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Cooperative research centers and faculty satisfaction: a multi-level predictive analysis

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Abstract Cooperative research centers (CRCs) are an important part of the innovation landscape in the US and are likely to play an increasingly important role in the US's emerging cooperative research-based innovation policy. However, in spite of considerable research on the technology transfer and economic development outcomes of CRCs, little empirical research has focused on the benefits and risks faculty may expose themselves to while participating in these partnership arrangements. Given these circumstances, this study attempted to address two questions: What outcomes do faculty experience from their participation in a CRC? To what extent is faculty satisfaction with their involvement in CRCs explained by variables at different levels of analysis? Questionnaire data were obtained from 275 faculty involved in federally-funded CRCs. Descriptive findings suggest participating faculty receive a mix of tangible and intangible benefits and few report negative consequences. Predictive analyses indicated faculty satisfaction is explained by variables operating at the organizational (university research funding), center (primary discipline) and individual-level (faculty benefits and symmetry with industry). Implications for future research and policy are discussed.

Keywords Cooperative research center · Science and technology policy · Technology transfer · Research collaboration · Faculty satisfaction

JEL Classification O32 · O38 · I23 · I28

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1 Innovation policy, cooperative research centers and faculty stakeholders

As nations around the globe try to grapple with the economic and social consequences of the most severe recession since World War II, it should come as no surprise that many countries are proposing and/or already implementing "innovation-based strategies" as part of their national recovery plans (Euro/Activ.com 2009). While each country or region's innovation strategy or framework has been customized to meet local circumstances and needs, most include some common elements. Perhaps one of the most central elements of past and emerging innovation-based strategies is initiatives designed to promote cooperative cross-sector research partnerships.

For instance, Priority 5 within Australia's *Powering Ideas* proposal indicates, "The innovation system encourages a culture of collaboration within the research sector and between researchers and industry" (Australia MIISR 2009). It aims to achieve this priority by doubling the level of collaboration between industry and universities over the next decade via various initiatives, including their Cooperative Research Centers program. Within the EU's *7th Framework* and the re-launched Lisbon Partnership, programs like the Joint Technology Initiative and newly formed European Institute of Technology and Innovation attempt to promote more effective synergies between S&T actors and sectors (Government Monitor 2009).

In the US, which at best has a history of ambivalence toward embracing technology or innovation policy (Lundvall and Borras 2006), a similar but less formally articulated pattern is developing. A variety of interests including the Information Technology and Innovation Foundation (ITIF) and Brookings Institution are calling for the creation of a National Innovation Foundation that would serve as "a new, nimble, lean, and collaborative entity devoted to supporting firms and other organizations in their innovative activity" (e.g., Atkinson and Wial 2008). Although the enabling legislation was not passed, many of these recommendations came closer to realization when *S.3078: National Innovation and Job Creation Act* was introduced in Congress by Senators Collins (R-ME) and Clinton (D-NY) during summer 2008.

Reports endorsing this strategy (Bendis and Byler 2009) and the enabling legislation have also highlighted the importance of fostering cooperative research alliances. Consistent with this position, a memo from the Obama administration's White House's Office of Management and Budget and the head of Science and Technology Policy has urged federal agencies "to take advantage of today's open innovation model" (Financial Times 2009).

What will the US's emergent cooperative research-based innovation strategy look like? While it is too early to know for sure, it seems certain a central element will be encouragement and expanded support for the development of cooperative research centers (CRCs).

1.1 Cooperative research centers in the US

While the term cooperative research center (CRC) can be and is used around the globe to describe any research center that supports and/or houses research involving cross-sector actors (e.g., industry, government, not-for-profit and/or university), in the US context (and in this paper) this term is usually used to refer to university-based, faculty-driven, typically interdisciplinary program of research supported jointly by a number of companies (Gray and Walters 1998).

There are a variety of reasons why CRCs seem likely to be a central element of the emerging US innovation policy. First, CRCs have been part of the US university landscape for many decades. Baba (1988) suggests the earliest example of this form of cooperative

research was the Institute of Optics at University of Rochester founded in 1930. Further, CRCs have been a vehicle for federal and state Science & Technology policy for almost 30 years, beginning with the development of NSF Industry/University Cooperative Research Centers (IUCRC) in 1980 and followed by the Engineering Research Centers (ERCs) and various state "centers of excellence" programs several years later (Gray and Walters 1998; Coburn 1995). Empirical evaluations of various federal CRC programs have uniformly validated their positive impact on technology transfer-related and economic development outcomes (e.g., Gray and Walters 1998; SRI 1997). Summing up research on CRCs available at the time, Feller (1997: 54) concluded: "Both industrial and university participants report a broad set of benefits for these centers, including patents and licenses, but extending well beyond these markers of technology transfer".

Not surprisingly given this background, one of the authors of the ITIF/Brookings report (Atkinson 2007) suggests an additional $2 billion should be spent for competitive grants to national industry consortia to conduct research at universities. More concretely, S.*3078: National Innovation and Job Creation Act* included a provision that would transfer NSF's IUCRC and ERC program "functions, personnel, assets, and liabilities" (and other programs) to the proposed National Innovation Council within the Executive Office of the President (GovTrack US 2008).

While the prospects for CRCs becoming a more important and productive element of the US's emerging innovation policy look positive, there may be at least one potential constraint on our ability to exploit this option. While many countries staff their CRCs with scientists who are full-time employees of their public or not-for-profit sector centers, most US CRC research is performed by "part-time faculty volunteers" and their graduate students. That is, US CRCs are typically staffed by regular departmental faculty who *choose* to participate or not in a center, usually through some release-time or summer salary support mechanism, and who can and often do choose to withdraw just as freely. Given longstanding concerns expressed about the conflicts and risks involved in these partnerships (e.g., Allen and Norling 1990; Slaughter and Rhoades 2004), increased faculty involvement and commitment to these arrangements cannot be taken for granted. Given these circumstances, and the significance of CRCs to the US's emerging innovation policy, it is reasonable to ask: what do we really know about faculty perceptions of and outcomes from participating in CRCs?

2 Research on CRCs and faculty

In spite of significant interest in cooperative research and CRCs in particular, extensive research on industry benefits (e.g., Coburn 1995), and Feller's (1997) conclusion about the *mutual* benefit derived from these activities, until recently relatively few studies have focused on the faculty involved in these partnership-based arrangements (Gray 2000). However, over the past decade interest in and research on this topic have gained some traction; we are in a better position to assess the benefits derived by faculty and the factors that mediate and moderate those benefits.

Given these circumstances, we attempt to accomplish three goals in this section: highlight the major questions that have been asked about faculty and CRCs; summarize what appears to be known and not known relative to those questions; and highlight issues and questions that deserve additional attention. Since the available body of empirical literature focused exclusively on faculty and CRCs is still relatively small, we also include relevant studies that examine faculty involved in a range of cooperative research modalities (e.g., consulting, contract research, CRCs).

Based on our review, the empirical literature on faculty and CRCs has focused on three questions. First, *why do faculty get involved in cooperative research*? That is, while some faculty appear open to cooperative research and in fact seek out these arrangements, other faculty are less inclined and/or unwilling to participate. Since outcomes of cooperative research may be related to who gets involved rather than what participants do or how they react, answering this question may help us understand outcomes. Second, *what are the objective outcomes for faculty*? That is, what kinds of concrete benefits (or losses) do faculty get from their participation? Finally, *what are the psychosocial outcomes for faculty*? Obviously, some of the reviewed studies deal with more than one of these questions. Answering these questions should give us a better idea of the constellation of factors that contribute to faculty member's decision to continue and/or terminate their involvement in these arrangements and how public policy might influence these factors.

2.1 Why do faculty get involved in cooperative research?

A great deal of the early research on faculty involvement in cooperative research focused on why some faculty get involved while others do not. In truth, much of this research was not very theoretically grounded and was justified primarily on the need to inform the policy process about changes in faculty willingness and interest in working with industry.

For instance, Rahm (1994) showed that the strongest predictor of engaging in cooperative research activities (e.g., spanning faculty) was expressing fewer concerns about the potential negative impact of cooperative research on university mission and values. In addition, the approach a faculty member takes to research was also important, with faculty who were involved in industry cooperative research being more likely to report that they were co-principal investigators (PI) rather than "sole PI" (i.e., they were collaborating), more likely to describe their research programs as multidisciplinary and more likely to report involvement in research centers. In other words, these faculty were engaged in what is now often called "team science" (Stokols et al. 2008).

In a study that looked at faculty who were extreme on federal support (50% or more federal and less than 10% from industry) or industry support (30% or more industry and less than 10% from federal), Strickland et al. (1996) found that industry-supported faculty differed in the type of research they performed and how they performed it. High industrial research faculty described their research as more experimental than theoretical, concentrated on synthesis rather than analysis, more oriented towards products and processes than publications, less long term focused, and more pulled by the market than by science and technology. Consistent with Rahm's findings, high industry supported faculty tended to work in a group of collaborating investigators. In a more recent study, Corley and Gaughan (2005) report that while participation in CRCs is not affected by gender, their data suggest that women involved in centers achieve a higher level of gender equity (e.g., grant writing and access to graduate students) in factors that support production of research than women involved in exclusively department-based academic scientists.

It is worth noting that according to Rahm's research (1994) the type of university a faculty member worked at is also important. So-called *spanning faculty* 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 engaged with firms through partnership mechanisms like research consortia and research parks.

2.2 What are the objective outcomes of faculty participation in cooperative research?

A relatively modest body of literature focuses on the objective outcomes of cooperative research for faculty. Much of this research appears to have been motivated by a desire to understand both the intended and unintended consequences of cooperative research.

Drawing upon theory of bounded rationality (March and Simon 1958) and focusing on the personal outcomes of collaborating, Lee (2000) found that faculty report receiving a combination of tangible and intangible benefits from participating in a cooperative research including: acquired funds for research assistant and lab equipment (67.1% rated this benefit as either "substantial" or "considerable"), gained insights 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%). Lee also reported that benefits were predicted by length of the project and the frequency of interaction between a faculty member and the firm.

While emphasizing the transaction costs related to the more bureaucratic processes involved in CRCs, Garrett-Jones and Turpin (2007) found that faculty are more likely to report receiving intangible/career benefits than tangible benefits from their participation. For instance, an overwhelming majority indicated participation had complemented their other professional work, enhanced collaboration and influenced the cohesion of the research team. A less impressive majority indicated that their involvement generated an important source of research funds or provided access to essential research facilities. Interestingly, role characteristics also seem to matter, with the perception of benefits differing for academic and government-affiliated collaborative researchers.

Findings related to more traditional measures of faculty productivity are complex and somewhat contradictory. Strickland et al. (1996) report that faculty involved in cooperative research were significantly more likely to report that their research resulted in patent applications, patents, "trade secrets" or commercialized products and processes. Surprisingly, faculty studied by Lee (1996) reported that creation of business opportunities was the least likely benefit of cooperative research.

In addition, Landry et al. (1996) found that collaborating with other investigators has a positive effect on productivity, unless the main collaborating partner was industry. In contrast, in a series of studies with faculty involved in biotechnology related research, Blumenthal and his colleagues (Blumenthal et al. 1986, 1996) consistently found that faculty involved in cooperative research with firms showed the same level of teaching but had a significantly greater number of publications, involvement with professional and service activities, and commercial outcomes like patents, compared to faculty not involved in such research. These results held even when controlling for variables such as academic rank and number of years since receiving their degree.

Findings related to unintended consequences of cooperative research are also somewhat contradictory. For instance, while faculty who reported receiving funding from industry were more likely than other faculty to report delaying publications, involvement in commercialization activities rather than industry sponsorship per se was associated with denying other investigators access to results (Blumenthal et al. 1997). With all their findings, Blumenthal and his colleagues were careful to point out the unique commercialization pressures faced by biotechnology scientists.

Since most of these studies involved descriptive and/or bivariate rather than multivariate analyses, it is possible the inconsistencies found in results on benefits and outcomes might be explained by variables that were not included and/or controlled for in these studies. For instance, Lin and Bozeman (2006) reported higher levels of research productivity among some CRC faculty (e.g., young and female faculty) with prior industry experience.

Drawing on a knowledge-based view of organizations that acknowledges coordination costs, Cummings and Kiesler (2005, 2007) reported that faculty involved in multi-university collaborations exhibited lower productivity than faculty involved in single university collaborations. Finally, it is also clear different modalities of cooperative research (e.g., centers, contract research, consulting) vary in meaningful ways and that these differences may affect outcomes. To this point, Roessner (2000) found that structural and other differences between CRC models can have a significant effect on tangible outcomes related to IP.

2.3 What are the psychosocial outcomes of involvement in cooperative research?

While research related to objective outcomes tends to include faculty involved in a range of cooperative research modalities, most of the research on psychosocial outcomes focuses specifically on faculty involved in CRCs. Not surprisingly, given the focus on psychosocial outcomes, research related to this question tends to have a more consistent and coherent theoretical framework. For instance, research that takes an intraorganizational perspective and looks at how faculty adjust to role changes tends to draw upon theories related to role conflict and role strain (Rizzo et al. 1970). At the same time, research that examines issues related to extra-organizational boundary-spanning issues, like Garrett-Jones and Turpin's companion piece in this volume, tend to draw on inter-organizational theory (Aldrich 1971).

Although preliminary, recent research suggests that many CRC faculty do experience psychological effects in the form role strain. Boardman and Bozeman (2007) found that "at risk" faculty—those who could distinguish different tasks, responsibilities and expectations between centers and departments—and faculty involved in less institutionally formalized centers, were more likely to show evidence of role strain. However, few other demographic, role or structural characteristics were predictive. Thus, we have little insight into which organizational and other factors mediate or moderate the effects of CRCs on faculty role strain.

Boardman and Ponomariov (2007) were interested in what factors affect the subjective valuation of applied and commercially relevant research for a large sample of faculty ($N = 348$) involved in multidisciplinary, multipurpose university research centers. They found that tenure status has a significant negative effect on two dependent variables: worrying about commercial applications distracting them from doing good research; and being more interested in developing fundamental knowledge than near-term economic and social applications. That is, faculty who were tenured were less likely to be concerned about commercial applications detracting them from doing "good research" and less likely to be concerned with developing fundamental knowledge than research with more near-term applications. The authors suggested that the tenure process, which tends to not value applied outcomes, may cause junior faculty to be cautious about engaging in cooperative research.

Findings from one of the few studies that have examined faculty involved in different types of cooperative research appear to support the contention that contextual factors like the structure of the cooperative partnership may affect psychosocial outcomes. Gray et al. (1987) found that faculty participants from two different types of industry-university collaboration—the University-Industry Cooperative Research Projects Program (Projects) and the Industry/University Cooperative Research Centers Program (Centers)—exhibited significant differences on two noteworthy psychosocial outcomes: goal importance and satisfaction. Specifically, Projects faculty, who were involved in a one-on-one, time-limited collaboration with a single firm, rated patent and product development as their most important goals (among seven goals) and general knowledge expansion as their least

important goal. Conversely, Center faculty—those who worked with a team of other faculty and received support and guidance from a consortium of firms on an ongoing basis—indicated general knowledge expansion as their most important goal and patent and product development their least important. Lending some support to concerns about the psychosocial consequences of CRCs, Center faculty also reported significantly lower satisfaction with their involvement in their cooperative activity than Project faculty.

2.4 Summary and conclusion

While our review of the empirical literature on faculty involvement in cooperative research, and more specifically in CRCs, begins to shed some light on why faculty get involved in CRCs and on the outcomes of their involvement, it also highlights how complex the outcome processes are and how little we truly know. For instance, it seems very clear that faculty involved in cooperative research and CRCs are different from faculty who are not involved, and that at least some of these differences are a result of a self-selection process. Specifically, involved faculty appear to see fewer threats to academic missions and values in partnering with industry, exhibit a preference for research that is more experimental and/or application-oriented and are open if not inclined to work collaboratively (e.g., team science) with other scientists. Further, Corley and Gaughan's (2005) research suggests CRCs may be attractive because they provide a more gender equitable environment than academic departments do. Importantly, the research also suggests there is more than individual differences at work in these processes. Specifically, Rahm's (1994) research demonstrated institutional processes and norms matter too, with faculty at "firm friendly" institutions showing higher rates of involvement.

A similar pattern of complex and sometimes contradictory relationships is revealed in the objective and psychosocial outcome literature. For instance, there appears to be empirical support both for and against the impact of collaborative research and CRCs on tangible vs. intangible benefits, on academic productivity and on unintended consequences like eroded academic freedom. Other studies suggest these discrepancies might be related to uncontrolled institutional (e.g., multi-institutional) or participant (e.g., prior industry experience) variables. The impact of participation in CRCs on psychosocial outcomes like role strain and/or conflict, the subjective assessment of the desirability of various outcomes, goals and, ultimately, satisfaction also appear to be dependent on variables like organizational structure, roles and characteristics of the cooperative research arrangement.

In summary, the objective and psychosocial outcomes of faculty involvement in CRCs appear to be a product of a complex interaction of self-selection processes and variables operating at the institutional, center, role and individual levels of analysis. A number of theoretical frameworks including resource-dependency, knowledge-based view of organizations, and role theory have been used to guide and justify these relationships. While the still modest body of research on faculty has begun to ferret out the primary relationships at work, it has not been targeted (e.g., findings are based on heterogeneous samples) and methodologically sophisticated enough (e.g., not multivariate) to address the complexity that appears to be at work. As a consequence, this limited literature seems to raise more questions than it answers.

Given these circumstances, the current research will have two major objectives: to help shed light on the outcomes faculty experience from participation in CRCs; and to attempt to understand what factors predict a key psychosocial outcome—satisfaction.

3 Methods

In the current study, we will address several broad research questions rather than test specific hypotheses. We take this exploratory approach for several reasons. First, although our review of the literature has highlighted trends and relevant predictors, this body of research is still very small and at times ambiguous if not contradictory on the importance of these variables. Second, the levels of analysis and number of potentially relevant predictors (and theoretical positions referenced for that matter) that were identified in the literature is quite large. As a consequence, although we could have tested a number narrow hypotheses, we felt it was more important to evaluate the relevance of the broad sweep of variables that have been supported by previous research, and begin the process of moving toward more parsimonious and robust predictive models.

The first question is descriptive in nature and attempts to enhance our understanding of the professional and other benefits faculty obtain from participation in CRCs, and to shed light on the debate about the relative importance of tangible and intangible outcomes as well as various unintended consequences.

Question 1 What outcomes do faculty experience from their participation in a CRC?

The second question is predictive in nature and attempts to clarify which variables explain an important psychosocial outcome, satisfaction. Since our literature review suggest the potential importance of factors operating at different levels of analysis, our predictive questions will examine variables operating at organizational, center and individual levels.

Question 2 To what extent do university, center and individual-level factors affect faculty satisfaction with their involvement in CRCs?

3.1 Design

Data were collected via questionnaire from a national sample of faculty involved in CRCs. Research question two was addressed by cross sectional multivariate predictive (OLS) analysis.

3.2 Study sample

Centers Data were collected from faculty involved in university-based CRCs. The vast majority of these centers were part of the NSF IUCRC program; additional data were collected from non-NSF centers that were structurally and operationally similar. In brief, IUCRCs are university-based, multidisciplinary research centers that are each supported by a consortium of membership firms. More detailed information about the IUCRC program can be found elsewhere.[1] Compared to other NSF and other national center programs, the IUCRC program provides very modest support (typically $70–120 K), which helps launch a center and support its administrative structure. Thus, the financial viability of IUCRCs is highly dependent on their ability to obtain funding from industry and other federal sources. Centers are typically based in engineering and/or applied science disciplines. Forty-two CRCs (38 IUCRCs and 4 non-IUCRC but consortial CRCs) were included in the final sample.

[1] For more information on IUCRCs, please refer to the program website (http://www.nsf.gov/eng/iip/iucrc/) or Managing the IUCRC: A Guide for Directors and Other Stakeholders (Gray and Walters 1998).

3.2.1 Faculty respondents

The sampling frame for the study included 572 faculty participants at 42 CRCs. Questionnaires were returned by 275 or 48 percent of the surveyed sample.

3.3 Procedures

Most of the data were collected through the IUCRC program's ongoing *improvement-focused* evaluation effort (Gray 2008). In brief, the evaluation involves on-site evaluators who administer to center faculty and industry participants a questionnaire addressing center processes and outcomes (referred to as the Process/Outcome Questionnaire). Center evaluators are responsible for summarizing questionnaire data, comparing it to national benchmarks, and providing feedback and consultation to center management. While this locally-based feedback evaluation is primarily designed to help center managers anticipate problems and improve center operations (Gray 2008), it also provided a basis for answering the research questions posed in this study. Faculty supported by the center received a copy of the questionnaire from their on-site evaluator. At least two follow up attempts were made to increase response rate. A similar process was used to collect data from the four non-NSF supported centers.[2]

4 Measures

4.1 Dependant variables

4.1.1 Faculty satisfaction

Faculty satisfaction with their involvement in a center is the primary dependent variable addressed in research question two. Although a comprehensive vetting of the literature on this construct is beyond the scope of this paper, satisfaction appears to be a particularly relevant psychosocial outcome for assessing faculty involvement in CRCs for a couple of reasons. First, satisfaction with one's job and work environment is one of the most widely researched and recognized constructs in the organizational literature (Spector 1997). Second, satisfaction has been shown to be related to many of the variables studied among CRC incumbents including: job characteristics, role states like role overload and ambiguity, group characteristics like cohesiveness, and leader relations (Kinicki et al. 2002). Third, and most importantly, since a variety of studies have highlighted the risk versus reward nature of faculty involvement in centers (and individual faculty are likely to experience both rewards and risks), satisfaction has the potential to provide a basis for judging the overall reaction of CRC faculty. Interestingly, in spite of the growing interest in psychosocial outcomes of CRC involvement, satisfaction has been relatively neglected.

For the current study, we measured satisfaction via a rationally created three-item scale included in the Process/Outcome Questionnaire. This mini-scale included items that addressed satisfaction with different facets of the CRC experience including: the quality of the research program, the research relevance (to industry needs), and center administration and operations. Faculty rated these items on a five-point Likert scale (1 = "not satisfied",

[2] In order to assess the impact of including non-IUCRCs in our sample, our analyses were re-run excluding faculty from these centers. The results did not change.

3 = "somewhat satisfied" and 5 = "very satisfied"). A principal components factor analysis of the data showed that these items constituted in a single factor (72% of the variance was explained by this factor) and exhibited more than adequate reliability (coefficient alpha = .80). As a consequence, we summed and averaged the items to create a faculty satisfaction scale. The scale showed a mean of 4.00 and a standard deviation of .76, indicating that faculty overall were quite satisfied with the centers.

4.2 Descriptive and predictor variables

4.2.1 University-level predictors

As our literature review suggested, university-level factors appear to affect the outcomes of and reactions to faculty involvement in cooperative research activities (e.g. Rahm 1994). As a consequence, we evaluated the predictive value of a number of university characteristics.

i. Type of university. Universities were categorized as public or private. The majority of the faculty in the sample came from public universities (87.7%).

ii. University research intensiveness. Research intensiveness was measured using the Carnegie Classification of the university.[3] Since the vast majority of universities were doctorate-granting research universities (82%), this variable was dichotomized: doctorate granting universities (very high or high research activity) versus other institutions.

iii. Total university research funding. A university's research funding was measured using the total research budget of the university, measured in thousands of dollars (National Science Board 2006). The mean budget in the sample was $197 million.

iv. Industrial percentage of university research funding. Rahms's (1994) research suggests that universities differ in how industry-friendly they are, and that these difference explain the willingness of faculty to engage in cooperative research. Percentage of funding obtained from industry was used to measure this variable. 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 6.8% (National Science Board 2006). The median value of 9.49% was also higher than the national average suggesting these universities were high on this dimension.

4.2.2 Center-level predictors

Our literature review has also suggested that the nature of the partnership arrangement (e.g., centers vs. one-on-one linkages) as well as the structural, resource and other characteristics of the center a faculty member participates in may affect various outcomes (e.g., Gray et al. 1987; Roessner 2000). As a consequence, we evaluated the predictive ability of various center-level characteristics.

i. Number of industrial members. One measure of a CRC's size and complexity is the number of industrial members that support it. The centers represented in the sample had a mean of 16 members.

ii. Center operating budget. Another measure of size and complexity of a CRC is its level of funding. The centers in this sample had a mean operating budget of $1.49 million.

[3] Carnegie Foundation (2009). Carnegie Foundation for the Advancement of Teaching. Retrieved August 15, 2009, from http://www.carnegiefoundation.org/classifications/

iii. Center age. Obviously, the age of a center can affect its maturity and the opportunity for faculty to derive various benefits and produce outcomes. The centers in our sample ranged in age from 1 year to 18 years, with a mean age of 7.5.

iv. Multi-university. Cummings and Kiesler (2005) demonstrated that multi-institutional collaborative arrangements may have a negative effect on measures of center productivity. In the present study, roughly half of the included centers had more than one site. This variable was dichotomized: single university center versus multi-university center.

v. Center primary discipline. Several of the studies included in our review suggested that faculty discipline can affect various outcomes (e.g., Blumenthal et al. 1996). However, since most of the centers in our sample include faculty from several disciplines, we made an attempt to characterize the primary disciplinary focus of the center. In order to do this, we asked center directors to characterize their centers as primarily: engineering science, natural science, other science or a combination of the previous categories. Since only a small percentage of respondents labeled themselves as non-engineering (natural science = 5.1%; other science = 14.1%; and combination = 5.5%), these categories were combined and centers were characterized as either engineering (including combinations that include engineering) (78.2%) or non-engineering (21.8%).

vi. Average faculty center funding. Obviously, the amount of funding a faculty member receives from a center could affect the amount of research they perform, the number of papers they produce and perhaps their satisfaction. Average faculty funding was computed by dividing the number of faculty members supported by the center by the total funding for the center (measured in thousands of dollars). The mean amount of funding for the faculty in the sample was $90,000.

4.2.3 Individual-level predictors

Since several of the studies summarized in our literature review reported that faculty roles and characteristics may predict outcomes (e.g. Boardman and Ponomariov 2007), various individual-level characteristics were assessed.

i. Academic rank. Academic rank has been shown by other researchers to predict various outcomes for CRC faculty (Boardman and Ponomariov 2007) and can be seen as a proxy for job security, status, and/or past performance. Rank was treated as a continuous measure and was coded as follows: 1 = non-tenure track faculty, 2 = assistant professor, 3 = associate professor, and 4 = full professor.[4]

ii. Tenure. Like academic rank, tenure has implications for security, status, and job stability. Tenure was also treated as a continuous measure and was coded as follows: 1 = non-tenure track positions, 2 = untenured but tenure track, and 3 = tenured.

iii. Type of research. The literature also suggests that the type of research a faculty member performs can affect both objective and subjective outcomes. Type of research is 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, broad/narrow scope, longer/shorter time frame. All three characteristics are presented on a five-point Likert scale, with a score of one meaning more basic, broad, or longer time frame and a score of five meaning more applied, narrow, or shorter time frame. The average respondent reported that their center research was slightly more applied ($M = 3.36$), narrow ($M = 3.13$) and shorter time frame ($M = 3.29$) than the research they typically performed.

[4] Predictive analyses were run with rank and tenure status coded as continuous and categorical predictors. Treating them as categorical predictors did not change our findings.

iv. Faculty outcomes. The faculty Process/Outcome Questionnaire included a set of self-report items that addressed both intended and unintended faculty "outcomes" that have been mentioned in the literature. Using a five-point bi-polar Likert response option faculty were asked to indicate whether participation in their center had a very negative effect (1), moderately negative effect (2), no effect (3), a moderately positive effect (4) or a very positive effect (5) for them. For our predictive analyses we attempted to evaluate whether outcomes exhibited an underlying factor structure and could be treated as a scale. Principal components factor analysis was performed on these items.[5] Results showed three factors: faculty benefits, perceived symmetry with industry, and faculty academic freedom. Together these factors explained 58% of the variance.

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* and exhibited adequate reliability (coefficient alpha = .71).

Perceived symmetry with industry. A two-item attitudinal measure, perceived symmetry with industry, emerged from the factor analysis. 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*. This measure exhibited adequate reliability (coefficient alpha = .71).

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*. This measure exhibited more than adequate reliability (coefficient alpha = .82).

5 Results

5.1 Outcomes of participating in CRCs

Table 1 shows the means, medians and standard deviations for the items in the faculty outcomes scales. On all scales, higher scores reflect more positive attitudes from faculty. Not surprisingly, participation in a CRC appears to have the greatest effect on concrete outcomes that are directly related to a faculty member's CRC research role. For instance, center participation had a moderately positive impact on the faculty member's ability to support graduate students ($M = 4.12$, SD = .73), amount of interaction with other faculty ($M = 4.09$, SD = .69), opportunities for research contracts (men = 3.99, SD = .73) and access to equipment ($M = 3.78$, SD = .79). Participation in the center appears to have a positive but slightly less pronounced effect on outcomes that are external to the center including chances for promotion and tenure ($M = 3.59$, SD = .72) and consulting ($M = 3.49$, SD = .68).

In addition, participation in their center appears to also have had a moderately positive effect on items that are part of the perceived symmetry with industry scale, including evaluation of the quality of industrial research ($M = 3.68$) and trust and confidence in industry ($M = 3.58$). In other words, most faculty report participation in the CRC has had a positive effect on their opinion of the quality of industry's research and trustworthiness.

[5] 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.

Table 1 Descriptive statistics for faculty outcomes

Variable	Mean	Median	SD
Faculty benefits			
Ability to support graduate students	4.12	4.00	.73
Amount of interaction with other faculty	4.09	4.00	.69
Opportunities for research contracts	3.99	4.00	.73
Access to equipment	3.78	4.00	.79
Chances for promotion and tenure	3.59	3.00	.72
Opportunities for consulting	3.49	3.00	.68
Faculty academic freedom			
Amount of autonomy in conducting research	3.44	3.00	.85
Ability to publish research in a timely fashion	3.44	3.00	.87
Faculty symmetry with industry			
My evaluation of the quality of industrial research	3.68	4.00	.78
Trust and confidence in industry	3.58	4.00	.77

Interestingly, there is little evidence center participation leads to unintended consequences related to academic freedom. While a small minority of faculty report negative impacts (about 12%), the overwhelming majority of participants report either no effect or a positive effect on amount of autonomy in conducting research ($M = 3.44$, SD = .85) and on ability to publish research in a timely fashion ($M = 3.44$, SD = .87), with the net effect of CRC participation on these items being positive.

5.2 Predicting faculty satisfaction in CRCs

Predictive data analysis included a mix of bivariate and multivariate (OLS) analysis techniques. Because of the exploratory nature of the research and our desire to achieve a parsimonious solution based on a large number of predictors, we followed a "trimming" approach (Tabachnick and Fidell 1996). First, a series of bivariate regression analyses were run for each predictor variables with satisfaction. Predictors that had a significant bivariate effect were evaluated via multivariate regression within each variable domain (university-level, center-level and individual-level). Predictors that were significant at the domain level were included in the overall multivariate model; a traditional significance level ($p < .05$) was used in the full model.

Consistent with our expectations that at least some of our predictors were explaining the same variance, the trimming approach to evaluating predictors helped reduce the number of variables tested in our full model regression. Specifically, based on bivariate regressions 12 of the 20 predictors tested were significant. Subsequently, only seven of these variables were significant based on domain-level multivariate regression.

The results for the overall multivariate regression model for faculty satisfaction are presented in Table 2. The full model includes seven predictors: type of university (public/private university), total university research funding, center primary discipline, average faculty center funding, perceived symmetry with industry, faculty benefits, type of research (broad/narrow scope). The model explained 32% of the variance in faculty satisfaction. Four of the seven variables (representing three different levels of analysis) significantly contributed to satisfaction in the final model: total university research funding, center primary

Table 2 Summary of overall multiple regression of faculty satisfaction on the predictor variables

Variable	*B*	*B*	*p*
University characteristics			
Type of university	−.14	−.06	.34
Total university research funding	.08	.14	.03
Center characteristics			
Center primary discipline	.25	.14	.02
Average faculty center funding	.00	.06	.32
Individual characteristics			
Perceived symmetry with industry	.37	.34	.00
Faculty benefits	.37	.22	.00
Type research (narrow/broad)	−.03	−.03	.62
R^2	.32		

Note: $n = 221$, $df = 7$

discipline, perceived symmetry with industry and faculty benefits. Each significant predictor had a positive effect on faculty satisfaction, with perceived symmetry with industry having the strongest effect ($B = .34$), followed by faculty benefits ($B = .22$), center primary discipline ($B = .14$) and finally university research budget ($B = .14$). The results of this model imply that faculty who come from universities with larger research budgets, who participate in a non-engineering center, who perceive greater symmetry with industry and who report receiving more benefits are more likely to be satisfied with the center.

Because previous research has suggested psychosocial outcomes might be moderated by faculty roles (Boardman and Ponomariov 2007), exploratory analysis was performed to see if tenure interacted with any of the significant predictors. The interaction terms did not significantly contribute to the model.

6 Discussion

Our analyses focused on answering two questions: What outcomes do faculty experience from participation in CRCs? To what extent do various university, center and individual-level variables predict faculty satisfaction? While other researchers have examined faculty benefits, there is still some uncertainty about the extent to which faculty reap tangible vs. intangible benefits and/or also experience certain unintended consequences. Based on our literature search, the issue of faculty satisfaction with CRCs has been all but neglected in the empirical literature.

Based on our findings, participation in CRCs appears to have the greatest effect on tangible benefits that are directly related to a faculty member's CRC research role like support for graduate students, opportunities for research contracts and access to equipment, as well as a less tangible outcome in the form of increased interaction with other faculty. Participation also appears to have a positive but less pronounced impact on outcomes that are external to the center including chances for promotion and consulting.

Interestingly, we find little evidence that participation in CRCs has an extensive negative effect on faculty academic freedom. While a small minority reported a negative effect on autonomy in conducting research and ability to publish in a timely fashion, the

overwhelming majority of faculty reported no effect on academic freedom. Interestingly, more faculty reported a positive effect on these outcomes than a negative![6] We speculate that the limited scope of this problem is based on at least two factors: while firms have the ability to influence or even steer faculty research that option is very constrained in an industrial consortium where a consensus must be reached among many firms; while firms have the ability to delay publication, they rarely exercise those rights (Behrens and Gray 2000).

CRC participation also appears to have a positive impact on the two attitudinal items included in our perceived symmetry with industry mini-scale: evaluation of the quality of industrial research and trust and confidence in industry. We think this finding is noteworthy. While some have expressed concern about potential conflicts in cooperative research arrangements (Kenny 1987), our findings show that after an extended period of collaborating with industry, most faculty respondents are reporting a higher opinion of the quality of industry research and trustworthiness. While this finding does not end the debate about unintended consequences, it certainly provides a counterpoint to the bleak picture of cooperative research conflicts and compromises portrayed in books like Washburn's (2005) *University Inc*.

While multifaceted, our findings appear to paint a relatively positive picture of the outcomes of participation in CRCs for faculty. On balance, faculty appear to realize some tangible and intangible benefits, and few report any negative impacts on their academic freedom. The net effect appears to be a somewhat more favorable attitude toward industry by faculty.

Our review of the literature on both objective and psychosocial outcomes of CRCs for faculty found various inconsistencies and modest effect sizes. We speculated that faculty outcomes are probably affected by university, center and individual variables that had not been included and/or controlled for in prior studies. At the same time, we suggested a multivariate evaluation of possible predictors would yield a more parsimonious model than the many bivariate analyses we found in the literature. Our findings on faculty satisfaction appear to support both these assertions.

Overall, CRC faculty examined in this study are "quite satisfied" with their involvement in CRCs ($M = 4$ on 5-point scale). Results from the multivariate analysis show that a sizeable percentage of the variance (32%) in faculty satisfaction is predicted by variables at three organizational levels: the university, the center, and individual.

At the university level faculty were more satisfied when they came from universities with larger research budgets. We speculate that university research funding has an effect on satisfaction primarily because of the limited level of support provided by the IUCRC program examined in this study.[7] Consistent with this speculation, the most frequent answers given by respondents to an open-ended question in our survey about "improving center operations" highlighted the need for more funding and/or membership support. We suspect the consequences of this modest funding formula for faculty can be buffered to some extent at universities with large research budgets and slack resources but less so at universities where the CRC is expected to "pull its own weight".

[6] While this finding might seem counter-intuitive some faculty have told us that they find industry's influence less onerous than the imperative to publish in the most disciplinary journals and that requirements for regular reports by industry helps faculty publish sooner.

[7] As mentioned earlier, IUCRCs receive modest support for operating purposes (about $70–125,000/year). As a consequence, research projects are supported primarily by the limited funding provided by industrial membership fees.

At the center level, faculty were more satisfied when they came from centers that were labeled non-engineering. Upon closer examination of the disciplines comprising these centers, it was discovered that most represented highly applied and what some would describe as "transdisciplinary" fields (Stokols et al. 2008) such as textiles, health science, management, and computer science. We speculate that centers comprised of faculty from such fields were even more comfortable with the more applied and multidisciplinary nature of CRC research than their counterparts in discipline-focused engineering programs.

While contextual factors operating at the university and center-level appear to affect satisfaction, the strongest predictors relate to an individual faculty member's receipt of benefits and their perception of their industrial partner. In the organizational psychology literature, job satisfaction has consistently been linked with receipt of both intrinsic and extrinsic rewards (Spector 1997). In the case at hand, we believe our respondents are providing a satisfaction rating of their CRC "job" and this assessment is affected by the rewards they receive. However, CRC involvement is not a typical "job". As others have suggested, it requires faculty members to commit themselves to a collaborative research arrangement with an external partner who may or may not share their values (Kenny 1987) and whose motives are often viewed with suspicion (Slaughter and Rhoades 2004). As a consequence, it should come as no surprise that perceived symmetry with industry, an attitudinal measure that taps into values and trust, would be the strongest predictor of faculty satisfaction.

6.1 Conclusions

While we believe we have helped to shed additional light on the complex dynamics involved in faculty outcomes from and reactions to their involvement in CRCs, for a number of reasons we believe these findings should be interpreted with caution. First, our findings are based on a specific CRC model, the IUCRC, and may not generalize to other types of CRC. In fact, one of our findings, that a university's overall success in securing research funding may help negate the effects of limited IUCRC funding, highlights the importance of understanding the critical features of different CRC models. In addition, because of the limited and sometimes contradictory nature of the research available on this topic, our analysis involved an exploratory evaluation of a set of variables that were previously tested by other researchers. Obviously, now that we have demonstrated the importance of variables at different levels of analysis, it will be important to move forward with a hypothesis-driven theoretically-guided approach in future research. Finally, although we made an attempt to demonstrate the psychometric properties of the measures used in this study, there is clearly room for additional work on CRC construct development. In particular, there is an evident need to develop and validate a more comprehensive and psychometrically sound measure of faculty CRC satisfaction.

CRCs are a significant and critically important mechanism for supporting collaborative research in the US, and they are likely to play an expanded role in the US's emerging innovation policy. However, their continued viability depends upon the ability of these complex boundary-spanning structures to produce industrial and broader economic benefits, but also to create benefits for the faculty "volunteers" who perform most of the research. Our findings suggest that the typical faculty member involved in the IUCRC program benefits in both tangible and intangible ways and exhibits relatively high satisfaction. These findings seem to bode well for the stability and long term viability of CRC partnerships, in general.

However, consistent with the arguments in the companion article in this special issue (Garrett-Jones et al. 2010), our findings also suggest that a faculty member's subjective evaluation of their involvement is the product of a complex set of contextual factors and individual factors related to institutional support, personal rewards and a psychological contract with their external partners. Unless these factors are supportive, faculty satisfaction and potentially organizational commitment may suffer.

In essence, CRCs constitute a social technology (Gray and Walters 1998), and it is the role of social scientists to discover the core factors that determine their success, with regard to both economic benefits and faculty incentives to participate. This study is a first attempt to better isolate the unique effects of contextual, center and personal attributes on faculty satisfaction. However, more work is needed before a consensus is achieved among evaluators and researchers, and a more theoretically-based and comprehensive model can be tested across the various forms of CRC partnership models. In the meantime, if policy makers and program managers want CRCs to achieve their technology transfer and economic development goals, we suggest they continue to attend to the institutional, structural and individual factors that will maintain faculty interest and commitment.

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