Handbook on the Theory and Practice of Program Evaluation

Edited by Albert N. Link, Professor of Economics, University of North Carolina at Greensboro, US and Research Professor, Max Planck Institute on Entrepreneurship, Growth and Public Policy, Germany and Nicholas S. Vonortas, Professor of Economics and International Affairs and former Director, Center for International Science and Technology Policy, The George Washington University, US

"The economic crisis has simultaneously placed a strong emphasis on the role of R&D as an engine of economic growth and a demand that limited public resources are demonstrated to have had the maximum possible impact. Rigorous evaluation is the key to meeting these needs. This Handbook brings together highly experienced leaders in the field to provide a comprehensive and well-organized state-of-the-art overview of the range of methods available. It will prove invaluable to experienced practitioners, students in the field and more widely to those who want to increase their understanding of the complex and pervasive ways in which technological advance contributes to economic and social progress."

- Luke Georgiou, University of Manchester, UK

Theoretical and empirical research on program evaluation has advanced rapidly in scope and quality. A concomitant trend is increasing pressure on policymakers to show that programs are "effective." Now is the time for a comprehensive status report on state-of-the-art research and methods by leading scholars in a variety of disciplines on program evaluation. This outstanding collection of contributions will serve as a valuable reference tool for academics, policymakers, and practitioners for many years to come.

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There has been a dramatic increase in expenditures on public goods over the past thirty years, particularly in the area of research and development. As governments explore the many opportunities for growth in this area, they - and the general public - are becoming increasingly concerned with the transparency, accountability and performance of public programs. This pioneering Handbook offers a collection of critical essays on the theory and practice of program evaluation, written by some of the most well-known experts in the field.

As this volume demonstrates, a wide variety of methodologies exists to evaluate particularly the objectives and outcomes of research and development programs. These include surveys, statistical and econometric estimations, patent analyses, bibliometrics, scientometrics, network analyses, case studies, and historical tracings. Contributors divide these and other methods and applications into four categories - economic, non-economic, hybrid and data-driven - in order to discuss the many factors that affect the utility of each technique and how that impacts the technological, economic and societal forecasts of the programs in question.


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10. Evaluating cooperative research centers: a strategy for assessing proximal and distal outcomes and associated economic impacts

*Drew Rivers and Denis O. Gray*

**INTRODUCTION**

This chapter describes a methodology, refined during a recent feasibility study, for capturing economic impact data from private sector firms involved in cooperative research with universities. We focus on a specific science, technology and innovation (STI) programmatic initiative—cooperative research centers (CRCs)—and explore a possible approach for overcoming barriers to gathering return on investment and other financial data from CRC member firms. Building on the foundation laid by the ongoing evaluation of the National Science Foundation (NSF) Industry/University Cooperative Research Centers (IUCRC) program, our study had two objectives: first, to assess the existing program evaluation protocols with regard to capturing estimates of economic outcomes generally; and second, to pilot test an interview-based approach for gathering credible and persuasive data on more distal economic outcomes.

We first analyzed archival data sources and concluded that the existing IUCRC evaluation strategy does a good job of addressing the program’s explicit partnership and capacity-building objectives, and at measuring outputs and proximal outcomes like publications and patent applications based on center research. While these instruments do capture economic outcomes to some extent (for example, cost savings or cost avoidance), they do not consistently capture more distal (and likely more significant) economic outcomes derived from process, product and service innovations. Most respondents to these existing evaluation instruments appeared either unable or even unwilling to disclose these types of outcomes.

As a consequence of these findings we examined the value of a complementary assessment strategy: confidential interviews with key informants inside firms that had been nominated as potential “high impact beneficiaries” of ideas and technologies generated by established IUCRCs. This
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assessment strategy proved to be successful in gathering rich information on how these centers contribute to innovation and in obtaining credible, quantitative estimates of the economic impacts of IUCRCs on program stakeholders. We conclude the chapter with a discussion of the benefits and potential challenges of our approach for assessing the distal outcomes and economic impacts of CRCs.

COOPERATIVE RESEARCH PARADIGM AND COOPERATIVE RESEARCH CENTERS

One of the most important science, technology and innovation (STI) policy developments over the past thirty years has been the development and the widespread diffusion of a government-supported cooperative research paradigm that attempts to foster closer, more collaborative and, hopefully, more productive ties between public and private sector research performers. Readers interested in understanding the global reach of this phenomenon are encouraged to review the special issue devoted to this subject in Science and Public Policy (38(2), March 2011).

A key programmatic element of this emergent stream of STI policy is the cooperative research center (CRC), an “organization or unit within a larger organization that performs research and also has an explicit mission (and related activities) to promote, directly or indirectly, cross-sector collaboration, knowledge and technology transfer, and ultimately innovation” (Boardman and Gray, 2010, p.450). We have argued elsewhere that CRCs are both a complex and flexible form of boundary-spanning intermediary organization (Gray et al., 2013). CRCs are conceptually and organizationally interesting because they embody three of the most important and powerful trends in STI over the past three decades: the collectivization of research, the emergence of a cooperative research funding paradigm in government, and the growth of an open innovation paradigm. Because of the flexibility that policy makers and program designers can exercise in incorporating these and other organizational features, CRCs are best thought of as a general class of boundary-spanning organization. As a consequence, CRCs can be and have been developed to achieve a variety of STI-related objectives. In fact, the typical “multi-purpose” CRC might target a combination of scientific, technological, commercialization, entrepreneurial and human capital goals.

Over the past several decades, CRCs have grown in number and importance within national innovation systems around the globe. While the lack of a common definition makes it difficult to accurately pin down the number of CRCs operating in the US, let alone globally, the numbers
appear to be large and growing. The only attempt to produce a census of a similar but more narrowly defined form of organization – university–industry research centers – in the US, resulted in an estimate of about 1100 (Cohen et al., 1994). However, given the increasing popularity of “collective/team-based science” and the collaborative research paradigm of government funding over the past thirty years, the numbers are almost certainly much higher. According to the Research Centers and Services Directory (Gale, 2009), there are nearly 16000 university-based and other non-profit research centers and 8000 government-based research centers in the US and Canada. We believe a significant percentage, perhaps between 15–25 percent, meet the definition of a CRC. This growth in the number and importance of CRCs is not limited to the US. According to a recent paper, CRCs similar to US Engineering Research Centers exist in Japan, China, UK, Korea, Belgium, Ireland, Germany and Australia (Lal and Boardman, 2013). Thus, CRCs have become a pervasive and important programmatic vehicle within most advanced national innovation systems.

**Program Evaluation Challenges of CRCs**

Interestingly, many of the qualities that make CRCs important and versatile programmatic interventions constitute complicating factors when one considers their evaluation. Many of these factors derive directly from the inherent complexity and flexibility of the CRC model. As suggested above, there would appear to be at least three dimensions of this factor.

1. **Organizational/programmatic complexity:** CRC programs can and do vary dramatically in terms of the extent to which and the manner in which they incorporate key programmatic and organizational features. As suggested above, key dimensions include: collective research (for example, how multi-disciplinary and team-based they are); mechanisms for cross-sector collaboration (for example, bilateral vs. consortial); where they are housed (for example, university vs. not-for-profit government lab); and the amount of funding they are provided, to name only a few.

2. **Research complexity:** CRCs can vary on the kind of research they engage in (fundamental, precompetitive, applied) and the field or area of research they contribute to (for example, biotechnology, electronics, nanotechnology and manufacturing). These differences have big implications for the types of organizations that centers attract, how intellectual property rights are handled and the likelihood of commercial outcomes.
3. **Goal/outcome/stakeholder complexity**: CRCs can also vary significantly in terms of their goals and the stakeholder groups that are supposed to benefit from them. A list of stakeholders (and related goals) for a typical multi-purpose CRC would include: scientific community (knowledge creation); industry (competitiveness; commercialization), local or national government (economic development); and faculty, university students and pre-college populations (human and social capital development). Since CRCs that promote stronger linkages between industry and university are often considered controversial, there is also a need to address unintended outcomes (Behrens and Gray, 2001).

Beyond their inherent complexity and flexibility CRCs pose at least two other evaluation challenges.

4. **Outcome latency**: Because of the amount of time needed for scientific research to have an impact and to translate into commercially viable outcomes, most CRCs are funded for extended time periods, typically five to ten years. More importantly the effects of these efforts are typically not apparent for perhaps a decade or two longer. As a consequence, a report from OECD (1987) suggests that the measurement of the distal outcomes of various STI initiatives is by far the most conceptually and methodologically challenging type of evaluation research.

5. **"Value added" expectation**: Feller et al. (2013) have suggested that one of the most difficult challenges inherent in CRC outcome evaluation is the expectation, sometimes codified in their enabling legislation, that evaluators provide evidence of "value added" or "additionality" beyond outcomes that would be provided by more traditional funding schemes like individual investigator awards. According to their analysis, these expectations create significant methodological and analytical challenges for the program evaluator.

CRCs present some unique challenges for program evaluators based on their complexity and expectations about the timing and nature of anticipated outcomes. This general class of boundary-spanning R&D organization can vary significantly in terms of program/organization, research focus and goals/stakeholders. There does not appear to be any evaluation "magic bullet" to solve this problem. It simply suggests evaluations will have to be program-specific, will have to be very careful and precise about the construct validity of treatment (for example, what type of CRC) and effects (for example, what kind of effect for what stakeholder group) and may have lower external validity (Shadish et al., 2002).
At the same time, we believe issues related to the latency of important outcomes and the need to demonstrate the value added or additionality of various outcomes while challenging are more tractable given the right evaluation strategy. Based on this assumption, in the remainder of this chapter we will attempt to do three things:

1. describe a specific CRC program and highlight select components of its multifaceted process and outcome evaluation strategy;
2. provide an analysis of archival data to demonstrate how the existing program evaluation attempts to assess outcomes for one stakeholder group—industrial firms;
3. describe a recently conducted feasibility study that attempted to strengthen our ability to document relatively distal outcomes and their impacts for this stakeholder group.

The IUCRC Program and Its Multi-Faceted Evaluation Strategy

Our analyses suggest there are four major types of CRCs defined by two dimensions: university-based versus non-university-based, and bilateral versus network (consortial) partnership arrangement (Gray et al., 2013). The National Science Foundation’s Industry/University Cooperative Research Centers (IUCRC) program is representative of one sub-category of CRC: a university-based, organized research unit supported by a consortium of firms. In an earlier publication we provided a more detailed description of the program.

Like other CRCs, the program’s most important goal is to develop and transfer new knowledge and technology to industry; it also attempts to enhance graduate education. In contrast to many highly funded center programs discussed in the literature, NSF attempts to achieve this end by way of very modest cost sharing (about $75,000 a year per site) for up to 10 years. Ultimately, NSF hopes to create self-sustaining centers.

In brief, IUCRCs are university-based, industrial research consortia. The research performed in the centers tends to be strategic or proprietary fundamental research and is carried out primarily by faculty and graduate students. IUCRCs follow a relatively standardized set of policies and procedures: members pay an annual fee (usually between $30,000 and $50,000 per year), and they get equal access to, and ownership of, all research and intellectual property; findings, know-how, and technology are transmitted through a variety of means, including periodic reports and semiannual meetings; and members get one vote on the center’s Industrial Advisory Board (IAB) (Gray, 2008, pp 80–81).

The IUCRC program currently supports 56 centers involving about 120 universities, over 1000 firms, nearly 1000 faculty, 1500 graduate students
and nearly 400 undergraduates. Centers tend to be diverse in terms of budget ($300,000 to $15 million), number of research personnel (5 to 73) and number of industry members (4 to 103). Centers also represent diverse areas of technology: manufacturing, computer science, nano- and micro-technology, chemical processing, biotechnology, and advanced electronics, to name a few.

The IUCRC program has been the subject of a novel and ongoing evaluation effort for over thirty years. It is framed around three primary objectives: to promote continuous improvement by giving actionable, data-based feedback, analysis, and advice to the centers and NSF; to identify and communicate program-wide best practices; and to document IUCRC outcomes and accomplishments for centers and the NSF IUCRC program. The most novel aspect of the evaluation effort has been its commitment to an “improvement oriented evaluation” strategy related to objectives 1 and 2 (above) that is implemented through a team of onsite “embedded” evaluators. The rationale for and procedures that support this effort are described in more detail elsewhere (Gray, 2008).

Consistent with the third objective, the evaluation effort was also designed to assess program outcomes and impacts. This multifaceted evaluation effort has included: monitoring of program implementation and inputs; annual assessment of process and outcome data by onsite evaluators via questionnaires and direct observation; and episodic collection of more targeted outcome and impact data by the IUCRC Evaluation Team based at North Carolina State University and other evaluators. These activities have focused on various stakeholder groups (members, faculty and directors) and outcomes (satisfaction, organizational commitment, sustainability, publications, technology transfer). A detailed description of the evaluation system, instruments, reports and publications can be found on the project website (www.ncsu.edu/iucrc).

In the following sections we review the evaluation’s success in documenting the program’s impact on member firms and highlight an attempt to enhance its ability to document more distal outcomes and impacts for this stakeholder group.

ASSESSING MEMBER OUTCOMES BASED ON ANNUAL MEMBER SURVEYS

The IUCRC program’s stated goals primarily emphasize partnership and capacity-building (for example, research infrastructure, S&T workforce, international collaboration) and its evaluation activities have been designed to address these areas (see www.nsf.gov/eng/iip/iucrc/). It is
important to note that the IUCRC program does not have an explicit goal
to have a direct economic impact. However, since the program is supposed
to “contribute to the Nation’s research infrastructure” and encourage “the
nation’s research enterprise to remain competitive”, the program could
be expected to have an indirect but measurable impact on these types of
outcomes. These goals go directly to the notion of “value added” and
“additionality” of CRCs highlighted by Feller and his colleagues (2013).
Our goal was to see if this expectation is indeed the case.

In order to explore the existing evaluation effort with regard to capturing
economic outcome data, we reviewed three archival data sources from
the IUCRC Evaluation Project:

1. operational data reported by center directors on outputs and, to some
   extent, outcomes;
2. outcome data collected from member companies via the annu-
   ally administered Process/Outcome Questionnaire (that focuses on
   relatively immediate outcomes and impacts); and
3. reports of actual technology outcomes and impacts or “success stories”
documented in the 2009 Compendium of Technology Breakthroughs
(Scott, 2009).

A review of these data provided important information on the ability of
the existing evaluation effort to document proximal and distal outcomes
and economic impacts, and helped guide the design of our pilot study
described in the subsequent section.

Operational Inputs, Outputs and Outcomes

One source of relevant data on IUCRCs is the annual Structural
Information Report (for example, Gray and McGowen, 2010). These data
are provided by IUCRC center directors and cover a number of areas
including: funding amount by source; personnel counts (including center
staff and faculty PIs); membership counts; trained and graduated student
counts; and outputs/outcomes (for example, invention disclosures, patent
applications, publications, start-ups, copyrights, and licensing agree-
ments). Since IUCRCs are supposed to be collaborative, to leverage NSF
funds to support graduate students, and to create long-term partnerships,
one measure of the success of a center and of the program as a whole
in providing value-added outcomes is the extent to which NSF IUCRC
funding triggers funding from various stakeholders and how much lever-
ergaging results from this additional funding. Feller et al. (2013) have
described this outcome as “input additionality”.

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The Structural Information Report contains center and program-level funding data by source, including industry, university, NSF, other federal sources, state, and non-federal sources (for example, foundations). We analyzed these funding data for three fiscal years (ending in 2008, 2009 and 2010) and found that $1 invested by the NSF IUCRC program resulted in $6.3 to $9.9 in additional funding (member fees plus all other funding sources).

Centers vary in the amount of leveraging they achieve. To gauge center-level variation on these metrics we examined the leveraging realized for three IUCRCs during the 2009–10 fiscal year. Centers were selected to represent the low, average and high level in total funding. The center representing the low end of total funding produced $2.4 in additional funding for every NSF IUCRC program dollar. The center in the mid-range of total funding generated $5.4 for every NSF IUCRC dollar. The center representing the high end of total funding produced considerably more leverage, yielding $44.0 (industry plus other) for every NSF IUCRC dollar. Clearly, there is substantial evidence that even the lowest performing IUCRCs are producing significant leverage, with the highest performing centers leveraging NSF support in excess of 40 to 1.

**Perceived, Realized Outcomes and Impacts (2008–09 Program Year)**

The NSF IUCRC Process/Outcome Questionnaire is administered annually by onsite center evaluators to member organizations. The questionnaire is designed to provide local center stakeholders with relatively real-time feedback on center operations (for example satisfaction with different features of the center) and various outcomes that are reported by member firms. As described above, onsite evaluators use this feedback as the basis for their “improvement-oriented” evaluation efforts. Importantly, members are asked to report outcomes and impacts they observed “during the last twelve months”. While some outcomes including “networking with other scientists” are difficult to translate into quantifiable impacts, other outcomes like R&D activities and commercialized innovations might be converted into economic terms. Although all members receive the questionnaire and onsite evaluators are proactive in following up with respondents, the questionnaire is typically completed and returned by about 40 percent of all active members. Since our data only contain outcome information from a percentage of all members, one must be careful in interpreting these results.

Each program year IUCRC members (primarily R&D professionals from private sector firms) are asked to estimate the dollar value of all center-stimulated research projects, or follow-on funding, conducted
Figure 10.1 Impact of IUCRC research on member firms’ R&D spending

Internally or contracted out during the past year. This outcome, R&D spending based on center research, could be viewed as confirmation of the relevance of the center research to firms and as an indicator of future outcomes derived from ideas and technology stimulated by the center. We analyzed data from 213 respondents to the Process/Outcome Questionnaire who reported an estimated dollar value. The top graph in Figure 10.1 displays the distribution (based on collapsed data) of the reported dollar values. Thirty-eight percent of members reported zero
dollars. The average reported value for a member was $382 thousand and the median value reported was $25 thousand. The bottom graph in Figure 10.1 shows the dollar values in descending order. What is clear from this graph is that most of the follow-on funding is reported by a small number of respondents.

Total program-wide value for center-stimulated research projects among the sample of IUCRC members came to $81.3 million. Conservatively, every dollar of NSF IUCRC program funding stimulated roughly $9.6 in R&D spending by member companies (based on $8.5 million in NSF IUCRC program funding during the same period). Further, when a firm spends a dollar on IUCRC membership support, the firm typically invests another $3.48 internally, on average. Since just 36 percent of IUCRC members (213 out of 588 total members) responded to the Process/Outcome Questionnaire and also provided a numeric response to this item, we believe this could be a very conservative estimate of center-stimulated research.

Survey respondents also provide a self-report rating along a five-point anchored scale regarding the degree of impact of the center on their internal R&D, commercialization, and professional networking activities. The data suggest that centers have a greater impact on professional networking and on R&D activities, compared to commercialization. About 43 percent and 32 percent reported a high or very high impact on professional networking and on internal R&D, respectively. With regard to commercialization, just 8 percent reported a high or very high impact.

As a follow-up to these ratings items, another item in the Process/Outcome Questionnaire asked respondents in open-end format to describe in their own words the kinds of impacts they received (for example, a research advancement or product improvement) and to quantify those impacts if possible (for example, dollars saved or scientist months saved). Ninety-one respondents submitted a text response to this item. These responses provided us with insight into the types of benefits members are receiving and their willingness and ability to translate those benefits into economic terms. We coded responses into one or more of 16 categories which we then aggregated into five general categories of benefits: R&D related benefits, commercialization benefits, anticipated benefits, other benefits, and no or limited benefits.

About 70 percent reported R&D-related benefits, including the stimulation of new research projects, R&D project acceleration and associated cost reductions, and increases in the knowledge-base of the firm more generally. About 10 percent reported commercialization benefits like new or improved products or processes, whether planned, in development,
or already implemented. Fourteen percent reported other benefits, such as networking, student recruiting, and consultation from center faculty. A slightly higher percentage (16.5 percent) said they anticipated or were optimistic about future benefits. However, in only 5 percent of cases did respondents provide a quantitative economic estimate of the impact realized by their organization.

Analysis of Technology Breakthroughs

The final archival source of outcome data on IUCRCs can be found in the four volumes of the Compendium of Technology Breakthroughs (CTB) of IUCRCs disseminated by the NSF (Scott, 2004, 2007, 2009 and 2012). The methodology for collecting these reports is summarized in the CTB itself. In brief, the editor first asked each IUCRC director to identify center members who were particularly knowledgeable about the center’s research program and its impacts on science and technology. Next, the editor asked those knowledge experts to identify potential technology breakthroughs (defined as new or improved processes, products, services, or techniques that could be tied directly or indirectly back to the IUCRC) and to indicate which breakthroughs they would nominate for inclusion in the compendium. The editor then worked closely with those knowledge experts and IUCRC scientists to document nominated breakthroughs. There was no time limit for when the center had its impact or when the breakthrough happened.

To better understand the extent to which these breakthroughs were or could be quantified in financial terms we took a close look at the 173 cases described in the 2009 CTB. We coded each breakthrough on several dimensions, including type of breakthrough and stage of development, as well as whether a specific beneficiary was named and whether an attempt was made at reporting economic impacts.

With regard to type of breakthrough we found that about 42 percent of cases related to a new or improved process, while 10 percent related to a new or improved product. In terms of the stage of development, we interpreted 28 percent of breakthroughs to have already been commercialized in some capacity (and therefore potentially generating returns for beneficiaries). Other cases were nearing commercialization: about 15 percent of breakthroughs were under implementation for commercial application, while another 25 percent had reached a proof-of-concept stage.

We also considered whether organizations that benefited from the breakthroughs were identified and whether economic outcome data were recorded in the case summaries. We found that about 34 percent of cases named specific firms or institutions as beneficiaries, and another 5 percent
of cases referenced a start-up based on the breakthrough. However, in the majority of cases either no beneficiary was named or only a general sector or industry was identified as the potential beneficiary. Similarly, a large majority of cases (76 percent) either did not attempt to estimate economic impacts or provided only qualitative speculation on potential impacts (for example, "we expect this will produce commercially important process improvements"). Further, in 16 percent of cases we found realized outcomes were described in non-financial terms or as broader societal benefits. Specific, quantified economic outcome estimates were offered in only about 5 percent of cases.

CONCLUSIONS

Data collected through the existing IUCRC evaluation strategy have produced considerable evidence that the IUCRC program is achieving many of its important objectives and is having an impact on member firms and other external stakeholders. However, in terms of documenting distal outcomes and impacts of IUCRCs, these data also have their limitations.

Structural data collected from centers provide evidence to support explicit program objectives related to partnerships and capacity-building. Financial leveraging of program dollars with industry and other sector dollars could lead to potential economic impacts in cases where these investments seek to further develop innovations toward commercial application and are successful at doing so.

Questionnaire data collected directly from members regarding the benefits experienced during the recent 12-month period provide evidence of proximal outcomes and suggest firms benefit from participation in IUCRCs in a variety of ways. Just as centers were found to vary in funding levels, members also varied widely in reported value of center-stimulated R&D projects during the past year. We found most of this follow-on funding can be attributed to a small number of members. For example, while one member reported $50 million in follow-on funding, the median investment was just $25,000. In terms of economic impacts, these data suggest firms are more likely to report R&D-related impacts than commercialization-related impacts.

It is likely that R&D outcomes translate into cost savings and cost avoidances in the near term and commercialization outcomes down the road. For example, an industrial member of the Safety and Security Research Center reported the following impact: "Development of advanced video surveillance algorithms. Savings to company estimated at several hundred
thousand and at least six months’ savings in time.” Members will sometimes talk about anticipated benefits and impacts. An industrial member of the Cooling Technologies Research Center wrote, “There is a good chance this technology will be implemented in one or more of our high volume products in the 5–10-year frame.” Although we found that about 5 percent of our respondents provided economic impact estimates, the overwhelming majority did not. More often members reported benefits that are important to the organization but difficult, if not impossible, to quantify, like networking, student recruitment, knowledge transfer, and influence on their research strategy.

Case summaries of nominated technology breakthroughs in the CTB highlighted scientific and R&D outcomes that had played out over a much longer time frame of center activity and produced a much higher number of commercially relevant outcomes related to products and processes. Some outcomes and impacts may be very significant, with at least one CTB informant describing the market for a center-derived technology as exceeding $10 billion per year. However, many of these technologies were still in their early stages and respondents were frequently unwilling (for confidentiality reasons) or unable to provide economic estimates. More generally the summaries were valuable in communicating the nature of the breakthroughs, revealing how long some of them had been under development, identifying the potential beneficiary, and uncovering their qualitative impact.

In summary, questionnaire data collected from participants on a regular basis appear to provide substantial documentation of relatively proximal R&D outcomes but much less information about more distal commercialization outcomes. Investigations of nominated breakthroughs that look back over a long time frame have produced strong qualitative evidence that IUCRC research is contributing to and/or resulting in commercialized products, processes, services and techniques. Unfortunately, most respondents were unwilling or unable to provide economic impact estimates. When estimates were provided they were often made in non-financial terms or as speculation about prospective impacts. As a consequence, it would be difficult to document the more distal economic value of center activities based on the data obtained from the existing evaluation procedures.

The next section of this chapter provides an overview of our pilot study designed to capture the economic impact derived from more distal outcomes tied to IUCRC ideas and technologies.
ASSESSING MEMBER ECONOMIC IMPACTS BASED ON TARGETED CENTER AND BENEFICIARY INTERVIEWS

Impact Measures

To assess distal outcomes and their impacts related to NSF IUCRC program investments we adapted a benefit–cost methodology, which is the approach recommended for US government program economic evaluations (Office of Management & Budget, Circular A-94) and was extensively applied in the former Advanced Technology Program (ATP; Powell, 2006). Financial impact metrics generated using a benefit–cost methodology are described in detail by Tasse (2003) and Powell (2006) as well as by ATP program evaluators (Link and Scott, 2004; Pelsoi, 2005, 2007). The core metrics include the benefit–cost ratio (BCR), the net present value (NPV) of benefits, and the internal rate of return (IRR) from investments. Since the IRR calculation requires streams of benefits and costs (that is, multiple periods where both benefits and costs are estimated) and our data collection effort captured primarily aggregated year-to-date estimates, we focused on the BCR and NPV metrics.

In our case, the BCR is the ratio of the present value of estimated financial impacts (that is, benefits) to the present value of IUCRC program investments (that is, costs). We use a chain-type price index to inflation-adjust both estimated benefits and costs to the initial operating year of each center. Since IUCRCs typically operate under fiscal years that straddle two calendar years, we take the earlier calendar year as the base year. We then bring forward real benefit and cost dollars to present values using a 7 percent discount rate. A BCR greater than 1:1 indicates a center that performed above a breakeven threshold. The NPV is the net benefit of the investment in the center. We use the same information from the BCR calculation to calculate the NPV. The present value of costs is subtracted from the present value of estimated benefits.

Procedures

The objective of this phase was to assess the feasibility of gathering credible and persuasive quantitative impact estimates of distal outcomes related to IUCRC ideas and technologies, or what Feller and colleagues (2013) refer to as value-added impacts or “output additionality”. Based on findings from our review of existing program evaluation data and of the STI impacts literature, we developed our procedures on the following assumptions:
1. Since our existing evaluation data and the innovation literature (for example, Mansfield, 1991) suggest it may take years for IUCRCs to conduct research that influences a member firm’s internal R&D and then produce economically significant impacts, our pilot assessment should concentrate on a few relatively mature and/or graduated centers.

2. Since our preliminary analyses and other evidence (Tassey, 2003; Roessner et al., 2010) suggest that a disproportionate percentage of the total economic impact from centers is attributable to a small number of cases, our efforts should focus on obtaining feedback from these high impact beneficiaries.

3. Data collection should concentrate on capturing outcomes/impacts that past data collection efforts suggest could be quantified (for example, our review of archival data sources as well as published studies, for example Roessner et al., 2010). These include: R&D cost savings; cost savings from process and product improvements; sales and job creation from new processes and products; and spillover benefits to users and adopters of center technology.

4. Data collection should attempt to differentiate clearly between realized impacts from already commercialized innovations and prospective or forecasted impacts (Powell, 2006).

5. Since firms that report benefiting from IUCRCs often do not volunteer quantitative financial impacts, data collection efforts should utilize a more interactive, interview-based methodology and should provide all informants with confidentiality about the outcomes and impacts they report.

With these assumptions in mind, we targeted three mature IUCRCs (8 years old or older) where there existed persuasive anecdotal evidence that the center produced research and/or technology with the potential to have a significant economic impact. Centers were selected based on recommendations of IUCRC stakeholders including NSF IUCRC program managers, center directors, and program evaluators, as well as on success stories contained within the 2009 Compendium of Technology Breakthroughs.

We contacted the executive director at each of the three selected centers about the nature and purpose of our study and, if they agreed to participate, how they could help by connecting us with firms they believed have realized significant economic impact from IUCRC research and/or technology. All three directors agreed to help.

Once a director had identified beneficiaries, we conducted a short interview with the director to gather background information regarding how the organization had benefited from the IUCRC and to request an
introduction to their contact. Once the introduction had been sent, we followed up with an email to the beneficiary providing more information about the study, the confidential and voluntary nature of their participation, and a request for an interview. Once the interview was scheduled, we sent a confirmation email that outlined generally the types of questions we would be asking. We were successful in conducting interviews with 17 beneficiaries across the three centers (100 percent of those nominated). The success we achieved in these transactions was greatly enhanced by the relationship and trust that was built up over the years between the directors and local evaluators. In general, the interviews addressed the following areas.

1. The economic impacts of center-related ideas and technology on their organization, in the form of cost savings, new or improved processes and products, and subsequent impacts on profits or growth.
2. The time, resources, or other investments made by the organization to achieve these impacts.
3. Whether those impacts could have been realized without the center; if so, how long the organization would have been delayed in the absence of the center.
4. Other ways in which the organization is perceived to have benefited from the center.

These interviews allowed us to assess the feasibility of gathering information about more distal outcomes and economic impacts related to IUCRC ideas and technologies. The following sections review the results of these three case studies.

**Center for Intelligent Maintenance Systems**

**Background**

The Center for Intelligent Maintenance Systems (or IMS) launched in 2001. IMS is a multi-university center, with its primary site at the University of Cincinnati and partner sites at University of Michigan and Missouri University of S&T. According to the IMS website (http://www.imscenter.net/), the center’s vision “is to enable products and systems to achieve and sustain near-zero breakdown performance, and ultimately transform the traditional maintenance practices from ‘fail and fix’ to ‘predict and prevent’ methodology.” The center has been focused for most of its ten years of operation on frontier technologies in embedded and remote monitoring, prognostics technologies, and intelligent decision support tools.
Realized impacts
The nature of IMS process-related technologies allows for pervasive impact across an organization's operations. These impacts typically come in the form of improved process efficiencies that lead to cost savings (for example, reduced energy costs), cost avoidances (for example, avoided repair costs), or increased yield due to avoided downtime, and become quite significant in adopting firms with large and/or numerous operational facilities. Our six interviews discovered $570M in realized impacts enabled by IMS knowledge and technology. Impacts ranged widely, from $50 to $500M. See Table 10.1 for a summary of the six interview cases.

Funding of the IMS Center by NSF started in the 2001–02 fiscal year. Total IUCRC investments were $1.93M in actual dollars and $1.7M in real 2001 dollars. Multiple informants indicated that impacts have been accruing for several years, though accurate recall of impacts proved difficult, particularly in cases where impacts were pervasive across operations. We took impact estimates as an aggregate value in the current year, and then converted values to real 2001 dollars. Present value estimates were calculated using a 7 percent discount rate. Overall, we find for every dollar invested in IMS, the NSF creates $270 in return. Subtracting the present value of the IUCRC program investment from the present value of estimated impacts, we find an NPV of more than $840M.

Anticipated future benefits are similarly impressive. Informants already enjoying sizable impacts expect these to continue into the future (for example, Cases C and E). For others, preliminary testing results support the deployment of IMS technologies across operational facilities. Assuming full deployment over the next five years, Case D could enjoy more than $41M in annual cost savings.

Conclusions and observations
IMS impacts come almost entirely in the form of process efficiencies, like avoided downtime and maintenance costs. This is clearly in line with the center’s vision “to enable products and systems to achieve and sustain near-zero breakdown performance” (IMS center website). While informants were unable to translate these process improvements directly to consumer benefits (for example, lower prices), there seemed to be consensus that these improvements lead to increased market competitiveness, which in turn translates to a stronger national economy and greater employment rates. Additional impacts came in the form of the occasional student hire or the launch of a new product. Research by Scott et al. (1991) has suggested higher productivity by center alumni once they enter industrial positions. Also, in one case an IMS director contributed to early phases of product development, which led years later to a patent and commercial product.
### Table 10.1 Case summaries related to the Center for Intelligent Maintenance Systems

<table>
<thead>
<tr>
<th>Case</th>
<th>Impacts</th>
<th>Short Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$0.4M</td>
<td>The company discovered the IMS center through a university relationship involving the company's core technology. Five years later the company is applying IMS technology to predict and prevent machine failures and improve operational efficiencies.</td>
</tr>
<tr>
<td>B</td>
<td>$4.8M</td>
<td>This company captures benefits from IMS through several channels, including faculty consulting, technology transfer, and student hires. Early work with a co-director at the center ultimately led to a patent and product launch with a supplier partner. Further, prospective cost savings through operational efficiencies are estimated at more than $6.5M annually.</td>
</tr>
<tr>
<td>C</td>
<td>$65.0M</td>
<td>This global manufacturer leverages IMS technology to weed through enormous amounts of process-related data to identify potential threats to downtime and to increase process yield. Annual savings estimates top $65M and are expected to continue rising.</td>
</tr>
<tr>
<td>D</td>
<td>$0.1M</td>
<td>This five-year member of IMS has two early-stage yet promising projects using IMS-based technology. Pilot projects indicate significant cost savings; once fully deployed this technology could save the company more than $41M annually in improved machine performance and avoided downtime.</td>
</tr>
<tr>
<td>E</td>
<td>$500.0M</td>
<td>This company is deploying IMS-based knowledge and technology throughout its global network of manufacturing facilities. Improvements in predictive maintenance and machine performance have resulted in an estimated several million dollars per plant in savings, or about half a billion dollars annually.</td>
</tr>
<tr>
<td>F</td>
<td>$0</td>
<td>This company is a supplier of tools and technologies complementary to IMS technology. This company is in the process of market-testing a packaged version of center-based technology. Market acceptance (and potential) is uncertain, though the company is optimistic.</td>
</tr>
</tbody>
</table>

In general, NSF investments in the IMS center appear to be generating significant public returns. This is not to say that these innovations would never have happened in the absence of IMS. In fact, several informants described the center as an enabler and catalyst: the center provided...
important knowledge and foundational technology that the firm then translated into commercial applications with further internal investments. In fact, the notion of attribution was a persistent theme in the interviews. Informants typically cited internal investments in further testing and developing IMS knowledge and technology for application within their own facilities and operations. The transfer process could be two years or more before the technology is tailored to fit an organization’s particular context and needs.

The interviews also brought to light streams of impacts, or in this case that process improvements could provide ongoing efficiencies year-on-year. While these streams of impact could allow for an estimated internal rate of return (IRR), the question of attribution persists. In addition, informants identified potential future benefits from IMS technology. For example, one organization recently completed initial testing of IMS technology and had a multi-year plan to roll out the technology across several facilities. Whether that plan will be fully executed is uncertain.

**Berkeley Sensor and Actuator Center**

**Background**

The Berkeley Sensor and Actuator Center (BSAC) was founded in 1986 as the NSF Center for Microsensors and Microactuators, and is devoted to interdisciplinary engineering research on micro- and nano-scale sensors, moving mechanical elements, microfluidics, materials, and processes that take advantage of progress made in integrated-circuit technology. It has successfully recompeted for continuing IUCRC funding on at least two occasions. In 1998, BSAC expanded to a multi-campus NSF IUCRC with the addition of UC Davis, a major campus of the University of California 60 miles from UC Berkeley. BSAC continued with the NSF I/U program into 2008, and continues to operate as a graduated center.

According to the center’s website (http://www-bsac.eecs.berkeley.edu/), BSAC includes a multi-disciplinary research team of 120 graduate students and post-doctoral researchers led by 10 BSAC directors from the engineering faculties of electrical, mechanical and bio-engineering at UC Berkeley and UC Davis. BSAC directors oversee nearly 100 projects with cooperation, collaboration and guidance of 30 industrial member companies and government laboratories and 15 additional affiliated faculty from UC Berkeley and Davis. BSAC utilizes research laboratories throughout the engineering campuses at UC Berkeley and UC Davis, including intensive use of the UC Berkeley micro-fabrication facility (MicroLab).
Realized impacts
Based on the five interviews we estimate realized impacts of $144M. At the firm level, impacts ranged from $0 to $85M. Informants who reported no current financial impacts ($0) argued that non-quantifiable benefits were significant enough to fully justify their investments in the center. These benefits included exposure to MEMS (micro-electrical-mechanical systems) technologies and accelerated research timelines – in Case A, the informant believed that BSAC saved the company seven years in R&D; however, we were unable to ascribe a financial value to this benefit. Table 10.2 offers a summary of the cases related to BSAC.

NSF IUCRC investments in BSAC totaled $3.3M in actual dollars, or $2.6M in real 1986 dollars. Since BSAC lists a total of 26 “BSAC-inspired Start Ups” on their website (and we conducted interviews with just one or two of these), our impact estimates are probably quite conservative. Further, while two start-up firms were identified in the interviews, these relatively new ventures have only recently generated significant revenues. As a result, impacts were aggregated as a current-year return. We calculated both a BCR and NPV and found for every dollar investment in BSAC the NSF creates $31.2 in return. Subtracting the present value of the IUCRC investment from the present value of estimated impacts, we find an NPV of nearly $400M.

Most informants were unable to provide estimates of future benefits. The spin-out associated with Case B will probably continue operations; however, the informant could not disclose financial information or growth prospects. Both Case C and Case D are likely to continue their MEMS-based product lines, much of which can be linked back to BSAC. While Case A has near-term plans to implement BSAC technologies, Case B and Case E are probably several years from their first BSAC-related product lines. While prospective benefits could be significant, it is still too early to hazard an estimate.

Conclusions and observations
A common benefit cited by BSAC informants is the exposure to new applications of MEMS technology, and how this insight could influence their organization’s R&D roadmap. Unlike the IMS Center’s process monitoring and maintenance technologies, BSAC’s impact more often comes in the form of new companies and new products. While we uncovered $397M in net present value of BSAC knowledge and technology, it is likely that much of the center’s economic impact has yet to materialize. Informants from large organizations talked about new product lines and new market applications for MEMS technology. Further, two of our interviews included start-up firms with combined revenue estimated at over $100M.
### Table 10.2 Case summaries related to the Berkeley Sensor and Actuator Center

<table>
<thead>
<tr>
<th>Case</th>
<th>Impacts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$0</td>
<td>The company is currently in the process of transitioning a segment of its operations to technology based on BSAC research. The new manufacturing process will enhance the competitiveness of a $26M business unit with aggressive growth targets for the coming years. The informant is optimistic that the new technology will also help the company enter new markets.</td>
</tr>
<tr>
<td>B</td>
<td>$11.0M</td>
<td>The company launched a successful spin-off company based in part on technology linking back to BSAC. Revenues are estimated at over $10M. A former BSAC student and now current employee of the company has developed a new technology for the vehicle safety market. If successful, the new technology could generate several hundred million dollars in revenue for the company in the next five years.</td>
</tr>
<tr>
<td>C</td>
<td>$48.0M</td>
<td>This company has a long-standing relationship with BSAC, and includes multiple student hires and licensed technology. The informant estimates that as much as 50% of the company’s MEMS business could be attributable to BSAC research. We conservatively estimate that the company generates nearly $100M in MEMS-related revenue.</td>
</tr>
<tr>
<td>D</td>
<td>$85.0M</td>
<td>This start-up company was founded by a former BSAC student and incorporates center ideas and technologies into its product line. A recently landed contract with a global consumer brand accelerated the company’s growth, with revenues nearing the $100M mark. Double-digit growth rates are expected in the coming years.</td>
</tr>
<tr>
<td>E</td>
<td>$0</td>
<td>The company leverages its exposure to BSAC research and technology to help guide their R&amp;D strategy. The company is currently tracking multiple projects at BSAC for potential commercial application within the next 3–5 years.</td>
</tr>
</tbody>
</table>

Both start-ups are expected to grow significantly as the MEMS market expands. In addition, BSAC has inspired more than two dozen start-up firms (BSAC website). Our findings may only scratch the surface of this center’s impact.

Our BSAC interviews uncovered some challenges for conducting economic impact evaluations with these centers. First, BSAC – and other
IUCRCs – explore the cutting edge of technology. Understanding how center knowledge and technology translates to commercial application can be difficult for someone outside this technology community. A second challenge involved retrospective accounts of impacts. Several informants maintained long-term relationships with BSAC, some as long as 15 years. It is not surprising that these informants had significant difficulty recounting the various impacts related to the center. In one case, the company’s relationship with BSAC extended beyond the number of years in which the informant had worked for the beneficiary organization.

Finally, we recognized the challenge of accounting for the geographic coverage of impacts. Much as with the IMS center, BSAC beneficiaries often represent large, multinational corporations. In one case, the beneficiary resided outside the US, but the company maintained offices and research facilities within US borders. Further, the company sells its products to a global market. We did not separate US and non-US impacts in this pilot study but setting geographic boundaries warrants consideration when evaluating returns on public investments.

Industry–University Center for Surfactants

Background
The Industry–University Center for Surfactants, IUCS, was launched in 1998 at Columbia University and continued in the NSF I/UCRC program through to 2007. It operated as a single university center for all of that time. The original aim of the IUCS was to develop and characterize novel surfactants for industrial applications such as coatings, dispersions, deposition, gas hydrate control, personal care products, soil decontamination, waste treatment, corrosion prevention, flotation and controlled chemical reactions. After graduating from the IUCRC program, IUCS joined with another center and made significant changes to its research focus. In 2009 the center merged with the Particulate and Surfactant Systems Center at the University of Florida.

Realized impacts
The six companies interviewed reported an estimated combined impact of $5.5M. Estimated impacts ranged from $150k to $4M. See Table 10.3 for case summaries. Importantly, most informants focused on impacts related to the center’s more recent orientation toward green surfactants. This emergent area of research demonstrated significant enthusiasm among members based on reports of follow-on R&D investments (the primary basis for including this center in our sample), but to date the center has yielded mainly knowledge transfer and R&D efficiency benefits. Streams
### Table 10.3  Case summaries for the Industry–University Center for Surfactants

<table>
<thead>
<tr>
<th>Case</th>
<th>Impacts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$0.15M</td>
<td>This company is a long-standing member of the center. The informant sees great value in knowledge transfer and consultation with center staff, which inform the ongoing development of the company’s methods and processes. Knowledge transfer, including student hires, helps keep the company competitive and healthy in an industry faced with environmental challenges.</td>
</tr>
<tr>
<td>B</td>
<td>$0.5M</td>
<td>This small company leverages its relationship with the center to complement its limited R&amp;D staff. Several joint publications have given the company credibility in the market and have directly helped close sales deals estimated at $0.5M.</td>
</tr>
<tr>
<td>C</td>
<td>$0.3M</td>
<td>This multi-billion dollar company turns to the center for research work in green chemistry – an important growth area for the company. The Center’s expertise in this area has saved the company several hundred thousand dollars in avoided research costs. The informant is optimistic that center involvement will lead to new products and processes for the company.</td>
</tr>
<tr>
<td>D</td>
<td>$0.15M</td>
<td>This start-up firm benefits from the center’s expertise in surfactants and their evaluation capabilities. The company has benefited from research cost avoidance, and is also preparing to launch a surfactant product based on center technology around 2012.</td>
</tr>
<tr>
<td>E</td>
<td>$0.4M</td>
<td>This multi-national corporation takes advantage of the center’s facilities and expertise in surfactants. The company now employs several center graduates, and also benefits from applying center knowledge toward the enhancement of existing product lines. These product benefits could not be quantified.</td>
</tr>
<tr>
<td>F</td>
<td>$4.0M</td>
<td>This relatively new member of IUCS applies center knowledge and technology toward reducing production costs. The impacts are pervasive, but the informant estimates about $3M from improved product performance, and about $0.5M in saved research costs per year.</td>
</tr>
</tbody>
</table>

of benefits from product sales or process cost savings were not evident, although members were optimistic about the likelihood of future benefits. We include NSF IUCRC funding from the original 10-year lifecycle and the recent two years under the Particulate and Surfactant Systems Center.
IUCRC-specific investments totaled under $1.7M in actual dollars, or $1.4M in real 1998 dollars. We took impact estimates as an aggregate value in the current year, and then converted values to real 1998 dollars. Present value estimates were calculated using a 7 percent discount rate. Overall we find for every dollar invested in IUCS, the NSF creates $3.01 in return. Subtracting the present value of NSF IUCRC investments from the present value of estimated impacts, we find an NPV of roughly $6.44M.

Conclusions and observations
Informants reported no impacts related to the launch of new products or processes, though in one case the informant reported to be in early testing of a new "green" surfactant based on soybeans which could result in a new product and significant growth in coming years. Another beneficiary attributed about $3M incremental value from changes to existing product lines based on center knowledge and technology. In addition, beneficiary organizations have hired eight students trained in the center and have realized avoided R&D costs as a result of exposure to IUCS ideas and technologies.

Further, while the prospective benefits from IUCS knowledge and technology could be significant, there are also societal or environment benefits, what Feller et al. (2013) refer to as evidence of behavioral additionality, created by IUCS. This category of benefits was not readily apparent with either IMS or BSAC, and though very difficult to quantify, could reflect a more significant public return than any financial benefit.

Summary of Pilot Cases

The interviews with beneficiaries from the three IUCRC centers provide evidence regarding the feasibility of obtaining credible and persuasive economic impact estimates for centers and for the overall IUCRC program. Table 10.4 summarizes the impacts identified across these centers. Net present values of economic impacts ranged from nearly $10M to more than $800M. While we selected mature IUCRCs for this feasibility study, the IUCS center effectively reinvented itself in 2009 with the launch of its green chemistry research program. As a result, beneficiaries of center ideas and technologies are just beginning to explore commercial applications.

The inclusion of a process-related center (IMS) and a product-related center (BSAC) gave us insights into expected timelines for realizing economic impacts under different scenarios. With IMS's process-related technologies we might expect shorter time to commercial application (around 5–10 years) and incremental impact within each firm as the technology is
deployed across operations. With BSAC's technology we might expect longer time lines (maybe 10–15 years) as beneficiaries develop new products and begin marketing activities in established or even emerging markets where impacts can be far-reaching.

Arguably the variation in impacts across centers is as much about our ability to fully access outcome information as it is about the ideas and technologies emerging from the centers. For example, IUCS and BSAC could have impacts similar to IMS had we explored IUCS prior to its transition to green chemistry, or BSAC's more than 25-year history in MEMS research and technology. Further, prospective benefits from these three centers could potentially dwarf realized impacts, whether they involve ongoing and widespread efficiency benefits from IMS process technologies, the expansion of BSAC's MEMS technologies into new markets, or the potentially explosive growth of green chemistry applications emerging from the IUCS. Roessner and colleagues (2010) in their investigation of regional and national impacts of Engineering Research Centers (ERCs) reached similar conclusions about not only difficulty in gathering consistent impact information across centers but also in the potentially large prospective benefits yet to be realized.

SUMMARY AND CONCLUSION

Types of Impacts Realized by Participating Firms

Based on our interviews with nominated beneficiaries, it is apparent that members and to some extent non-member firms (for example, start-ups based on center research or IP) are receiving benefits from the IUCRCs with which they are affiliated or are otherwise connected. Clearly, some of the outcomes and impacts firms report and value quite highly, including access to pre-competitive research that influences the firm's R&D strategy and increases in human capital, are difficult if not impossible to quantify.
in financial terms. However, most of the informants included in our pilot study were able to provide rough financial estimates of at least some of the outcomes related to their involvement with an IUCRC.

A number of our informants indicated that center research had a significant and quantifiable impact on their R&D operations. These proximal impacts tended to be reported in terms of cost savings, cost avoidance or related efficiencies. Consistent with data provided via the IUCRC Evaluation Project’s Process/Outcomes Questionnaire data, some respondents reported financial benefits from not having to address certain issues in-house or because internal projects were able to complete their objectives more quickly because of center research. Other respondents indicated that they saved money by recruiting center students either because of improved recruitment processes and/or because center students were significantly more productive when they began their jobs. Such cost savings and efficiencies are likely to be observed within a few years of engaging with a center, and in many cases could be sufficient to justify continued membership in the center.

Longer-term outcomes came in the form of new and improved processes or products. Several informants, particularly those associated with the IMS center, indicated significant and quantifiable impacts on their internal manufacturing processes that they attributed at least in part to their involvement in the center. These process innovations could take many years to achieve commercial impact, beginning with a number of years of center research, a subsequent proof-of-concept or prototype, and then several years of internal development, testing and implementation. Since these technologies tended to be deployed internally within the adopting firm, they were described in terms of operational cost savings and avoided downtime. The realization of product-related impacts could be several years longer still. In addition to a development trajectory similar to process innovations, product innovations could also face regulatory approvals (for example, pharmaceutical or transportation innovations) as well as hurdles common to new product introductions (like marketing, manufacturing and distribution). These challenges were evident in several interviews, especially those related to BSAC technologies. For beneficiaries who had realized impacts from product-related innovations, these were often presented as revenues and associated job creation.

Data Collection Methodology Issues

On balance, the data collection strategy we used appeared to be effective and helped us collect credible economic impact data. The targeting of mature IUCRCs also appeared to pay off. It was apparent, even with these
highly successful centers, that center research could take several years to be translated into commercially viable products and processes, with more significant impacts just beginning to materialize after ten or more years. Our findings with the IUCS center reinforce this point. Though the center had existed for more than 10 years, the recent shift to green chemistry research precluded the discovery of sizable impacts from product or process innovations.

We believe that the cooperation of center directors was critical to our success in gathering information from beneficiary firms. Directors quickly saw the value of documenting impacts and were very cooperative in our data collection efforts. Given the potential sensitivity of the information we were after, we doubt our informants would have been willing to talk with us had it not been for the referral of the director with whom these beneficiaries maintained a close relationship. In this respect, the onsite evaluator who has established relationships with both the director and industrial members is in an ideal position to conduct this type of research and would probably be even more successful in gathering data on distal outcomes and their impacts.

Further, assurance of confidentiality was paramount. Based on conversations with informants, allowing them to maintain confidentiality contributed to their willingness to share economic estimates with us. Several of the informants indicated that in the absence of confidentiality they would have to go through a long protracted approval process—potentially taking several months to a year—within their firm to get permission to share information. Most indicated they would be reluctant to go through this process.

Similarly, the personal telephone interview format provided us with more insightful and complete information than that which has been obtained through the self-administered Process/Outcome Questionnaire. However, there were some limitations to our interview approach. First, most interviews were limited to 30 minutes, though a few ran over an hour. As a consequence, it was sometimes difficult to establish rapport with the informant and get a complete summary in this time frame. Second, our interviewers were not familiar with or trained in the technical content of the center’s research, which often required multiple requests to clarify the information provided. However, we feel this obstacle would be removed if the interviews were conducted by the local evaluators who had been immersed in the center’s activities for more than a decade.

Despite challenges with the phone interview format, our decision to target “outlier” beneficiaries seemed to pay off. In our analysis of archival data we recognized that most of the value of center research is associated with a handful of members. Further, targeting high impact cases
has been recognized as a viable strategy in the literature (Tassey, 2003). In our study, we focused on five or six beneficiaries for each of the three centers. Once again, our ability to successfully identify these beneficiaries and obtain cooperation was enhanced by the activities of the onsite evaluator and the relationship he or she had developed with the director and firms. Ultimately, we obtained impact data from roughly 15 percent of each center’s current membership and were able to obtain estimates on economic impacts that frequently justified many times the investment NSF IUCRC had made in that center. As a consequence we believe that a strategy of collecting impact data for a targeted but small subset of all members is worth pursuing.

Finally, in most cases the informant was able to recall with some clarity and conviction the impacts and the “causal path” that led from the center’s research efforts to the subsequent R&D or commercialization benefits realized by the firm. For some respondents, however, this proved difficult for one or more reasons. First, the initial transfer of the technology from the center to the firm pre-dated the tenure of the informant, so the informant lacked direct experience with the transfer event. Second, other actors had contributed to the development of the technology after the center’s initial work. Whether a product or process technology, we found that beneficiaries invested significant time and resources to get these innovations commercial-ready, and could often involve a partner or supplier in the development process. This created difficulty in recounting the role played by the center.

**Concluding Remarks**

In addition to providing developmental evaluation guidance to local centers (Gray, 2008), the existing IUCRC evaluation strategy appears to have succeeded in documenting proximal R&D outcomes. This is consistent with the program’s objectives. This current study attempted to assess the added value of the program by examining the more distal outcomes and economic impacts of IUCRC ideas and technology. Our highly targeted, confidential interviews with nominated beneficiaries of several mature IUCRCs produced a much higher yield of documented outcomes and economic impacts than we could discover through questionnaire responses and otherwise non-confidential interview data collection strategies. Our interview data strongly suggests that the IUCRC program and at least some individual centers are having a measurable economic impact on member companies and other external beneficiaries. These impacts are derived from a mix of proximal R&D outcomes, including internal R&D cost savings and avoidances that are relatively easy to document on
a year-to-year basis, and more distal outcomes and much larger impacts related to the implementation of new or improved processes, and revenues generated from new or improved products that appear to accrue to a small but important subset of all members.

In addition to realized impacts we were also able to obtain general information on forecasted impacts that might be validated with subsequent follow-up assessments. Since we picked centers that were judged to be “successful”, we do not know how representative these findings are. However, if one takes a portfolio approach to evaluating the IUCRC program at a national level, these findings alone, based on 17 members at three mature centers, appear to provide sufficient justification for NSF’s investment in the IUCRC program over many years. Given our success in documenting the economic impacts of the IUCRC program, we believe these evaluation methods could be used profitably by evaluators of other CRC programs. Nonetheless, given the current policy discussion about the value of government-funded STI partnership programs, there would appear to be great value to the IUCRC and individual centers in being able to document these kinds of outcomes and impacts in a systematic way and on an ongoing basis.

ACKNOWLEDGMENTS

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