiation of discussions, potential for a greatly enhanced scientific team, and a "window" into the interests of companies.
16. Equipment transfers and continuing interactions outside center activities with former center members who have left the university.
17. Work has influenced sponsors
18. Ability and readiness of faculty members to address member's immediate needs.
19. Project offered members connections with collaborating universities and with members of the other center
20. All center member companies can benefit from the result of this research.
21. Company visits have confirmed that they are trying research results. They were also interested in details
22. I think that I've added visions for automation possibilities (which are practical) and this has opened industrial sponsors to possibilities. Research is just coming to fruition with useful results for industry.

<u>Question 8:</u> How can your center improve its research and/or administrative operations?

<u>Good Things</u>

1. I think the center is great!
2. Our center is well run. I would very much like to continue my participation with center sponsored projects.
3. I am very happy with the center. Just the right combination of guidance and freedom
4. It is functioning well
5. I am very satisfied with the operation of the center. In general, I would like to receive more feedback from the industry members.

<u>Money</u>

1. More timely transfer of funds.
2. The state support should continue.
3. Direct $ per industry votes
4. Less staff and more grad students funded
5. More industrial funds are needed. The current membership level of $30,000 does not generate enough revenues to undertake substantial projects.
6. Have a plan for supporting projects for at least 2 years.
7. No budget cuts at the end of a project year.
8. Budget for center, expenses, etc. should be clearer.
9. Better collection mechanism- match companies budget, cycles to when bills sent.

10. More coordinated efforts between center and members to seek new funding.
11. The one thing that would be helpful would be to raise the center fees to $50,000.
12. Center needs more funds to work with
13. Expand resources to allow grad student travel to more technical meetings.
14. The university accounting system and accounting office functions need considerable improvement.
15. I would like to get a better idea of how the budget is being spent on. Its very hard to know what the current expenditures are versus the budget fund for a project.
16. Frankly- I get minimal support for ½ a student and do much more work for the center. It's a losing game.
17. More professor and university support.
18. Center should not cut-off funding of projects based on graduate student theses.
19. Need more support for marketing efforts.

Increase Membership

1. Increase industrial membership!
2. Greater recruiting effort.
3. Increase industry members
4. Increase the number of sponsors by about 50%. This will provide much needed resources for improved research and administrative operations.
5. Industry support needs to be increased, either more companies or higher annual membership fees. Need to confirm industry commitment prior to award of grants, so that they are not cut or reduced in middle of periods.
6. Need to activate member recruitment campaign.
7. Center is doing well. Attracting more members is always a plus.
8. More members
9. More member companies and core funding support to have more center projects.
10. We must get the other university to be more active in recruiting sponsoring companies. They still do not have the minimum number required by NSF. The efforts of most faculty in recruiting new members has been disappointing, both within and outside of the school.
11. It will also be helpful if the center faculties take active roles in recruiting members and perform their commitments in a timely fashion.
12. Add one or two members from aligned but not currently represented industry. Seek facilities access at National Lab with unique resources.

Increase Industrial Interaction

1. We need more industrial participation. Without member companies, active participation, center research will have little chance to be implemented.
2. More interactions with member companies
3. The industry participates the research on more regular basis if possible.
4. There needs to be a much better mechanism for linking researchers with center members (industries) in order to determine and evaluate industry's needs. Perhaps a workshop or open forum for discussion could be held. There also needs to be more opportunities for researchers and center members to interact.

5. Encourage and support (technically) more interaction between centers and industry as well as between the three centers.
6. Industry members need to clarify needs better
7. I would like to find ways to encourage all of our industry/agency members to be more responsive to our requests for their input. The members' emphasis (of those who attended the entire meeting) during the recent IAB meeting on developing a "roadmap" and other tools for improved member recruitment, etc. is a good sign. But still, we have a few members who are very giving of their time and ideas, and others who seem to be somewhat limited in their interaction with the center.
8. One member and one student is inefficient but through hard work he manages.
9. More emphasis in subcommittee meetings, having the companies specifying which topics/area they need to be addressed by the work being performed.
10. We need to find a way to stimulate project proposals from industrial sponsors- we lag far behind other centers in this regard. We also need to be more energetic in sponsoring short courses and symposia. We need to discuss these concerns, perhaps at the next IAB meeting.

<u>Communication and Coordination</u>

1. The center needs more attention to information flow to Pis. It seems that commitment to the center has lessened. Are the center members satisfied with the last year of administration? Are new members being identified and recruited?
2. Need better and more rapid dissemination of information and materials to members and faculty. Getting money to hire full-time administrator would help.
3. More effective communication and coordination between university office manager/accountant, university administrative assistant and other site secretary to the director.
4. If the faculty openly collaborate with each other more than what is happening now.
5. Develop an email and homepage system that researchers who are members can log on and keep in touch with each other. May help stimulate cross over research.
6. Better coordination between center projects, search for higher impact problems.
7. Greater need for communication between center members
8. I agree with comments made last year by some industry members that the technical committees need to function "better". Somehow these committees need to find/have more time to define and refine their proposal interests.
9. It is this scientist's opinion that the center needs to articulate a coherent vision and develop a plan to recruit members based on this vision. The current mission is simply too broad unless it is focused on developing a toolbox rather than trying to solve specific problems. On the other hand, there is a real need for innovative approaches to the study of ... In the opinion of this investigator, the center should concentrate on building a cooperative research network designed to solve problems for industry.
10. Better coordinated activities of Pis and develop strategies.
11. Establish faculty/staff advisory committee to recommend future role/direction of the center.
12. Perhaps we should use part of the members funds to have a bimonthly videoconference among the researchers at the 4 universities. Limit it to one hour and have a sort of "rapid fire" project review and action setting plan. This could have the benefit of having more of the researchers get to know one another. The members could participate, too. Some of our

members have suggested this type of thing for "subgroups" within the center (for instance, we are going to try to set up a videoconference for the lung/fiber projects soon) but at this moment, we really don't have many identifiable "subgroups".
13. Research administration: have regular seminars by scientists/faculty working on projects.
14. Decrease frequency of reports (written) from quarterly to bi-annual
15. Decrease publication lag time.
16. Elimination of the two-evaluator system. Go to one evaluator for the center (both sites).

Director

1. The director does a good job.
2. Concept of two directors is poor, one director with responsibilities and accountability.
3. Director still regards this as a "one man band" at ASU we are treated as second class citizens in so far as decision making is concerned. Even our inputs for the newsletter are ignored.
4. At the moment we have intern leadership at director. We need to actively recruit an outstanding director. The current office staff are outstanding but we do need leadership to focus on the directors of the center.
5. Directors run the model for the administration of other centers.
6. Director has done a wonderful job working to improve Center operations and be more responsive to the needs of academics and industrial affiliates. He has been open to changing the venue for the center meetings by having them jointly with other conferences.

Administration

1. I believe it functions well as it is. Perhaps fewer, but more complete, messages from the admin. Staff before meetings would be preferable.
2. Center leadership is very good. The staff is sometimes helpful, but more frequently are uncooperative and difficult to deal with. This has dampened our enthusiasm to participate.
3. Provide more job security for key personnel. Avoid "turnover", which can significantly affect progress.
4. In my opinion, the center is understaffed in administrative needs
5. Retention of personnel (lost a technician after three months). Higher salaries to attract top people to a small town.
6. Administration needs to market and promote member's research more.
7. Need less frequent administrative meetings, once per year should be accurate.
8. Administration needs to be more timely in requests for information. Requests are usually at the very last minute and therefore it is very difficult to respond in time.
9. Administrators are too separate from school program and absorbs too much of the funds. New reporting requirements make it difficult to be "partly" center and "partly" something else.
10. Allow center to continue LOCAL control. Some center procedures are "at-odds" with "standard" NSF guidelines. Prefer center ideas.
11. Short handed!
12. Overworked
13. More clarity on center's requirements for grantees how that change in administration.

14. Still challenges with multi-university issues. Administrator is doing a great job holding it all together.
15. It is my opinion that the center's administration had not been an obstacle to my research effort and thus it is doing a commendable job.
16. Administration works quite well, no complaint.
17. The center administration is very efficient and organized.

<u>Faculty and Students</u>

1. The center needs more faculty lines, especially at the level of assistant professorts since we have a lot of graduate students
2. Reduce activity reporting and faculty.
3. More faculty participation is desperately needed.
4. It is in pretty good shape. Emphasis on research seminars before students submit papers outside will help
5. Recruit higher quality students and postdocs.
6. More visitors, more postdocs

<u>Research</u>

1. Try to direct research towards a bit more longer term (2 years funding, for example)
2. More emphasis on fundamental research. Less on design projects
3. I think many of the current projects are too applied or limited in scope.
4. More emphasis on basic research that has industrial implication would be nice. Also, much of the work appears to be done in isolation- little cross fertilization and little effort to bring in many other projects.
5. I think the center would benefit from having a lot of short-term, directed research (as they do) but also a longer term research program (10 years). My research is quite fundamental and seldom can I make significant advances in 1 or 2 years.
6. More basic and innovative research, member complain about "mundane" proposals but that's all they fund. Basic research is discouraged.
7. The center could improve its research by having a few more modalities that it does not now have. This would require some equipment money.
8. Stability and diversification of research
9. More discretionary, high risk projects.
10. Need more core research and fundamental work
11. Need to promote research activities across other departments
12. Does serve industry as a job shop, but is week in fundamental science (partly based on short industrial time frame)
13. I am not aware of any publicly circulated requests for proposals during the past 2 years. If IRFPs are not opened to academic members, membership and enthusiasm will stagnate, at best. Some of the topics of the "research" projects currently funded are quite inadequate, in my opinion.