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University research centers and the composition of research collaborations[☆]

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ABSTRACT

Research collaboration is perhaps the singular feature that university research centers, broadly defined, share. Yet, there has been little systematic study of the center-level attributes that facilitate (or hinder) research collaboration at the individual level. This paper estimates whether center-level measures of research capacity and structure affect center affiliated university scientists' and engineers' collaborative behaviors. We consider the effects of center multidisciplinaryity, size, and center ties to private firms and to federally funded centers programs on the time allocated to collaboration with researchers from industry, other universities, government laboratories, and abroad. Our analyses compare center to non-center scientists and also address within-group differences among center scientists. The findings demonstrate some center-level attributes to "map" to the expected collaborative behaviors while other center-level attributes do not. We conclude with a discussion of areas for future research and implications for the design and management of university research centers.

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1. Introduction

Past studies often have not made significant progress in consistently understanding the effects of university research centers on research collaborations. Centers are generally believed to induce outputs and behaviors that, historically, have not been encouraged in the traditional context of the academic department (Ikenberry and Friedman, 1972), including the conduct of applied and commercially relevant research (Gray et al., 2001), patenting (Dietz and Bozeman, 2005), and other forms of technology transfer like student placement in industry jobs (Feller et al., 2002). However, centers have also

been shown to encourage and facilitate traditional academic behaviors such as publishing (Landry and Amara, 1998; Wen and Kobayashi, 2001), even to the exclusion of transfer activities (Bozeman and Boardman, 2003). The mix of results that have emerged from past studies of research centers is probably a function of the heterogeneity of the centers studied (among other factors). There are few clear-cut definitions of exactly what constitutes a research center; accordingly, in past research many different types of extra-departmental "organized research units" (Geiger, 1990) have been characterized using the "centers" label.

Perhaps the singular feature that all university research centers, broadly defined, have in common is the intention to foster collaboration among researchers. The composition of these collaborations may be multidiscipline, inter-organizational, and/or cross-sector, depending on the scientific and technical goals of the center (Bozeman and Boardman, 2003). Many centers are designed explicitly to induce interactions and collaborations among researchers

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across multiple departments and disciplines, universities, industry, government, and sometimes multiple countries (Friedman and Friedman, 1982). Correspondingly, understanding and assessing the extent to which centers influence the collaborative behaviors of scientists is among the central questions that must be answered in the evaluation of such centers and in the development of theories and policy proposals regarding the expected consequences of the centers mechanism.

By focusing on university research centers and research collaborations, this study contributes to the broader literature that compares different structures for coordinating researchers and research projects. Some previous studies have treated the structure or formalness of research collaborations as an outcome (e.g., Landry and Amara, 1998; Wen and Kobayashi, 2001). Other studies consider the impact of a variety of institutional forms, such as centers, on the behaviors and outputs of individual collaborators (e.g., Gaughan and Corley, submitted). While these and other studies (e.g., Peters and Fusfeld, 1983; Geisler and Rubenstein, 1989; Bonaccorsi and Piccaluga, 1994; Landry et al., 1996) have increased understanding of the context of scientific collaboration, important questions remain about how (and to what extent) “boundary spanning” organizations (Meyer and Rowan, 1977; Aldrich and Herker, 1977) designed to coordinate researchers from disparate disciplines and organizations beget boundary spanning individuals by inducing collaborative transactions.

In this paper, we explore how and the extent to which university research centers affect individual-level collaborative research by assessing how institutional variation across centers is related to the “composition” of scientific collaborative behaviors. While previous studies have focused on co-authorship to measure collaboration (Katz and Martin, 1997), we use the broader, yet in many ways more direct, operationalization for collaboration that focuses on time allocation (Bozeman and Corley, 2004). Thus, we measure scientific collaboration by analyzing the percentage of research-related work time that university scientists allocate to collaborative research with other researchers in a variety of settings including at the same university, at other universities, in industry, in government laboratories, and abroad.

Earlier studies of scientific collaboration compare the effects of competing institutional “types” (e.g., see Landry and Amara, 1998 for a comparison of “research teams” to “research centers,” as well as DiMaggio and Powell, 1983; Massey and Zemsky, 1994 for comparisons of colleges and universities across the Carnegie tiers of the U.S. university system). Controlling for institutional effects in this way can mask significant intra- and inter-institutional heterogeneity, especially regarding research centers (Stahler and Tash, 1994). We instead rely on institutional attributes to discern the effects within and across different types of university research centers on the collaborative behaviors of center scientists. For example, we consider the size of the center, the multidisciplinary of center faculty memberships, whether the center has ties to industry, and whether the center has ties to a government-sponsored centers program

(e.g., National Science Foundation Engineering Research Centers).

Taking a limited “organizational design” perspective, which we elaborate on below, we consider certain center-level attributes to be strategic in the sense that they are intended to have specified effects on center researchers’ behaviors. For instance, we would expect that exposure to private firms by the way of center affiliation should in most cases increase the percentage of research time devoted to collaborating with industry scientists. Participation in government-based centers programs, which usually emphasize multidisciplinary and applied research (Gray et al., 2001), should in most cases increase the percentage of research time allocated to working with scientists outside the home academic department. More generally, we would expect center-affiliated researchers to collaborate more – and work alone less – than their colleagues who are not center-affiliated. Thus, research centers are designed to achieve scientific and technical goals by including in the center fold the combination of participants and stakeholders who, synergistically as a collaborative unit, possess the scientific “capacity” (e.g., equipment, funds, expertise, social network ties, incentives) appropriate to achieving those goals.

In taking this approach, we are attempting to go beyond previous studies of the research collaborations of center-affiliated researchers by exploring the relationship between organizational characteristics and individual behaviors. Most previous study assessing the effects of organizational and institutional attributes on research activity has focused on university-level characteristics (e.g., total research expenditures, quantity of faculty, institutional prestige) and aggregated, university-level production (e.g., of patents, Payne and Siow, 2003; Carlsson and Fridh, 2002; Coupé, 2003; Foltz et al., 2003; of licensing agreements, Turk-Bicakci and Brint, 2005), but often these studies have not explained the effect of organizational attributes on individual scientists’ behaviors.

This study uses data from a national survey of university scientists that have been merged with institution-level data tracking variation across the university research centers with which respondents indicate affiliation. We utilize OLS regression analysis to examine the relationship between center-level attributes and the composition of center scientists’ collaborative research. Our analyses compare center to non-center scientists and also address within-group differences among center scientists.

2. Center design and research collaboration

While new and emerging modes for scientific collaboration, including but not limited to university research centers, have elicited useful labels and heuristics (e.g., “triple helix” in Leydesdorff and Etzkowitz, 1996, 1998; “mode II” in Gibbons et al., 1994), there is little theoretical treatment of the effects of these modes on the behaviors, collaborative or otherwise, of individual scientists. Corley et al. (2006) and Youtie et al. (2006) acknowledge a dearth of theory and propose frameworks that examine collaboration-level characteristics. Yet, these studies remain focused on collaboration-level effects instead of individual-level

behaviors among collaborating researchers. Based on case analyses of inter-organizational research collaborations, including some centers, both the Corley and Youtie studies demonstrate that cross-discipline and cross-sector research occurs, but their cases do not demonstrate the extent of such collaborations, nor do they isolate particular institutional or organizational features that may foster particular types of individual-level interactions.

To guide our thinking about the effects of university research centers on individual-level collaborative behaviors, we expand upon this line of inquiry by taking a limited “organizational design” perspective. This perspective considers certain center-level attributes to be strategic in the sense that they were incorporated into center design with the intention of eliciting specific behaviors on the part of center faculty. This approach is limited in that we do not make the assumption that university research centers, by necessity, are “strategically designed.” For example, funding decisions for federally funded centers programs seem focused predominantly on scientific feasibility and relevance rather than on design features that address the organization and management of centers (Bozeman and Boardman, 2003). What little guidance or “strategy” for center design and management is exercised oftentimes seems to come *ex post*, by the way of “best practices” based on anecdote rather than on premeditated, theory-informed design.¹ However, with our approach we do assume, upon center establishment and after, that center management at the least selects participants and stakeholders from across the disciplines and sectors with the intention of promoting research collaboration among those selected. Therefore, in our analysis we emphasize the participants and stakeholders to which center scientists are exposed by the way of center affiliation, though we also consider structural characteristics, such as “size” and “multidisciplinarity” (these are explained below).

To help formulate hypotheses, we draw conceptually from institutional and organizational theories as well as from the concept of “scientific and technical human capital” (e.g., Bozeman et al., 2001). Hall (2002) notes contemporary understanding of institutionalization as a process whereby organizational structures take form, and rules and processes for interaction are articulated to establish collective identity and to promote collective functioning. One of the fundamental steps in this process, at least with respect to designing inter-organizational collaborations like centers, is the identification of participants that can help to achieve a set of predetermined goals. Agranoff and McGuire (2001) call this process “activation,” which entails the identification and solicitation of “appropriate” and complementary partners for collaboration (Lipnack and Stamps, 1994; Landau, 1991; Scharpf, 1978). For a university research center, this part of the organizational

design process may include the recruitment of scientists and stakeholders from industry, government, multiple universities as well as multiple disciplines, depending on the center goals (Bozeman and Boardman, 2003).

Participants and stakeholders in university research centers, scientists and non-scientists alike, are “activated” into center design due to the “scientific and technical human capital” (S&T human capital) they embody, individually and collectively. S&T human capital has been defined as the sum of researchers’ professional network ties and their technical skills and resources (Bozeman et al., 2001, p. 636). When scientists affiliate with a center, their respective professional networks and resource caches are enhanced by other scientists participating in the center (Dietz and Bozeman, 2005), especially when these “other” scientists have different disciplinary backgrounds and/or come from different organizations and sectors. Thus, university research centers are strategic exercises in S&T human capital enhancement that may be used as policy tools to foster collaborative networks that create cross-disciplinary and cross-sector synergies to further a field of research and development.

The concept of S&T human capital helps further to explain how center participants and stakeholders, once “activated,” affect individual-level behaviors. Given that any one center scientist alone does not possess the totality of S&T human capital necessary to achieve the scientific and technical goals of a center, and presuming an interest on the part of center scientists to achieve center goals (at least to the extent that it furthers their respective research agendas), it seems imperative that center scientists interact and collaborate with one another. Accordingly, we expect that the “composition” (e.g., the percentage of research time allocated to working with researchers with various backgrounds and sector origins) of the individual-level collaborative behaviors of center scientists should, at least in part, be predicted by center-level features, including ties to industry, government laboratories, and to external universities both in the U.S. and abroad. A similar use of the concept of S&T human capital is used by Dietz and Bozeman (2005), who demonstrate that career ties to private sector organizations correlate positively with the individual-level production of patents—arguably a scientific output more characteristic of scientists who include private sector organizations in their respective S&T human capital “constitutions” than of scientists who have no such ties and career experiences.

A notable exclusion from this discussion of center design is the slew of factors considered when discussing “institutional design” (e.g., for the management of common pool resources), including the articulation of rules, incentives management and alignment, interdependence, among other factors identified by theories of rational choice and collective action.² This exclusion is purposeful inso-

¹ To illustrate, the National Science Foundation Engineering Research Centers Program has a management/professional association that emerged separate from the NSF. The primary output of this association is a “best practices” manual to guide ERC directors in the design and management of their multidiscipline and cross-sector centers. See <http://www.erc-assoc.org/manual/bp.index.htm>.

² Further, this explication of how center-level attributes may affect the collaborative behaviors of individual university scientists does not use the concepts of organizational context and climate (Glick, 1985; Schneider and Reichers, 1983) to explain how the factors considered by the institutional design perspective “operate” to alter individual-level behaviors.

far as centers share faculty with academic departments, and therefore are the predominant authors neither of the opportunities and constraints nor of the norms and expectations (Glick, 1985; Schneider and Reichers, 1983) that center faculty face on a workaday basis (Boardman and Bozeman, 2007). As suggested above, it would be incorrect to presume that centers programs and/or management engage in many of the organization and management activities suggested by the institutional design perspective, at least regularly and formally, for no small reason that centers usually do not have significant, if any, line management or promotion authority over center faculty (Bozeman and Boardman, 2003). We discuss this unique challenge of center design and management further in relation to the findings below.

3. Variables and hypotheses

This paper assesses the impacts of center-level variation, related to the stakeholders and participants engaged in the center as well as structural features, on individual researchers' collaborative behaviors. The center-level characteristics considered in this study are center ties to industry (1: industry ties; 0: no such ties), center ties to a federally funded university research centers program (1: centers program ties; 0: no such ties), the quantity of academic disciplines represented by a center's faculty membership (multidisciplinarity), and the quantity of scientists working in the center (size).³ To the best of our knowledge, center-level characteristics, at least as explanatory variables, have been considered just once previously in a study based on interviews with university scientists affiliated with NSF Engineering Research Centers and Science and Technology Centers (Boardman and Bozeman, 2007). In this previous study, center ties to an academic department were demonstrated to mitigate center scientists' reports of "role strain"—whereby center tasks and duties were perceived as divergent with department tasks and duties, constituting additional workload. To the extent that studies of other organizations, predominantly of private firms, have considered institutional heterogeneity as antecedent to research collaboration, most emphasize varying levels of firm-level resource dependence (e.g., Mowery et al., 1998; Sakakibara, 1997) and transaction costs (e.g., Pisano, 1991) to predict and explain firm (versus individual) entrance into research-related strategic alliances and consortia.

Collaborative behavior is measured by the percentage of time spent working with researchers of varying backgrounds and organizational affiliations. We use responses to a survey item (see below) asking both center affiliated and non-affiliated university scientists to estimate the percentage of research-related work time they allocated during the 12 months preceding their participation

in the survey to working (1) alone, (2) with researchers in their "immediate work group," (3) with researchers at the same university but outside their immediate work group, (4) with researchers abroad, (5) with researchers at another U.S. university, (6) with researchers in industry, and (7) with researchers in government laboratories. The sum of all seven percentages equals 100% for the research-related time allocation for each respondent. By focusing on the backgrounds and organizational affiliations of the researchers with which respondents spend time collaborating, we are able to address the "composition" of scientific collaborations in terms of the "home" institutional context of the individual scientists' collaborators. There is precedent for this approach to the study of scientific collaboration. In a similar study using different data and focused on individual-level rather than on contextual explanatory factors, Bozeman and Corley (2004) use time allocation measures to evaluate the "cosmopolitanism" of scientific collaborations, a concept we explore further below.

3.1. Hypothesis: research conducted alone

Hypothesis 1. The percentage of research-related work time spent conducting research alone is negatively associated with center affiliation, no matter the institutional characteristics of the center.

Since the dependent variable in this hypothesis measures lack of collaboration generally (rather than the extent of specific types of collaboration), this hypothesis does not consider the effects of center-level characteristics. No matter the organizational characteristics of the center, center affiliation in all probability instigates a tradeoff between the percentage of work time allocated to research conducted alone and that allocated to collaborative research.

3.2. Hypotheses: collaborating with researchers at the home university

Hypothesis 2. The percentage of research-related work time spent collaborating with researchers at the home university is negatively associated with (a) affiliation with a center that has industry ties and (b) affiliation with a center that is part of a federally funded centers program.

This hypothesis relies on the ideas of strategic design in inter-organizational collaboration (Agranoff and McGuire, 2001; Lipnack and Stamps, 1994; Scharpf, 1978; Landau, 1991) and S&T human capital (Bozeman et al., 2001; Bozeman and Corley, 2004) as generally described earlier. Specifically, the more diverse the organizational affiliations of a center (e.g., ties with industry, ties with a centers program), the more diverse will be center scientists' personal network ties (Bozeman and Corley, 2004), which may lead to collaborations with researchers from a variety of organizations and sectors. There is some empirical precedent to support this reasoning. Lee and Bozeman (2005) demonstrate that career trajectory diversity – specifically, having held jobs in the government and private sectors in addition to academia – is associated with increased collaboration. Conversely, the less diverse the organizational

³ The binaries are employed as indicators of survey respondent affiliation with centers that possess the noted characteristics (i.e., ties to industry, ties to a centers program) to facilitate the comparison of center scientists to non-center scientists. The count variables for size and multidisciplinarity are operationalized as indicators of center-level structural features and therefore can be included only in analysis of within group differences among center scientists. This is explained further below.

affiliations of a center, the less diverse will be the collaboration patterns of center scientists. Therefore, scientists working in centers without external ties, while they may enhance their research networks at their home universities, will not develop as diverse social capital networks as will scientists affiliated with centers that include participants and stakeholders from other universities, organizations, and sectors.

3.3. *Hypotheses: collaborating with researchers at other universities*

Hypothesis 3. The percentage of research-related work time spent collaborating with researchers at other U.S. universities is negatively associated with affiliation with a center that has industry ties.

Hypothesis 4. The percentage of research-related work time spent collaborating with researchers at other U.S. universities is positively associated with (a) affiliation with a center that is part of a government centers program, and (b) the number of scientists working on a center faculty.

Given the general rationale for [Hypothesis 2](#), why expect that industry ties would decrease the likelihood of collaboration with researchers at other universities? Industry-linked centers typically work with local companies to support local technology-based economic development. Therefore, though perhaps exposed to researchers from other universities, center co-location (in this case with private firms) may see center scientists working to serve local industry research and transfer needs. However, we remain highly tentative in this expectation in that, using the inverse of the reasoning used for [Hypothesis 2](#), centers with ties to industry are more likely to have ties to a government centers program that require ties to both private firms and to multiple universities ([Gray et al., 2001](#); [Feller et al., 2002](#); [Bozeman and Boardman, 2004](#)). Therefore there may be competing effects within the same center. We discuss this further below.

The rationale for expecting a positive relationship between the quantity of center faculty and percentage time allocated to collaborative research with other universities is more probabilistic. The more university researchers to which one is exposed by the way of center affiliation, the greater the chances of exposure to researchers from other organizations, including other universities and private firms.

3.4. *Hypotheses: collaborating with researchers in industry*

Hypothesis 5. The percentage of research-related work time spent collaborating with researchers in industry is positively associated with (a) affiliation with a center that has industry ties, (b) affiliation with a center that is part of a federally funded centers program, (c) the number of disciplines represented by a center's faculty membership, and (d) the number of scientists working on a center faculty.

Centers with industry ties have such ties for a reason, usually to promote collaborative research and technology transfer from a university to private firms ([Feller et al., 2002](#); [Gray et al., 2001](#)). Accordingly, the probability of university scientists affiliated with such centers collaborating with their industrial counterparts increases. Since many federally funded centers programs require centers to have industry partners ([Bozeman and Boardman, 2004](#)), we expect centers with programmatic ties to have the same effect. The rationale for expecting a positive relationship between the multidisciplinary and size of center faculty membership and percentage time allocated to collaborative research with industry is more probabilistic. Research combining theory and method from multiple disciplines typically is more “applied,” or at least “use-directed” ([Stokes, 1997](#)), and therefore potentially more commercially relevant, which may alter the behaviors, collaborative and otherwise, of university researchers towards work with industry ([Etzkowitz, 1998](#); [Slaughter and Leslie, 1997](#); [Hicks and Katz, 1996](#); [Gibbons et al., 1994](#); [Ziman, 1994](#)). However, we remain tentative in this expectation since we control for “multidisciplinary” and not for “interdisciplinarity.”⁴ The rationale for the expected effect of center size is explained for [Hypothesis 4](#).

3.5. *Hypotheses: collaborating with researchers in government laboratories and with researchers abroad*

Hypothesis 6. The percentage of research-related work time spent collaborating with researchers in government laboratories is positively associated with (a) affiliation with a center that has industry ties, (b) affiliation with a center that is part of a government centers program, and (c) the number of scientists working on a center faculty.

Hypothesis 7. The percentage of research-related work time spent collaborating with researchers abroad is positively associated with (a) affiliation with a center that has industry ties, (b) affiliation with a center that is part of a government centers program, and (c) the number of scientists working on a center faculty.

We discuss these hypotheses together because the center-level data do not include any clear-cut center characteristics that may lead to increased collaboration with scientists in government laboratories or abroad. The hypotheses describe direct positive relationships between the independent and dependent variables because of the general diversity rationale laid out above—i.e., centers with

⁴ It is important to note that we do not intend to measure “interdisciplinarity.” Interdisciplinarity has been defined as faculty from different disciplines working together on the same project; multidisciplinary is defined as faculty from different disciplines working independently on different aspects of a project ([Friedman and Friedman, 1982](#)). In our data collection efforts, we had to use the more general concept to maintain reliability and validity. Though research conducted for a center may be multidisciplinary, it need not be interdisciplinary. The rationale we employ for [Hypothesis 4c](#) relies on multidisciplinary increasing the likelihood of interdisciplinarity. However, it may be the case that centers with a singular focus on a single or a few disciplines actually increase interactions with industry for development and transfer related activities.

ties to diverse participants and stakeholders across the sectors will beget individual-level collaboration patterns that are diverse. While there is evidence (reviewed above) that centers programs target collaborations with industry and across universities, we know of little programmatic efforts (at the time of data collection for this study) or systematic study demonstrating centers affiliating with government laboratories and/or with international partners.⁵

3.6. Collaboration “cosmopolitanism”

The variables (but not the data) we use to measure scientific collaboration “composition” are the same that [Bozeman and Corley \(2004\)](#) use to construct their collaboration cosmopolitanism scale, which measures “how close or far away a participant’s collaborators are” (p. 607). Since the center-level characteristics we assess may be interpreted as (albeit rudimentary) measures of center-level “cosmopolitanism,” we run an additional model with the expectation of a positive relationship between individual-level collaboration cosmopolitanism and (a) center ties to industry and (b) center ties to a government centers program. We discuss the details of the scale in the findings section below.

3.7. Controlling for individual-level effects

In our assessment of the relationship between organizational heterogeneity across centers and research collaborations, we also consider numerous control variables, at the individual level, including respective quantities of government and industry grants as well as indicators for tenure status (1: tenured; 0: not tenured but tenure-track), gender (1: male; 0: female), and multiple binaries for academic fields (e.g., 1: computer science; 0: not computer science). While we do not present formal hypotheses regarding the expected effects of these measures, we no less expect them to alter the composition of university scientists’ collaborative behaviors insofar as there are numerous individual-level reasons to collaborate ([Melin, 2000](#)).

4. Data

4.1. Individual-level data

The data that we use for our analysis were drawn from a national survey of university scientists that was conducted from August 2003 to July 2004 by a team in the Research Value Mapping Program at Georgia Tech. The sample design for the survey included tenured and tenure track scientists and engineers employed in “Research Extensive” (formerly “Research I”) universities, as defined by the Carnegie Classification (Carnegie Foundation for the

Advancement of Teaching, 2002). The sample was stratified by academic discipline, academic rank, and gender. For alternate research purposes EPSCoR (Experimental Program to Stimulate Competitive Research) university and HBCU (Historically Black Colleges and Universities) faculty were included in the original sample, but these two groups were not used for the analysis in this paper.

The scientific disciplines in the sample included biology, computer science, mathematics, physics, earth and atmospheric science, chemistry, and agriculture. The five sub-disciplines of engineering that were included were chemical, civil, electrical, mechanical, and materials. Sociology was also included in the sample, but only to compare engineers with a group of non-natural/physical scientists. Thus, we did not use sociology as a discipline in our analysis for this paper.

The sampling frame is comprised of 36,874 names of faculty—and our team sampled a total of 4916 individuals. The data were collected via a mail survey that followed [Dillman’s \(2000\)](#) “tailored design method.” The final response rate for the survey was 38%. After removing sociologists and faculty employed at EPSCoR universities and HBCUs from the sample, the final *N* for this dataset included 1647 university researchers. From this set of scientists, 32% indicated affiliation with a university research center. The survey focused on the following domains of faculty activity: funding, collaboration, institutional affiliations (including with centers), career trajectory, and distribution of work effort (including time allocations).

4.2. Center-level data

In addition to asking whether respondents affiliate with a university research center, we also asked respondents to list the name of the center with which they affiliate. From this list of center names, our team developed an ancillary dataset tracking institutional variation across these centers. The center-level data were retrieved using multiple coders on the basis of a search protocol combining Web searches, institutional and programmatic sources, and phone and e-mail contacts with center representatives, as required. For each center, several variables were collected for the dataset. These included the number of disciplines represented by faculty membership, the number of faculty members in the center, whether the center has industry partners or an industrial advisory board, whether the center is part of a federally funded centers program, how the center is organized in the larger context of the home university, and other measures. After reliability testing, these center-level data were merged with the survey responses for each respondent to form the dataset that we used for the analysis in this paper.

[Table 1](#) presents descriptive statistics for some of the key demographic, disciplinary, productivity and center-related variables in the dataset. Slightly less than half of the sample were men and almost three-quarters of the sample were tenured. There was a clear split between the number of respondents in science and engineering fields. About 41% of the respondents were in engineering fields, followed by 35% in the physical sciences, 8% in computer sciences and about 8% in the agricultural sciences.

⁵ Though when the data collection was conducted for this study, international partnerships and collaborations with federal laboratories were not emphasized by federal centers programs, recently the National Science Foundation Engineering Research Centers program has emphasized international partnerships for its “Gen 3” solicitation for applications (NSF 07521).

Table 1
Descriptive statistics for sample

	N	Mean	S.D.
Male	1644	48.54%	0.50
Tenured	1644	72.93%	0.44
Disciplinary categories			
Biology			
Engineering	1644	40.82%	0.49
Physical sciences (including math)	1644	34.85%	0.48
Computer sciences	1644	8.39%	0.28
Agricultural sciences	1644	8.27%	0.28
Productivity variables			
Number of industry grants	1644	0.14	0.44
Number of government grants	1644	1.17	0.95
Number of students supported by grants	1642	4.02	4.35
Center-related variables			
Affiliated with a center	1644	32.12%	0.47
Affiliated with a center with industry ties	1644	9.85%	0.30
Affiliated with a center with program ties	1644	9.98%	0.30
Number of disciplines represented in center	404	5.82	3.39
Number of scientists in center	404	35.58	39.57

5. Descriptive results by center affiliation

In [Table 2](#) we outline by center affiliation status the average percentage of work time that respondents spend on different types of collaboration.

The results presented in this table show that [Hypothesis 1](#) was verified by the data—i.e., the percentage of research-related work time spent working alone is negatively associated with center affiliation when not controlling for other institutional characteristics of the center. On average, center affiliated faculty spend about 12% of their research time working alone while non-center affiliated faculty spend about 20% of their time working alone.

Without controlling for other variables, we find that center affiliated faculty members spend significantly more research time working with researchers in the immediate work group, researchers at the same university, and researchers in U.S. industry. On the other hand, non-center affiliated faculty members spend significantly more time working alone and with researchers in other nations. Yet center affiliation does not have a significant impact on the amount of time that faculty spend working with researchers at other U.S. universities or researchers in government laboratories. Both center-affiliated and non-center affiliated faculty members spend the largest portion of their research work time working with colleagues in their immediate work group.

[Table 2](#) also reports the averages of the collaboration cosmopolitan scale for the respondents by center affiliation status (for the details on the inception of the scale, see [Bozeman and Corley, 2004](#)). The scale was created by multiplying the fraction of time spent by each respondent on the collaboration type by the cosmopolitan rank of that variable. Thus, if a respondent spends 100% of her time working alone (i.e., the variable with the lowest cosmopolitan rank), she would have a cosmopolitan scale of 0 (i.e., the minimum value). But if a respondent spends 100% of her time working with researchers in other nations (i.e., the variable with the highest cosmopolitan rank), she would have a cosmopolitan scale of 5 (i.e., the maximum value). As expected,

center affiliated researchers had a significantly higher ranking on the cosmopolitan scale than non-center affiliated faculty. The next step in our analysis was to determine if the effects of center affiliation on collaboration patterns persisted when controlling for discipline, gender, and grant activity.

6. Regression results

6.1. Controlling for demographic and career variables

The OLS regression results in [Table 3](#) use the percentages of research work time spent in the seven collaboration settings as the dependent variables in seven models. Each model includes a variety of control variables including gender, discipline, quantity of industry grants, and quantity of government grants.

When controlling for these variables, we find that center-affiliated faculty spend less time working alone, but significantly more time working with people in their immediate work group and home university, though without controlling for center-level features. In this series of models, center affiliation does not significantly affect the amount of time that faculty spend working with researchers in other nations, other universities, industry, or government labs.

When comparing the results of the OLS with the results in [Table 2](#), we see that the effect of center affiliation on industry collaborations and international collaborations disappears when controlling for grant activity, discipline, tenure status and gender. Without these control variables, center affiliated faculty were more likely to work with researchers in industry and less likely to work with colleagues in other nations. But with the controls, many demonstrate independent effects on research collaborations. Yet, centers are quite heterogeneous. They differ in size, multidisciplinaryity, types of participants, and types of external stakeholders (such as industry and government funded centers programs). Therefore, we expect that controlling for center-level variation will refine the impact that we observe of center affiliation on collaboration patterns.

Table 2
Dependent variables: descriptive statistics and differences of means by center affiliation

Variable	All (N = 1642)		Non-center (N = 1116)	Center affiliated (N = 528)
	M	S.D.	M	M
Collaboration cosmopolitanism scale (CCS)				
Weighted collaboration cosmopolitanism scale	1.53	0.71	1.49***	1.6
CCS dimensions: percentage of research-related work time spent				
Working alone (on research that at no point includes a collaborator)	17.69	23.04	20.37***	11.89
Working with researchers and graduate students in my immediate work group	45.52	26.36	43.01***	50.85
Working with researchers in my university, but outside my immediate work group	11.04	13.35	9.76***	13.77
Working with researchers who reside in nations other than the U.S.	5.78	10.03	6.11*	5.10
Working with researchers in U.S. universities other than my own	9.99	12.36	10.29	9.35
Working with researchers in U.S. industry	3.06	6.01	2.76***	3.70
Working with researchers in U.S. government laboratories	3.52	8.20	3.41	3.76

* Significant at 10%.

*** Significant at 1%.

6.2. Controlling for demographic, career, and center institutional variables

These regression findings collectively point up that center-level stakeholders and participants influence research collaboration at the individual level. In Table 4, we present a series of regression models that include control variables for center-level variation. Instead of using the binary center affiliation indicator as we did in earlier models, here we use non-mutually exclusive binary variables for affiliation with centers that have particular attributes. For example, a respondent may be affiliated with a center that has industry ties as well as ties to a federally funded centers program, or with a center that has just one or none of the two attributes. Thus, the added variables include one for whether the respondent is affiliated with a center that has industry ties, one for program ties, and an additional variable that indicates if the respondent is affiliated with a center that does not have industry or program ties.⁶ The purpose of this series of models is to explore the relationship between collaboration patterns and the presence of industry or program center ties.

The regression results in Table 4 demonstrate that being affiliated with a center that has industry ties is correlated with increased collaboration within the home university and industry, but decreased collaboration with researchers at other universities. On the other hand, affiliation with a center that has government program ties is correlated

with a decreased time spent working alone and larger amounts of time spent on collaborating with the immediate work group. Lastly, being affiliated with a center that does not have industry or program ties is correlated with increases in collaboration with researchers in the immediate work group and at the home university and decreases in international collaborations and working alone.

In sum, the results in Table 4 demonstrate that the “comprehensive” binary center affiliation variable that was used in Table 3 masked some of the effects of center affiliation on collaboration. Affiliation with a research center that has industry ties is (not surprisingly) correlated with an increase in industry collaborations. Yet, this type of center affiliation does not significantly decrease the amount of time that researchers work alone. Affiliation with a center that has program ties is correlated with a decrease in the amount of time spent working alone. This is also true for affiliation with centers that do not have program or industry ties. Therefore when accounting for stakeholder heterogeneity across centers (such as industry and government centers program linkages), center affiliation seems to foster collaborations with industry and other universities.

In our analysis thus far, we have been able to assess the collaboration patterns of the entire sample because we did not include control variables that were particular to the center structure (and thus required that the respondents have some type of center affiliation). In the next group of regression models, we include specific center structure variables as control variables, such as center size and the multidisciplinary of the center.

6.3. Center scientists only: controlling for demographic, career, and center institutional variables

The next series of regression models focuses only on center-affiliated respondents. In these models, we include

⁶ Because the sample includes respondents who did not indicate affiliation with a center, we had to include these three binary indicators for center affiliation to account for all types of center affiliation. While the indicators for affiliation with a center that has industry or federal centers program ties are not mutually exclusive (insofar as a single center may have both types of ties), these variables are mutually exclusive with the third indicator for affiliation indicating ties to a center with neither industry nor government program ties.

Table 3
Regression results (OLS): binary center affiliation indicator

	(1) Alone	(2) Immediate group	(3) Outside immediate group but still at home university	(4) Other nations	(5) Other universities	(6) Industry	(7) Government labs
Affiliated with a university research center	−4.135*** (1.011)	4.080*** (1.336)	3.281*** (0.698)	−0.695 (0.476)	−0.499 (0.582)	0.205 (0.310)	0.086 (0.425)
Quantity of industry grants	−2.694*** (0.794)	3.208*** (1.203)	−1.215* (0.621)	−0.534 (0.368)	−0.938** (0.448)	2.824*** (0.425)	−0.443 (0.383)
Quantity of government grants	−5.149*** (0.569)	2.758*** (0.736)	0.619 (0.406)	0.705*** (0.257)	0.667** (0.301)	0.307* (0.160)	1.010*** (0.227)
Quantity of students supported by grants	−0.797*** (0.159)	0.858*** (0.196)	0.082 (0.092)	−0.164*** (0.048)	−0.007 (0.064)	0.050 (0.037)	−0.011 (0.049)
Engineering	3.158 (2.270)	−8.407*** (2.851)	−0.074 (1.603)	0.414 (0.720)	−1.084 (1.080)	2.851*** (0.358)	1.385** (0.579)
Physical sciences	3.022 (2.308)	−12.238*** (2.869)	−4.161*** (1.602)	4.411*** (0.848)	5.052*** (1.158)	0.450 (0.301)	2.578*** (0.652)
Computer sciences	2.086 (2.812)	−4.803 (3.470)	−0.528 (1.923)	0.020 (0.915)	1.795 (1.465)	1.838*** (0.534)	1.464* (0.819)
Agricultural sciences	−0.458 (2.802)	−11.488*** (3.342)	1.741 (2.016)	−0.920 (0.890)	0.213 (1.386)	3.970*** (0.718)	3.574*** (1.015)
Tenured	−1.924 (1.219)	1.150 (1.438)	0.401 (0.706)	1.697*** (0.531)	−1.435* (0.736)	0.648** (0.301)	1.151*** (0.399)
Male	6.828*** (1.067)	−3.340*** (1.283)	−2.342*** (0.656)	0.001 (0.491)	−1.014* (0.600)	0.682** (0.283)	−0.160 (0.404)
Constant	24.122*** (2.377)	46.960*** (2.948)	11.334*** (1.659)	3.055*** (0.774)	9.601*** (1.199)	−0.571* (0.340)	−0.216 (0.568)
Observations	1640	1640	1639	1639	1640	1640	1640
R ²	0.15	0.09	0.05	0.06	0.06	0.13	0.03

Robust standard errors in parentheses.

* Significant at 10%.

** Significant at 5%.

*** Significant at 1%.

Table 4
Regression results (OLS): multiple center affiliation indicators, full sample

	(1) Alone	(2) Immediate group	(3) Outside immediate group but still at home university	(4) Other nations	(5) Other universities	(6) Industry	(7) Government labs
Center has industry ties	1.365 (1.644)	−0.881 (2.234)	2.522* (1.434)	0.133 (0.811)	−3.210*** (0.858)	1.183** (0.610)	−0.021 (0.662)
Center has program ties	−5.088*** (1.464)	5.534** (2.160)	0.921 (1.167)	−0.741 (0.984)	1.342 (1.063)	−0.444 (0.470)	0.001 (0.633)
Center has neither industry nor program ties	−6.128*** (1.290)	5.869*** (1.884)	4.504*** (1.021)	−1.171** (0.578)	−0.994 (0.823)	−0.148 (0.382)	−0.403 (0.544)
Quantity of industry grants	−4.116*** (0.826)	4.608*** (1.206)	−1.064* (0.613)	−0.806** (0.372)	−0.721 (0.462)	2.796*** (0.413)	−0.452 (0.404)
Quantity of government grants	−6.795*** (0.562)	4.465*** (0.687)	0.855** (0.367)	0.376 (0.240)	0.692** (0.279)	0.407*** (0.153)	1.014*** (0.202)
Engineering	1.776 (2.313)	−7.017** (2.891)	0.046 (1.623)	0.131 (0.720)	−0.859 (1.077)	2.791*** (0.360)	1.345** (0.567)
Physical sciences	3.108 (2.345)	−12.362*** (2.902)	−4.130** (1.610)	4.405*** (0.848)	5.053*** (1.156)	0.402 (0.299)	2.547*** (0.651)
Computer sciences	1.046 (2.845)	−3.749 (3.472)	−0.469 (1.921)	−0.171 (0.926)	2.031 (1.469)	1.734*** (0.537)	1.417* (0.832)
Agricultural sciences	−0.507 (2.851)	−11.444*** (3.393)	1.734 (2.014)	−0.927 (0.893)	0.228 (1.389)	3.942*** (0.715)	3.556*** (1.011)
Tenured	−2.636** (1.213)	1.947 (1.435)	0.480 (0.700)	1.533*** (0.527)	−1.437** (0.729)	0.690** (0.298)	1.136*** (0.388)
Male	7.042*** (1.076)	−3.609*** (1.287)	−2.418*** (0.653)	0.073 (0.489)	−0.949 (0.599)	0.635** (0.284)	−0.154 (0.401)
Constant	23.960*** (2.401)	47.203*** (2.972)	11.423*** (1.661)	3.023*** (0.774)	9.513*** (1.195)	−0.429 (0.344)	−0.145 (0.565)
Observations	1642	1642	1641	1641	1642	1642	1642
R ²	0.14	0.08	0.06	0.06	0.06	0.13	0.03

Robust standard errors in parentheses.

* Significant at 10%.

** Significant at 5%.

*** Significant at 1%.

the earlier control variables that measure the presence of program and industry center ties, but we also add control variables that measure the size and multidisciplinary of the center.⁷ The multidisciplinary of the center was assessed using a count variable that identified the number of disciplines represented by the faculty members within the center.⁸ Center size was assessed by counting the number of scientists and engineers who are listed as full time center faculty members.

The results in Table 5 demonstrate that when we control for center structure variables such as size and multidisciplinary, affiliation with a center that has industry linkages is correlated with increased time spent working alone. We did not observe this result before adding the center structure variables. But it is important to remember that the reference group is now comprised of researchers affiliated with centers that have neither industry nor federal centers program ties (versus in the above analyses where researchers not affiliated with centers comprised the reference group). One possible explanation is that for researchers working in centers with industry ties, a larger proportion of their collaborators are located off campus when compared to researchers working in centers with neither industry nor programmatic ties.

Other aspects of the regression remain the same as the results above (using the entire sample). Thus, adding the two center structure variables did not change the positive correlation between industry-center linkages and industry collaborations. The addition also did not change the negative correlation between industry-center linkages and collaboration with researchers at other universities. However, the addition of the center structure variables removed the significance of all relationships between collaboration patterns and affiliation with a center that has government program ties. This does not negate the results for the entire sample, but rather demonstrates differences among center scientists only.

Another noteworthy result is that the level of center multidisciplinary is significantly correlated with a decrease in industry collaborations. This is the reverse of the relationship that we hypothesized (Hypothesis 5), though we were tentative initially. We speculate that this is related to the fact that industry collaborations could be more focused on the commercialization of research or technology transfer—both of which would probably draw on specific disciplinary skills. We elaborate on this and the other findings in the next section.

⁷ We did not include these measures in the regression analyses using the entire sample of university researchers, center-affiliated and non-affiliated, because unlike the binary variables indicating affiliation with a center (with ties to industry and/or government centers programs or with no such ties), the count measures for center size and interdisciplinarity measure structural features of a center but do not indicate affiliation of any sort (e.g., with a center with X faculty members and Y disciplined represented by those members). Therefore, center affiliation is required of all data points to validate inclusion of the center size and multidisciplinary variables in the model specification insofar that zero values for these variables (in the instance of non-affiliated respondents) would have no meaning.

⁸ For multidisciplinary, the NSF discipline classification scheme was used.

Table 5 Regression results (OLS): multiple center affiliation indicators + center attributes (size, multidisciplinary), center scientists only

	(1) Alone	(2) Immediate group	(3) Outside immediate group but still at home university	(4) Other nations	(5) Other universities	(6) Industry	(7) Government labs
Center has industry ties	5.495** (2.130)	-3.201 (2.821)	-0.960 (1.558)	0.243 (0.979)	-4.255*** (1.119)	1.591** (0.713)	0.526 (0.818)
Center has program ties	-0.516 (1.808)	1.439 (2.629)	-1.286 (1.345)	0.048 (1.170)	1.293 (1.251)	-0.373 (0.594)	-0.043 (0.698)
Center multidisciplinary	-0.608 (0.397)	0.760 (0.505)	0.323 (0.281)	0.158 (0.149)	0.055 (0.180)	-0.269* (0.110)	-0.144 (0.108)
Center size	0.075* (0.041)	-0.040 (0.046)	-0.006 (0.023)	-0.019 (0.012)	-0.025* (0.013)	0.012 (0.007)	-0.004 (0.007)
Quantity of industry grants	-3.999*** (0.920)	3.199 (1.786)	-1.388 (0.943)	-0.469 (0.602)	0.138 (0.650)	3.225*** (0.607)	-0.679 (0.393)
Quantity of government grants	-3.617*** (0.819)	0.700 (1.375)	1.044 (0.745)	0.004 (0.514)	1.088** (0.434)	0.347 (0.300)	0.976*** (0.312)
Engineering	-0.594 (3.737)	-2.132 (5.657)	-0.981 (3.297)	-1.135 (1.402)	-3.033 (3.193)	2.786** (0.792)	2.623** (0.555)
Physical sciences	-0.242 (3.775)	-0.121 (5.696)	-5.960* (3.131)	1.760 (1.584)	-1.065 (3.262)	0.817 (0.723)	3.778*** (0.863)
Computer sciences	0.522 (4.618)	-2.630 (6.982)	0.721 (4.208)	-2.493 (1.515)	-1.006 (3.644)	0.790 (1.085)	3.674* (1.669)
Agricultural sciences	-0.056 (5.483)	-5.675 (6.917)	-0.045 (3.732)	-0.519 (2.029)	-1.948 (3.429)	3.033* (1.501)	4.768** (2.038)
Tenured	-3.407 (2.084)	-0.070 (2.837)	-0.365 (1.498)	1.573 (1.029)	-2.253* (1.240)	0.809 (0.581)	1.286* (0.668)
Male	5.096*** (1.695)	-0.620 (2.449)	-2.932* (1.379)	-0.444 (0.878)	0.611 (1.046)	0.937 (0.553)	-0.987 (0.635)
Constant	17,300*** (3.911)	49,851*** (6.223)	15,484*** (3.422)	4,326** (1.620)	12,510*** (3.886)	0.279 (0.908)	-0.637 (0.839)
Observations	386	386	385	386	386	387	386
R ²	0.13	0.02	0.07	0.04	0.07	0.22	0.07

Robust standard errors in parentheses.

* Significant at 10%.

** Significant at 5%.

*** Significant at 1%.

7. Discussion and conclusion

In the previous section, we outlined specific findings for each of the regression models. Here, we revisit our hypotheses and outline our findings within a broader science policy context, with particular emphasis on centers policies and management strategies.

Hypothesis 1 was that center affiliation would be negatively correlated with time spent working alone on research. This hypothesis was verified both when we did (Table 3) and did not (Table 2) control for individual-level variables beyond center affiliation. **Hypothesis 2** addressed the amount of time that researchers spend collaborating with others in their home university. This hypothesis includes collaborating both within and outside of the immediate work group. Specifically, we hypothesized that collaboration time with researchers at the home university would be positively correlated with a center that has no industry or centers program ties. The results verified this hypothesis (Table 4) for two cases. First, affiliation with an industry-linked center was positively correlated with collaboration outside the immediate work group but within the university; moreover, affiliation with a federal centers program-linked center was positively correlated with collaboration within the immediate work group.

This group of findings demonstrates, at least on a rudimentary level, that centers alter the behaviors of researchers in one of the primary ways intended—by facilitating research collaboration. Similar, that centers with industry ties increase collaboration time with researchers outside the immediate work group but at the same university (Table 4) suggests that center scientists may be branching out to researchers in other departments, perhaps to researchers with diverse backgrounds to address relatively applied work, another intended effect of university research centers.

The findings for subsequent hypotheses have direct implications for policy and for center design. **Hypothesis 3** was that collaboration with researchers at other universities would be negatively correlated with industry-linked center affiliation. **Hypothesis 4** was that collaboration with researchers at other universities would be positively correlated with program-linked center affiliation and center size. In both cases (Tables 4 and 5), industry-linked center affiliation was negatively correlated with collaboration at other U.S. universities. But program-linked center affiliation was not significantly correlated with collaboration with researchers at other U.S. universities.

These findings suggest that there may be potential oversight by centers programs regarding the effects of the diversity of stakeholders to which researchers are exposed by the way of center affiliation. Though most federally funded centers programs require that centers be comprised of faculty from multiple universities, presumably to facilitate collaboration across institutions of higher learning, affiliation does not increase the time allocated to working on research with faculty at other universities. This implies that center management (usually the principal investigators for the center) has failed to coordinate adequately researchers who are not co-located or, more pessimistically, that the lead investigators have no intention of collaborat-

ing outside the university, at least not extensively enough to alter their reported time allocations.

Assuming the relatively optimistic scenario, one explanation may be that federal centers programs, because they usually require numerous and divergent stakeholders to be included in the center fold, are causing unintended tradeoffs at the individual level regarding time allocated to research collaborations. That affiliation with a center with industry ties has a negative effect on time allocated to collaboration with researchers at other universities suggests as much, since most federal centers programs require the inclusion of industry partners in addition to a multi-university faculty membership. Center programs and management must consider an “optimal” rather than a “maximized” mix of center participants and stakeholders, one appropriate to the scientific and technical (and also, if applicable, the social and educational) goals of the center.

Hypothesis 5 focused on collaboration patterns with industry researchers. Specifically, we hypothesized that industry collaboration would be positively correlated with industry-linked center affiliation, program-linked center affiliation, and center multidisciplinary. This hypothesis was verified for industry-linked center affiliation (Tables 4 and 5), but not for the other two center attribute variables. **Hypotheses 6 and 7** stated that time spent working with researchers in government labs and time spent working with international collaborators would both be positively correlated with industry-linked center affiliation, program-linked center affiliation, and center size. Neither of these hypotheses was verified by the regression analysis.

The findings for industry-linked center affiliation suggest that exposure to private firms has the intended effect on university researchers: increased university–industry research collaboration at the individual level. However, the discussion of tradeoffs above implies that such collaborations may come at a cost. More important, the effect on time allocated to research collaboration with industry is relatively small. While 30 years ago any research-related interaction with industry on the part of department-based university faculty was considered a policy success, today centers program administrators and center directors need to address not only the extent to which they would like to facilitate university–industry interactions amongst center faculty, but also the types of interactions to promote.

The findings in this study collectively point up that center stakeholders and participants influence research collaboration at the individual level. But not all of our expectations were met by the results from the regression analyses. To ensure that center participants and stakeholders interact to the extent and in the ways intended, center program officials and/or center management are faced with a unique challenge insofar that they are not entirely (or even partially in many cases) in control of numerous other “design” factors that affect the behaviors of individual researchers, most importantly the incentive structure to which center researchers are subject as faculty in academic departments. Previous research has demonstrated this to result in a devaluation of applied and commercially relevant research among untenured but tenure track center faculty (Boardman and Ponomarev, 2007).

A number of policy and management scenarios come to mind that extend beyond the findings of this study. For instance, centers may implement strategic guidelines for faculty development and for opening communications with academic departments. It is unclear across the broad and diverse population of university research centers the extent to which centers engage in these activities, though previous research on federally funded centers programs suggests that such activity is not the norm (Boardman and Bozeman, 2007). The point is to ensure that centers consider where they are headed as academic institutions in addition to where they are headed in terms of research collaboration. Such consideration probably will have to occur at the level of center management, on a center by center basis.

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