The Effects of Organizational Resources on Scientists' Research Production across Ranks: Does Collaboration Matter?

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Abstract

This study addresses two major questions: First, do resources provided by academic departments influence scientists’ production differentially across ranks? Second, does collaborative network size mediate the relationship, if any, between organizational resources and research production? Data from a national survey of academic scientists and engineers in Carnegie-designated Research I universities is used to assess the possible differential effects of resources on production by rank and to explore the possible mediating role of collaboration on production. Overall, preliminary findings suggest that certain organizational resources affect research production and these effects are different for scientists in each stage of their career. Also, the impact of certain organizational resources is in some instances partially mediated by collaborative network size.

Introduction

Scientific production at academic institutions not only contributes to new knowledge creation but also through knowledge transfer helps promote industrial development. In addition to these broader implications, scientific production of individual scientists is also important for their promotion in academia, since promotion in research universities in US is highly dependent on the quantity and quality of publications. In this context, resources are the means to do research and performance of scientists depend strongly on their ability to make use of resources provided by their institution (Lazega et. al., 2006).. If the means are limited or removed, research production will surely suffer. Therefore, a better understanding of the relationship of resources to production is critical to an improved understanding of the conduct of science.

Knowledge production by academic scientists is a collaborative process in which certain resource inputs are transformed by the work of the scientist(s) into knowledge outputs such as research publications or patents (Lee and Bozeman,2005; Bozeman and Corley, 2004). This production process is embedded in an organizational environment that shapes the preferences and actions of the scientist by providing or withholding the organizational resources required to produce knowledge as well as through norms, practices, and policies that govern the use of these resources (Fox, 1991; Fox and Mohapatra, 2007; Lambright and Teich, 1981). These resources can range from intangible resources like leadership and institutional commitment ((Bohen and Stiles, 1998) to tangible resources like graduate students, equipment, and lab space (Dundar and Lewis, 1998). Also, the resources available from organizations can vary. For example, academic departments vary in the quantity and quality of graduate students they can attract to their programs (James, E.1990). Because graduate students play an important role in the conduct of science, the nature of the pipeline of graduate students can constrain research production (Dundar and Lewis,1998; Rushton and Meltzer, 1981). Also, inadequacy of research equipment and additional funding required for its maintenance and other instrumentation requirement may also hamper conduct of research (Babu and Singh,1998).

While much is known about the impact of resources on research production generally, little is known about how the differential impact of resources across a scientist's career. For example, is the availability of a bench of graduate students more important for an assistant professor just starting their career or a full professor who may be more experienced in using graduate students effectively? Further, is equipment and lab space equally important to scientists throughout their careers or does the need increase (or decrease) as their career progresses?

The second aspect of this research recognizes that departmental structure, support and incentives are necessary but not sufficient determinants of successful research outcomes (Fox and Mohapatra, 2007; Dundar and Lewis, 1998). Knowledge production also requires the cooperation of other scientists from within and across organizations who engage in this transformation process as research advisers and collaborators (Katz and Martin, 1997). Collaboration has received much recent research attention. Earlier studies suggest that collaborative research activities lead to more efficient division of labor (Chompalov and Shrum, 1999; Lee and Bozeman, 2005), enhanced credibility (Chompalov and Shrum, 1999), acquisition of new skills, access to costly equipment, communication of new information, and publishing opportunities (Lee and Bozeman, 2005: 676; Bozeman and Corley, 2004; Acedo, 2006). However, little is known about the potential interplay of organizational resources with research collaboration. Do scientists who lack organizational resources build a stronger network of research collaborators in order to access the required resources as resource dependency theorists would suggest? Or do scientists with resources use these resources to attract other scientists to their network in a "rich get richer" approach?

In response, this study has two objectives. First, it attempts to tease out the relationship of organizational resources on production by exploring the influence of different types of organizational resources on production for scientists at different stages in their career. Second, it explores the possible role of collaboration in mediating the effect of organizational resources on production. Specifically, we ask what types of tangible organizational resources most affect research production and how do these effects differ across academic rank? Also, to what extent does collaboration mediate the effect of these tangible resources on production?

We intend to contribute to current literature in two ways. First, instead of aggregately examining the effects of organizational resources, this study decomposes the resources provided by departments into seven specific types. The employment of this approach is based on the assumption that different types of resources may not have the same effects on production, especially considering variations across ranks (we will discuss the argument in the next section). Second, given the existing evidence that resources, collaborative networks, and research production are highly correlated, this study makes a further step towards unraveling the possible role that collaborative networks play in the relationship between organizational resources and research production.

This investigation proceeds by first reviewing previous research on the relationships between organizational resources, collaborative network, and production including the theoretical argument on variations across rank. This section develops specific testable hypotheses. Next, data, measures, empirical models, and method employed in this paper are presented. Finally, results, implications and future direction of this research are discussed.

Literature and Hypotheses

Effects of Organizational Resources on Research Production

Earlier work attached primary importance to departmental attributes influencing research production of faculty. Departmental structures, norms and availability of resources were found to improve research production (Dundar and Lewis, 1998). Access to resources such as laboratory equipment, facilities and funds are prerequisites of scientific work (Singh, 1970). As mentioned in the introduction, scientists especially those who are in an early phase of their career, need material and human resources to be able to conduct research.

The importance of various kinds of resources on research production has been found out in the literature. Crewe (1988), in his analysis of research production in the departments of politics in U.K. universities found a large variation in departmental average publication rates. He showed that such variations arose due to differences in resources and opportunities for research which included travel money, teaching loads, the availability of research funds, and the research ethos. Availability of technology and computing facilities on performance, availability of travel and institutional funds and star faculty in the department, student-staff ratio, the quality of computing facilities, and the availability of secretarial, administrative, and teaching assistance as organizational resources have been shown to effect departmental research performance (Dundar and Lewis 1998; Johnes, 1988a). Other organizational resources that are found to influence research production include graduate students who held research assistantships in engineering and physical sciences (Dundar and Lewis, 1998), resource adequacy, stimulative leadership, concern for advancement, external orientation, and professional commitment (Babu and Singh,1998, p.309). Resource adequacy includes "adequate equipment with maintenance provisions, and adequate funds for research" (p.311) Based on the empirical findings showing a positive relationship between organizational resources and research performance, we expect that the availability of resources offered by organizations for faculty will positively affect their research performance.

H1: Availability of resources provided by an organization will be positively related to scientists' research production.

Effects of Organizational Resources on Collaborative Network

Organizational resources not only matter for research performance, but they also have impacts on scientists' collaborative network. As Fox and Ferri (1992) contend, organizational human and material resources are important for the performance of faculty and vary based by gender and level of collaboration. As known the principal purpose of academic work is to contribute to knowledge creation and dissemination of that knowledge. As mentioned previously scientists need resources to conduct research to produce knowledge, otherwise knowledge creation and dissemination is likely to suffer. Scientists also need additional resources to get recognition and visibility in the academia to get access to more resources in order to be able to more productive partly because promotion especially in research institutions is highly dependent on the quantity and quality of publications. In this context, in case of inadequacy of resources especially during the times of reduced funds to universities, highly competitive nature of receiving research grants, and increasing cost and complexity of conducting research, establishing collaborative research activities are not only critical for but also the means to have access to resources required for performing scientific work.

There is a growing number of studies analyzing different aspects of collaboration. One stream of literature on collaboration discusses the motives for collaborative activities of scientist. Major motives are centered on the need to have an access to resources that are lacking and/or insufficient. These include levels of funding, scientific instrumentation, research facilities (Clarke, 1967; Heffner, 1981; Meadows, 1974; Katz and Martin, 1997, Lazega et., al. 2006). Previous research also showed that providing funds for expensive equipment and other laboratory needs exceeded the financial capability of any single research department because of increasing complexity and costs of instrumentation requirements. (Katz and Martin, 1997). For instance, standard experiment in high energy physics requires combination of diverse tasks and expertise which is beyond one's capability (Katz and Martin, 1997). Steps in conducting experiments include "building detectors and accelerates, writing software for controlling the equipment and data, funding-raising, liaising with the laboratory management, managing collaboration" and etc, (Katz and Martin, 1997, p.8). This ultimately implies necessity of establishing collaboration. Another motive that was found to facilitate collaboration is relatively low cost of travel and other channels of communication. In this regard, departmental provision of scientists' travel expenses is important for scientist's decision to be involved in collaborative research activities beyond his departmental boundary especially in geographically different location.

Based on the discussion above, literature and previous empirical studies generally admit the argument that availability of resources matters to collaborative activities. However, resources dependence theory and accumulative advantage theory predict different directions of the relationship. On the one hand, availability of resources is sine qua non of scientific work. Resource dependency theory posits that since individuals and organizations have tendency to maximize their self interests for success, those who do not have essential resources will resort to forming links with others in order to get access to adequate resources that will minimize their dependence on others (Pfeffer and Salancik, 1978). Because it was assumed that "environment contains scarce and valued resources." [1] Accordingly, faculty falling short of adequate resources in their departments will seek to obtain additional resources through establishing collaborative relations which will likely to enhance their skills and knowledge. In other words, resources a scientist has will be negatively associated with his collaborative network size.

On the other hand, cumulative advantage theory (also called as Mathew effect) informs a positive relationship between availability of resources and collaborative activities. Merton (1988) argued that opportunities and material rewards for scientific research that were yielded to successful outcomes accumulate over time for both individual scientists and organizations involved in scientific enterprise (p.606). Specifically, this cumulative advantage will lead senior scientists to an 'edge position' in cases of collaboration and in cases of independent multiple discoveries made by scientists of distinctly different ranks. Credit in recognition through peer review is usually given to a senior professor who has initial comparative advantage, high visibility and recognition in contrast to relatively un known junior faculty and graduate students. Merton views this practice as unfair which he thinks triggers unequal allocation of resources. The misallocation of credit in the reward system results that the rich get richer and relatively unknown scientists tend to get disproportionately little credit for comparable contributions (Merton, 1968, p. 57). That is, the research resources in a society will highly concentrate on those possessing cumulative advantages, usually are senior scientists and eminent scientists.

The disproportional concentration of resources will reinforce the extension of eminent scientists' collaborative network. Given the assumption that availability of resources will motivate collaborative activities, eminent scientists' prestige would attract a disproportionate share of colleague faculty and promising graduate students than junior scientists. Review of the literature suggests that access to new web of networks improves performance of faculty who have not been known yet in academic circles which may ultimately result in higher visibility and recognition. Therefore, junior faculty who need to have more recognition and visibility despite adequacy of resources at their disposal will seek to establish more

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[1] http:www.istheory.yorku.ca/resourcedependencytheory.htm

collaborative ties with senior faculty. It turns out that senior faculty are likely to have more collaborative ties and contribute to scientific enterprise through collaborating especially with junior scientists or graduate students. Ultimately, the argument of cumulative advantage theory leads us to conclude that resources a scientist has will be positively associated with his collaborative network size.

In sum, both resource dependence theory and cumulative advantage theory recognize that availability of resources will matter to collaborative activities. However, they predict opposite direction about the relationship between availability of resources and collaborative network size. Here the hypothesis will be built based on the argument that availability of resources provided by an organization is related with collaborative network size, but the direction of the relationship will be left for empirical testing.

H2: Availability of resources provided by a department will be associated with collaborative network size.

Effects of Collaborative Network Size on Research Production

Science has increasingly been driven by collaboration of scientist that cross beyond departmental, institutional and even national boundaries (Melin and Person, 1998) since many research activities have become expensive and gained interdisciplinary nature due to complexity of research questions . Collaboration in the literature is defined as joint activity of producers and users of scientific and technical knowledge who share and use that information and knowledge towards a common goal (Bozeman and Boardman, 2003; Alberts et.al, 2001). Collaborative activities enhance and promote research production in a number of ways: First, collaboration provides participant faculty with an access to new skills, expertise, technical know-how and specialized knowledge (both codified and tacit), costly equipment, publishing opportunities (Lee and Bozeman, 2005, p,676; Bozeman and Corley, 2004, Acedo, 2006) .Second, it has been shown that collaboration resulted in in efficient division of labor (Chompalov and Shrum, 1999; Lee and Bozeman, 2005), enhanced credibility (Chompalov and Shrum, 1999). Access to such opportunities, tangible and intangible resources strengthens and complements competencies and abilities of a scientist which is likely to result in higher production. As shown in earlier studies, joint effort spent for a scholarly work increased its rate of acceptance and improved quality (Laband and Tollison, 2000; Urbancick, 1992, Gordon, 1980).

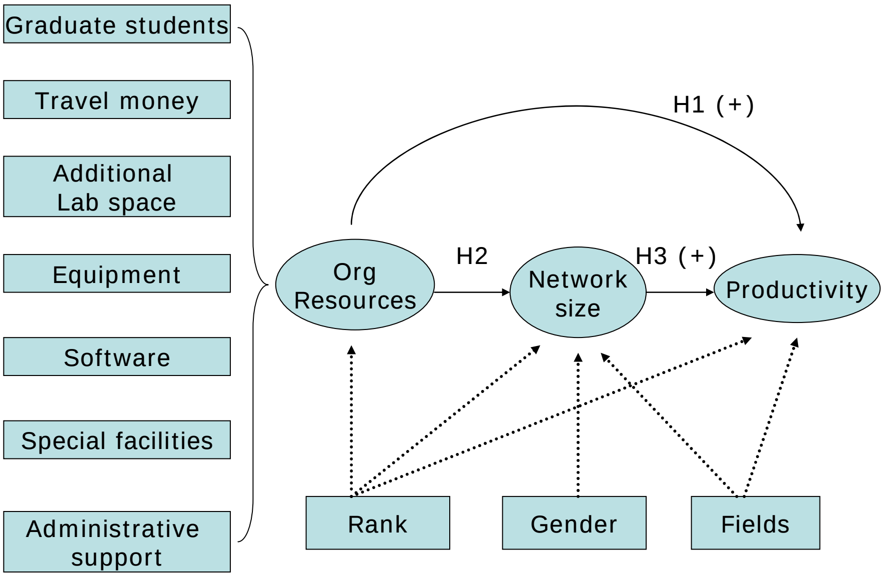
A collaborative activity ranges from advising to co-authoring a scholarly paper (Katz and Martin, 1995). Collaboration has been shown in the literature to be positively related to production (Beaver, 2001; Link and Bauer, 1987; Lotka, 1926; Link et al., 1996; Fox and Mohapatra, 2007; Lee and Bozeman, 2005; Rey-Rocha et., 2002). Furthermore, analysis of the organizational characteristics of work and publication production among academic scientists, external collaborative links outside university of campus was found to be positively significant and more important than internal ones that affect production (Fox and Mohapatra, 2007). In addition to previous findings, frequency and type of collaborative relations among scientists specialized in chemistry were found to effect research production measured by number of publications (Pravdic and Oluic-Vukovic, 1986). Findings further revealed that collaboration with prolific authors were positively associated with higher levels of production and most productive authors were the ones that were the most frequently collaborating

To sum it up, overview of the literature reveals a positive relation between collaborative activities and research production. As the empirical studies suggested, having access to additional resources through collaborative relations enhances capacity and capabilities of a scientist which results in higher production. Therefore, we expect that faculty who have larger collaborative network size will likely to be more productive.

H3: Collaborative network size will be positively related to scientists' research production.

Several control variables are also included into the models, including female, fields, and ranks. Previous literature points to lower level of production of women scientists (Fox and Mohapatra, 2007; Long and Fox, 1995; Gowan et., al., 1979). Previous studies show variations in performance different scientific disciplines. For instance biomedical and basic scientists were found to be the most productive (Blackburn et. al., 1978). Ranks also appear to highly correlate with collaboration and production. According to cumulative advantage theory, senior scientists have cumulated their recognitions, which are reinforced by US academic reward system, in the academic community longer than junior scientists. This cumulative advantage will lead senior scientists to an edge position in cases of collaboration and in cases of independent multiple discoveries made by scientists of distinctly different ranks. It has been argued that senior scientists usually have disproportional credits than the comparable work of junior scientists. Previous empirical studies also confirm positive effect of accumulated advantage of full professor and/or senior professors over junior ones on their higher production levels (Blackburn et., al. 1978; Clark and Lewis, 1985; Long, 1978). In order to eliminate the cumulative advantage effects, scientists' rank need to be controlled. Figure 1 displays conceptual framework of the study build from our discussion of the literature**.**

Figure 1 The Effect of Collaborative Network Size on the Relationship between Organizational Resources and Scientists' Research Production



Data, Models, and Method

Data source

The data reported in this paper derives from the first stage of a large three-year project, "Women in Science and Engineering: Network Access, Participation, and Career Outcomes," funded by the National Science Foundation. A national survey was designed to comprehensively investigate academic scientists' network structure, collaborative behavior, and academic production. Respondents were asked to provide their academic background, research activities (e.g., publications and grant applications), perception of their work environment, and general demographics. In addition, two main categories of questions contribute to the data of network analysis. First, name generator questions were used to identify informal and formal collaborators. Second, a series of "name expander" questions were used to capture the nature of the collaboration, including the level of relationship, types of collaborations, grant activities, and so on. The survey was implemented online using Sawtooth Software® and completed in March 2007.

The survey sample was drawn from the population of academic scientists and engineers in six disciplines (biology, physics, chemistry, computer science, electrical engineering, and earth and atmospheric science) in Carnegie-designated Research I universities (151 universities.) The sample was stratified by gender, rank and discipline. Male faculty were slightly over-sampled due to the lower response rate for men observed in the pretest. 3,677 individuals were surveyed and response rate is 50.1%.

Emeritus and research scientists (27 respondents) and scientists outside the six primary fields of study (214 respondents) were removed from the sample for this paper, resulting in a final total sample size of 1,601. Responses were fairly evenly distributed across the six fields, gender (48% women) and rank (27 % assistant professor, 28 % associate professor, and 45 % full professor.) In terms of field, approximately 18% of respondents are from biology, 19% from chemistry, 13% from electrical engineering, 17% from physics, 16% from computer science and 18% from earth and atmospheric sciences. Table 1 shows the descriptive statistics of the variables.

Table 1 Descriptive Statistics of the Variables

Variables	N	Mean	SD
Primary Variables			
Research Production	1592	3.76	5.35
Internal Collaborative Network Size	1450	2.46	1.54
External Collaborative Network Size	1450	2.62	1.66
Graduate students, postdoctoral fellows or laboratory technicians	1305	0.38	0.49
Travel money for conferences	1305	0.36	0.48
Additional lab space	1305	0.18	0.39
Equipment: purchases, maintenance, and technical support	1305	0.35	0.48
Software: upgrades, troubleshooting, etc.	1305	0.38	0.49
Special classroom facilities	1305	0.17	0.38
Administrative support for grant writing and grant management	1305	0.29	0.45
Control Variables			
Female	1601	0.46	0.50
Biology	1601	0.17	0.38
Chemistry	1601	0.18	0.38
Computer Science	1601	0.16	0.37
Earth and Atmospheric science	1601	0.18	0.39
Electric Engineering	1601	0.13	0.34
Physics	1601	0.17	0.38
Assistant Professors	1601	0.27	0.44
Associate Professors	1601	0.28	0.49
Full Professors	1601	0.45	0.50

Measures and Models

In this study, the term, organization, refers to academic departments within university. The independent variable is organizational resources, which consist of seven specific resources provided by departments: 1)Graduate students, postdoctoral fellows or laboratory technicians; 2) Travel money for conferences; 3) Additional lab space; 4) Equipment: purchases, maintenance, and technical support; 5) Software: upgrades, troubleshooting, etc.; 6) Special classroom facilities and; 7) Administrative support for grant writing and grant management. The respondents were asked of the resources they asked for from their department/unit in the past two academic years, which did they receive(yes or no).

The primary dependent variable is scientist’s research production which is measured as the average number of published journal articles over the past five years. There are two intermediate dependent variables – internal and external collaborative network size which are counts of the invidiuals with whom the respondent collaborates with. Members of the respondent's collaborative network were identified using two name generator questions that asked the respondent to name up to five individuals per item inside or outside the university with whom they collaborated with on research in the last two years.Internal network size was measured by sum of named collaborators working within the university. External network size was measured by sum of named collaborators working outside the university.

Control variables include dummy variables for the six fields (chemistry, computer science, electrical engineering, physics, biology, and earth science) and female. In order to eliminate the effects of cumulative advantage, we also control for the rank (assistant, associate, and full professors). Given the assumption that the deviation of production of scientists within the same rank will not be too large, separately running each model across rank sets up a baseline for the comparisons.

Based on the discussion above, the study examines the mediate effect of collaborative network size by estimating four models. The first model addresses the relationship between organizational resources and individual research production. The second model presents the relationship between organizational resources and internal collaborative network size. The third model investigates the relationship between organizational resources and external collaborative network size. The last model tackles the relationship between organizational resources and individual research production by adding, collaborative network size as a mediate variable, into the model.

Methods

As shown in Table 1, the primary dependent variable-shows characteristic signs of a non-normal distribution. The standard deviation (5.35) for average production is larger than mean (3.76) and skewness (X) and kurtosis (Y) measures exceed the standards for a normal distribution. , Because average production violates the multivariate normality assumption of ordinary least squares regression. we used preferable approach is negative binomial regression, which provides a robust estimation when over-dispersion is presented in the count variable (Hilbe 2007).

The intermediatedependent variables, internal and external collaborative network size,, are both normally distributed and were estimated by ordinary least squares regression (OLS) analysis. Another assumption of OLS is that the independent variables should be independent from each other. In order to make sure our data satisfy this assumption, we checked how much our independent variables were correlated with each other. The most common way to diagnose multi-collinearity is to see the Variance Inflation Factor (VIF) of variables. VIF increases with the degree of multicollinearity between variables. The lowest value of VIF is 1, which means no collinearity. The well-accepted practice is that VIF should be lower than 10. The largest VIF value of independent variables in both model 2 and model 3 was 1.763. Given the rule of thumb, our models do not face serious multi-collinearity problems. In all four models, missing values were excluded from all analyses, and the analyses were undertaken with Stata 9.

Results

Table 2 presents the negative binomial estimation for organizational resources on research production (model 1). As expected by hypothesis 1, each resource has some effects on production except administrative support for grants, and various organizational resources have different effects on production across rank. Human capital (graduate students, postdoctoral fellows or laboratory technicians) is modestly associated with research production of assistant professors ($p<0.05$). Additional lab space is a strong predictor of research production for both associate and full professors ($p<0.01$). Equipment is significantly related to production but only for full professors. However, contrary to our hypothesis, software is negatively associated with production of associate professor ($p<0.01$). Moreover, the coefficients of travel money and special classroom facilities for full professors are also significantly negative ($p<0.01$). One explanation for those unexpected results is that some resources are not directly relevant to productivity but matter for teaching activities (e.g, software updates and special classroom facilities). The emphasis on teaching activities may reduce available time for research and then decrease production. On the other hand, it is not clear why travel money does not have positive effect on production of full professors. One possibility is that full professors usually are supported by grants. Therefore, even if travel money is not offered by departments, grants could provide them sufficient funding to attain conferences.

These results appear a crucial implication: Different resources are important for scientists' production at different stages in their career. Specifically, assistant professors whose departments provide access to graduate students, post-doctoral fellows or laboratory technicians are more likely to produce research while other types of resources such as lab space and equipment are not important at this early stage in one's career. At contrast, additional lab space is strongly important for associate and full professors. It reflects the fact that assistant professors are in the early career stage and in the beginning stage of establishing their own lab (Stephen & Levin, 2001) so that the resource does not matter for their production that much.

With regard to the control variables, associate professors and full professors in chemistry significantly are more likely to publish than those in biology ($p<0.01$). Associate professors in electric engineering have higher production than those in biology as well ($p<0.1$). Scientists in physics have higher production than those in biology across ranks (p<0.01). However, scientists in computer science have lower production than those in biology across ranks. Gender is not important for publication average at all.

Table 2 The Effects of Organizational Resources on Research Production (Model 1)

	Assistant professor	**Associate professor**	**Full professor**
Graduate students, postdoctoral fellows or laboratory technicians	0.21**	0.05	0.002
Travel money for conferences	-0.10	-0.07	-0.22***
Additional lab space	-0.09	0.38***	0.26***
Equipment: purchases, maintenance, and technical support	0.02	0.16	0.18**
Software: upgrades, troubleshooting, etc.	-0.13	-0.29***	-0.12
Special classroom facilities	0.15	-0.02	-0.27***
Administrative support for grant writing and grant management	-0.14	0.15	0.12
Female	-0.09	-0.04	-0.03
Chem	0.22	0.49***	0.33***
Cs	-0.29*	-0.37**	-0.34***
Eas	0.02	-0.07	-0.12
Ee	0.15	0.27*	0.16
Phys	0.67***	0.95***	0.68***
Log Likelihood	-690.89	-836.33	-1378.68
N	359	379	562

Dependent variable: research production

*<0.1 **<0.05 ***<0.01

Table 3 presents the OLS estimation for internal network size (model 2). As hypothesis 2 expects, availability of resources affiliating with scientists is significantly related to scientists' internal collaborative network size across ranks. Note all significant coefficients are positive, which may means availability of resources provided by a department helps scientists to extend their collaborative network within university. The positive coefficients also imply cumulative advantage theory would provide a better explanation than resource dependence theory for our data. That is, scientists working in a resource-richer department will attract those who are seeking for complementary resources to collaborate with them.

Specifically, the importance of different kind of organizational resources for scientists to extend their internal collaborative network varies across ranks. Results show that human capital and special classroom facilities are important for assistant professors to attract internal collaborators. For associates, resources don't matter at all. For full professors, additional lab space, equipment and grant administrative support are associated with larger internal networks.

As of control variables, female is weakly and positively related to internal collaborative network size of full professors. This means female full professors are more likely to have larger internal collaborative network size In terms of fields, faculty in computer sciences have larger internal collaborative network size than those in biology across all three ranks. Assistant and associate professors in electrical engineering have larger internal network size than those in biology. Last, full professors in physics have larger internal network size than those in biology

Table 3 The Effects of Organizational Resources on Internal Network Size (Model 2)

	Assistant professor	**Associate professor**	**Full professor**
Graduate students, postdoctoral fellows or laboratory technicians	0.41**	0.14	0.20
Travel money for conferences	-0.09	-0.18	0.11
Additional lab space	0.11	0.23	0.77***
Equipment: purchases, maintenance, and technical support	-0.14	0.26	0.27*
Software: upgrades, troubleshooting, etc.	0.02	0.04	0.19
Special classroom facilities	0.45*	0.16	0.06
Administrative support for grant writing and grant management	0.06	0.23	0.43***
Female	-0.26	-0.10	0.22*
Chem	0.29	0.06	0.22
Cs	0.56*	0.54*	0.81***
Eas	0.34	0.15	0.26
Ee	0.61*	0.96***	0.38
Phys	0.18	0.37	0.37*
R Square	0.05	0.07	0.11
N	326	351	519

Dependent variable: Internal collaborative network size

*<0.1 **<0.05 ***<0.01

Table 4 presents the OLS estimation for external network size (model 3). Results provide some support for the hypothesis that departmental resources are associated with external network size (H2). Graduate students, lab space, software support, and grand administration support are important resources for the external network size of at least one rank of professor. Travel money, equipment, and classroom facilities were not associated with external network size.

Results also show that the organizational resources that extend external collaborative network vary by rank. For assistants, graduate students/postdoc is significant resources for them to extend external network size. For associates, additional lab space and grant administrative support are two key resources associated with larger number of external collaborators. But, availability of software has negative effects on external collaborative network size. For full professors, only grant administrative support matters for their external collaborative network size. One explanation is that senior faculty have cumulative advantage, which is not necessarily related to organizations. Therefore, external collaboration may not be motivated by availability of organizational resources affiliating with senior faculty, but motivated by senior faculty's own recognition and personal resources such as capacity of receiving grants.

Table 4 The Effects of Organizational Resources on External Network Size (Model 3)

	Assistant professor	**Associate professor**	**Full professor**
Graduate students, postdoctoral fellows or laboratory technicians	0.36**	-0.06	0.22
Travel money for conferences	0.22	-0.07	-0.02
Additional lab space	0.08	0.63***	0.24
Equipment: purchases, maintenance, and technical support	-0.29	0.07	0.11
Software: upgrades, troubleshooting, etc.	0.17	-0.40**	0.01
Special classroom facilities	0.17	-0.24	-0.29
Administrative support for grant writing and grant management	-0.24	0.36*	0.35**
Female	0.26	0.35**	0.37**
Chem	-0.71**	-0.32	-0.11
Cs	-0.13	0.14	-0.24
Eas	0.97***	0.46*	0.99***
Ee	0.02	-0.07	0.02
Phys	0.27	0.16	0.37
R Square	0.14	0.09	0.10
N	326	351	519

Dependent variable: External collaborative network size

*<0.1 **<0.05 ***<0.01

Note all significant coefficients are positive except the coefficient of software for associate professors, which means generally availability of resources provided by a department help scientists extend their external collaborative network outside university. It can be argued that previous unsupported findings for resource dependence theory come from the employment of inappropriate network type. It is expected that scientists working in the same institution will be provided similar level of resources, and external collaborative network size will be a more appropriate arena to test resource dependence model. However, the results of model 3 still generally suggest that cumulative advantage theory provide a better prediction in external collaborative network size.

As of control variables, female is positively related to external collaborative network size of associate and full professors (p<0.05). It means female scientists are more likely to have larger external collaborative network size than male scientists in their mature career stages. In terms of fields, assistant professors in chemistry have smaller external collaborative network size than those in biology. Scientists in earth and atmospheric science have larger external network size than those in biology across ranks.

Table 5 presents the Negative Binomial Regression estimation for model 4, which include both organizational resources and collaborative network size as independent variables to predict research production. The results point out that internal collaborative network size does not have any significant influence on production, but external collaborative network size matters for production across ranks, especially for associate professors and full professors. Which supports the hypothesis 3 but suggests the distinct effects of internal and external collaborative network size.

Table 5 The Effects of Organizational Resources and Collaborative Network Size on Research Productivity (Model 4)

	Assistant professor	**Associate professor**	**Full professor**
Internal Collaborative Network Size	0.03	0.02	0.04
External Collaborative Network Size	0.05*	0.17***	0.09***
Graduate students, postdoctoral fellows or laboratory technicians	0.24**	0.03	-0.06
Travel money for conferences	-0.14	-0.07	-0.26***
Additional lab space	-0.15	0.23**	0.26***
Equipment: purchases, maintenance, and technical support	0.07	0.13	0.14*
Software: upgrades, troubleshooting, etc.	-0.18*	-0.22**	-0.08
Special classroom facilities	0.12	-0.02	-0.22**
Administrative support for grant writing and grant management	-0.15	0.07	0.02
Female	-0.06	-0.10	-0.04
Chem	0.29*	0.46***	0.28**
Cs	-0.22	-0.41**	-0.37***
Eas	-0.02	-0.19	-0.22*
Ee	0.20	0.27*	0.11
Phys	0.66***	0.86***	0.61***
Log Likelihood	-629.66	-759.66	-1248.29
N	325	350	517

Dependent variable: research productivity

*<0.1 **<0.05 ***<0.01

Some interesting results appear as we compare the results of model 4 to model 1. After the collaborative networks size was included into the model, the effects of organizational resources change, especially for full professors. For assistant professors, the negative effect of software becomes significant in model 4. For associate professors, the effect of additional lab space and software remain but become less significant ($p<0.05$). For full professors, availability of equipment still matter for production but the significant level becomes weaker ($p<0.1$). Moreover, the significant effects of special classroom facilities decrease and become positive ($p<0.05$). The results confirm our expectation that collaborative network size rmediates the relationship between organizational resources and research production. With regard to control variables, collaborative network size did strengthen or weak the variation of production among the fields.

In sum, we find some support for all three hypothesis. However, the resources that are important for research production vary by rank. The relationship between organizational resources and collaborative network size generally exists in a positive way. Scientists with more resources are likely to have larger collaborative network size. But, the effects of different resources on extending internal and external collaborative network size vary across ranks as well. Furthermore, scientists with larger external collaborative network size appear to have higher production. Last but not the least, the effects of organizational resources on production change after collaborative network size is taken into account in the model. Which support our expectation that collaborative network size has a mediate function in the relationship between organizational resources and research production.

Discussion

Two main questions were addressed in the paper. First, how does resources provided by departments influence scientists’ production across ranks? By decomposing organizational resources to seven specific resources, we are able to identify how the demand of resource types varies among scientists in different rank. We argue that the career stage and senior faculty’s cumulative advantages can explain the effect differential across ranks.

The second question this paper tackles is: Does collaboration mediate the relationship between organizational resources and research production? In order to answer this question, we tested two hypotheses (H2 and H3) built from the theories. Findings reveal that: (1) There is a positive relationship between external collaborative network size and research production. That is, larger external collaborative network size, higher research production. (2) The relationship exists between organizational resources and collaborative network size (for both internal and external network). Both of resources dependence theory and cumulative advantage theory contend that collaborative activities are motivated by availability of resources. However, the two predict contradictory sign of coefficients about the relationship. Informed by the resource dependence model, availability of organizational resources will be negatively related to collaborative network size. The rationale is that people will need to seek for resources from other people when they do not have enough resources for survival. On the other hand, cumulative advantage theory indicates the importance of recognition in science community and argued that the social selection process will lead to the concentration of scientific resources and talent. As Merton (1968) contended, this pattern of recognition, skewed in favor of the established scientist, results that the rich get richer at a rate that makes the poor become relatively poorer. Following the logic of the rich get richer, cumulative advantage theory implies that scientists working in resources-richer departments will have better capacity to attract other scientists as collaborators. Our results suggest that cumulative advantage theory better explains the relationship of resources, collaboration and productivity than resource dependency.

Limitations and Future Work

Although our evidence does not support resource dependence theory, it is unwise to degrade the validity of resource dependence theory. Traditionally, resource dependence model is used to explain inter-organizational collaboration. Thus, it can be argued that our unsupported findings for resource dependence theory may be due to misapplication of analysis unit. However, the model has been employed to explain the use of different knowledge networks at the individual level from a resource-based perspective (van Rijnsoever, Hessels, and Vandeberg, 2008). Therefore, what we suggest is to refine the research design and to ask for more empirical studies instead of rejecting the application of resource dependence model at the individual level.

Given the confirmed relationship mentioned above, we further examine the role of collaborative network size by adding it in the model with other organizational resources variables. The comparison between model 4 and model 1 preliminarily support the mediate effect of collaborative network size in the relationship between organizational resources and research production. That is, collaborative network size does change the influence of organizational resources on research production. But, we can barely know how much and in which direction, from our analysis, that collaborative network size mediates the effect of organizational resources. In addition, these findings leave unanswered a large question about endogeneity among organizational resources, collaborative network size, and research production. Does increased research production lead to the department providing more resources to the scientist? Does increased research production lead to the extension of collaborative network size of scientists?

Based on the limitations of the study, we propose a future study which will examine the direct and indirect effects of organizational resources and collaborative network size on research production. Path analysis will be employed to answer three questions: (1) how much influence organizational resources directly have on production, and (2) how much influence collaborative network size directly has on production, and (3) how much influence of organizational resources indirectly works through collaborative network size. We can not understand interactions among the variables (may offset or strengthen each other) by only examining aggregate effects. Secondly, phase two of the Netwise project will certainly help us to better analyze the endogeneity issue. In the interim, we plan to use instrumental variables and other quantitative techniques to address possible endogeneity in the models.

Implications

Two policy and management implications are worth mentioning. First, scientists in different rank would need different types of organizational resources for their production. Organizational managers should take the differences into account for the design of resource allocation system. Second, collaborative network size, as our findings found out, seems to have a mediate effect on the relationship between organizational resources and research production. It means that the interaction between organizational resources and individual resources, if we regard collaborative network as a personal resource for information exchange and academic recognition, etc., should be taken into account to explain the production. Higher organizational resources are not automatically related to higher research production. The demand of different kinds of resources and mediate effect of collaborative network size complicate the linear relationship between organizational resources and scientists' research production.

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