Encouraging Innovation: Should Internal Funding Programs Favor Faculty Who Are Already Productive?

Soyeon Ahn
University of Miami

Susan E. Morgan
University of Miami

Ali Mosser
Vital Research

John L. Bixby
University of Miami

Abstract: *While it has been established that participation in interdisciplinary teams is likely to have a positive impact on researchers' careers, it has been questioned whether these researchers were already destined for success. If high-achieving faculty members are simply taking advantage of the availability of internal funds to boost their already high rates of productivity, internal programs designed to support the formation of novel teams and to enhance the impact of an institution's research portfolio may not be advancing their objectives. In this study, we examine whether applicants to an interdisciplinary funding program are already more productive than other faculty members, including those who apply for traditional (non-interdisciplinary) internal funding support. Data were drawn from several sources: Academic Analytics, which provides productivity data that allows for comparisons of faculty members within fields; the Office of the Vice Provost for Research's data on internal funding program applications; the Office of Research Administration's data on external grant proposal submissions; data from an internal survey on perceptions of the university's research climate; and Scopus, which provides individual faculty members' h-indices and lists of publications and citations. Results indicate that faculty members who join interdisciplinary research teams and are awarded internal funding are not more or less likely to be "superstars." This not only provides support for assertions that interdisciplinary programs can lead to team innovation and professional growth of individual faculty members, but also provides a blueprint for the establishment of baseline measures that can be used to help evaluate the impact of internal funding programs.*

Keywords: *Science of Team Science, Interdisciplinary Teams, Productivity*

Introduction

Academic institutions are economic engines in most regions in the U.S. and a significant source of scientific discovery and innovation (Association of Public and Land-Grant Universities, 2014), but more than this, they are seen as a powerful force for social change (Klein, 2008). Major funding agencies including the National Institute of Health (NIH) and National Science Foundation (NSF) recognize that the type of innovations required to make an impact on societal challenges require collaborations among researchers across disciplines (Stipelman et al., 2014). One set of criteria used by funding agencies for evaluating the viability of funding proposals focuses on the history of collaborations of an interdisciplinary team (Bennett et al., 2010). Thus, creating the conditions required for successful interdisciplinary collaboration is an imperative for research-intensive universities. One method for encouraging individuals to collaborate is the provision of pilot funding for teams that aim to address grand societal challenges. While there is no shortage of applicants for these opportunities for internal funding, universities face the difficulty of determining which teams are the most likely to succeed.

While the characteristics of successful teams are fairly well established, the attributes of faculty who are willing to engage with opportunities to collaborate across disciplines are still unclear. Hall and colleagues (2018) have identified this as a priority area for researchers who study processes and outcomes of scientific teams. Specifically, we are interested in whether funding should be directed toward faculty teams comprising members who are already highly productive and impactful in their own respective fields. The "productivity" question is often couched in language directing review committees to evaluate the "qualifications" or "accomplishments" of applicants. However, whether or not past productivity of team members is a predictor of a team's success has not been well established.

Facilitating Factors for Productive Collaboration: Features of Organizations

The conditions required to motivate researchers to collaborate with each other is a long-standing question. These can be divided into organizational structural characteristics and individual attributes. Structural features of organizations that incentivize collaborations include the availability of pilot funding (Baldwin & Chang, 2007; Iglič et al., 2017; Lotrecchiano et al., 2016); recognition and reward of researchers who engage in collaborations (Boardman & Corley, 2008; Lotrecchiano et al., 2016; Welch & Jha, 2016); and institutional norms that favor collaborations (Boardman & Corley, 2008). Other structural factors likely help motivate and support collaborations, including the availability of designated collaborative spaces, specific types of financial support provided to teams, and clear tenure and promotion policies that support interdisciplinary collaborations, but the real-world impact of these factors requires additional empirical investigation (Falk-Krzesinski et al., 2011).

Personal Characteristics of Productive Team Scientists

While structural features of organizations provide necessary support for interdisciplinary collaborations, personality characteristics and other personal attributes of researchers are also

associated with a greater willingness to collaborate. For example, researchers with positive attitudes toward collaboration are (not surprisingly) more likely to collaborate, and their teams are likely to have more impressive scholarly outcomes (Stipelman et al., 2010). Termed "readiness to collaborate," this constellation of attitudes includes the desire to build relationships with researchers outside of one's field, wanting to learn new skills, excitement about the prospect of advancing science, and the enjoyment of learning new information (Lotrecchiano et al., 2016).

Another key characteristic of researchers who are more likely to collaborate is cognitive openness (Baldwin & Chang, 2007; Belkhoujaa & Yoon, 2018; Mo et al., 2015). Researchers who are curious about a topic of importance and who are open to learning about it from many different disciplinary perspectives are not only motivated to collaborate, but may also contribute to positive internal team processes by being more personally affirming of the knowledge resources contributed by each member of the team, a communication behavior that supports team success (Woolley et al., 2010). Openness is a cognitive trait that is likely to produce positive attitudes toward collaboration.

Researcher Productivity

The variety of skills, resources, and experiences that individual researchers bring to a team are also important to the eventual success of a team (Woolley et al., 2015). These often translate into an individual team member's productivity. The question of whether highly productive faculty members make better collaborators has been explored in several lines of research. Highly productive faculty "superstars" more easily attract collaborators because of their prestige, their ability to attract financial support, and their access to cognitive resources through their personal and professional networks (Jeong & Choi, 2014). Superstars' demonstrated successes in producing scientific and technical knowledge is also a motivating factor for would-be collaborators who want to enhance their own productivity (Frenken et al., 2005). Thus, productivity can be seen as generating even greater productivity among team members. Further, top faculty members are likely to attract other top faculty members as potential collaborators (Lungeanu et al., 2014).

Although it is an unintended consequence of these patterns of collaboration, those with the greatest productivity have access to greater resources. In addition to attracting greater funding support, productive researchers have larger networks of previous collaborators and greater access to outlets for dissemination of their work because they are more likely to serve on editorial boards than less productive researchers (Frenken et al., 2005; Lungeanu et al., 2014). However, rewarding productivity in the form of internal pilot funding can be a double-edged sword. A case study of Stanford (Biancani et al., 2018) suggests that interdisciplinary initiatives can exacerbate inequalities by further advantaging scholars who are already highly productive and well-resourced. Academic institutions whose initiatives tip the balance in favor of already-productive faculty members may be hindering progress toward important goals such as increasing the competitiveness of funding proposals or generating meaningful technological innovations that are readily adoptable by key stakeholders.

There is evidence that individual research productivity is not a particularly good indicator of whether a diverse team will succeed in meeting its goals for productivity and innovation. Woolley and colleagues (2010, 2015) have studied the impact of a wide variety of factors including gender, disciplinary/professional background, and prior accomplishments on the outcomes of diverse teams. Their results indicate that individual team members do not need to be particularly accomplished in order to come together to generate innovation. A "satisficing" level of knowledge competence is necessary; top scholar status isn't required. Other factors are considerably more important, especially team communication processes, which result in the creation of "collective intelligence" that can be successfully applied to complex problems (Woolley et al., 2010).

In fact, it appears that productivity is less important than positive attitudes toward and experiences with interdisciplinary collaboration. Stipelman and colleagues (2010) establish a clear empirical link between the number of publications/scholarly presentations and attitudes toward collaboration, rather than to previous productivity. It may well be that the personal chemistry of a group constitutes the sort of "magic" that generates team innovation and productivity, far beyond what could be predicted by the records of individual scholars (Hara et al., 2003). The more we know about who is engaged in interdisciplinary research efforts (relative to those who choose not to engage), the better we can understand the nature of the impact of interdisciplinary team science on individual faculty careers. The research question that guides this study is:

> RQ1: Are the members of teams who receive competitive awards for interdisciplinary research more productive prior to receiving the award than other faculty ?

To answer this question, we have consulted a number of sources of data and indices of productivity and impact for faculty at the University of Miami. These include Elsevier's Scopus (h-index), Academic Analytics (relative impact of a scholar within their own field), University of Miami's Office of Research Administration (ORA, for number of grant applications and awards for each faculty member), and the Office of the Vice Provost for Research (OVPR), which maintains records on which faculty have received internal funding awards through the university's primary funding mechanisms to support research and creative activity, including interdisciplinary team awards. This allowed us to compare faculty who (1) were members of interdisciplinary teams awarded funding through a highly competitive, rigorously evaluated process; (2) were members of interdisciplinary teams not awarded funding; (3) were not members of interdisciplinary teams applying through this mechanism but who did receive other internal (individual-level) awards; and (4) other faculty members who have not applied for (or did not receive) internal funding. Additionally, we report on data collected through the university's Research Climate Survey, which allows us to compare the responses of faculty who have received interdisciplinary research funding support with faculty not participating in the program.

U-LINK

The internal funding mechanism supporting interdisciplinary team research, U-LINK (University of Miami Laboratory for INtegrative Knowledge), was offered at the University of Miami between 2017–2020. (See Morgan, Ahn, et al., 2020; Morgan, Bixby, et al., 2020, and Morgan,

et al., 2019). The U-LINK program offered significant financial support and other resources for interdisciplinary teams across two phases of funding. Phase I teams received a total of $40K that was explicitly designated to support "protected time" for team formation and collaboration processes; most faculty used these funds for summer salary. Phase I teams were also provided with meeting facilitation services (as needed) and designated meeting space in each campus's library. Additionally, a matchmaking process integrated librarians as full members of each of the teams. Teams that received Phase I funding were eligible to compete for Phase II funding, which provided $150K in funding, renewable for a second year, contingent on satisfactory progress. In addition to the forms of support awarded to teams in Phase I, Phase II teams received full funding for a full-time doctoral research assistant. Each year, 5-6 teams received Phase I funding and 2-3 teams received Phase II/Phase II renewal funding. (See https://ulink.miami.edu for additional program information and a list of projects for each phase of funding.)

Teams requesting U-LINK funding were evaluated on several criteria. These included interdisciplinary team composition (two or more departments/disciplines represented), whether the team was proposing to develop one or more implementable solutions (or feasible approaches) that could address a grand challenge to society, the innovativeness of the team's approach, and the identification of appropriate stakeholder groups who agreed to engage in the collaboration process. U-LINK teams receiving funding had to meet a number of requirements: (1) actively engage key stakeholders in their collaborative work; (2) attend an annual full-day team science training program covering best practices and skills-based workshops; (3) submit progress reports and attend an annual Symposium presenting the outcomes of their work; and (4) apply for external funding in year two of Phase II funding. All teams that were renewed for Phase II funding met all requirements.

The award process was highly competitive in all three years. Table 1 presents the number of applications received and the number of applications that were funded. Members of an internal advisory board that included the Vice Provost for Research and Associate Provost for Research (co-directors of the U-LINK program), a development officer, and eight additional faculty from the arts, humanities, social sciences, and STEM fields evaluated each application. After a triaging process based on overall scores, an extensive discussion of the remaining applications resulted in consensus decisions about which teams would receive funding..

Table 1. Number of U-LINK Applications Received and Funded

Award Year	Phase I applications received	Phase I applications funded	Phase II applications received	Phase II applications funded
2018	42	5	--	--
2019	17	6	5*	3
2020	21	6	7	3

*Note: One team deferred their Phase II application until the following year due to team personnel changes.

Methods

Setting

The institution's factbook reported a total of 3,226 (2,697 full-time and 529 part-time) faculty members across three campuses. Of 3,226 faculty members in the institution, 1,891 (51%) identified as male and 1,335 (49%) identified as female. In addition, 1,757 (54%) identified as White, 817 (25%) identified as Hispanic or Latino, 135 (4%) identified as Black, 381 (12%) identified as Asian/Pacific Islander, and 136 (4%) identified as "other," including American Indian, 2 or more races, and unknown.

The institution is composed of regular (n = 1,030, 38%), educator (n = 1,102, 41%), research (n = 184, 7%), librarian (n = 59, 2%), and associated (n = 322, 12%) faculty members. According to the Higher Education Research and Development Survey Fiscal Year 2018 (National Center for Science and Engineering Statistics, National Science Foundation, 2019), the institution spent $357,104,000 on research and development, including $181,958,000 received from the federal government, $18,374,000 from state and local government, and $146,132,000 from other sources including institutional funds, business, and nonprofit organizations. This results in the institution ranking 72nd in the nation in terms of total research and development expenditures. In addition, the institution's medical school received $133,469,892 from NIH in 2018, and it was ranked 40th among all US medical schools for research expenditures (Blue Ridge Institute for Medical Research, 2018). The institution's factbook in reported that 14% ($510.1 million) of the institution's operational funding was derived from grants and contracts.

Data Collection

The data used in the current study were drawn from multiple sources. First, a list of faculty names who have received the institution's internal grants was obtained from the Office of the Vice Provost for Research (OVPR). Second, for all faculty members in the institution, a number of scholarly productivity measures were extracted from Academic Analytics (AA). From the AA database, we obtained faculty academic rank, discipline, and year of highest degree earned. Third, we extracted the h-index, the number of total publications and the number of citations per year for the last three years from Elsevier's Scopus database. Fourth, a dataset containing the number of extramural grant proposals all faculty members submitted as Principal Investigator (PI) or Co-PI from 2017 to 2019 was obtained from the institution's Office of Research Administration (ORA). All data were merged based on faculty members' last and first names. Lastly, we incorporated data from an institution-wide research climate survey administered in Fall 2019 (which asks whether respondents have applied for (or received) several types of internal funding, including U-LINK); the resulting data set from the OVPR allowed us to compute factor scores measuring attitudes toward interdisciplinary research and perceived support from institution for interdisciplinary research and to compare scores according to type of funding activity. (Please see Appendix A for survey items.)

Variables and Measures

Our research question was examined based on the following four sets of variables: (1) academic background; (2) scholarly productivity; (3) attitudes toward interdisciplinary research; and (4) perceived support from institution for interdisciplinary research.

Faculty Academic Background

Academic Analytics (AA) reports an individual faculty member's academic characteristics, including (1) academic rank as assistant, associate, or full professor, (2) broader field of study, which includes biological and biomedical sciences; business; education; engineering; family, consumer and human sciences; humanities; health professions sciences; natural resources and conservation; physical and mathematical sciences; and social and behavioral sciences, and (3) year of highest degree earned, from which we calculated years of experience in the field by subtracting from 2019.

Scholarly Productivity

Multiple quantitative metrics for individual faculty members' scholarly productivity were used. First, four scholarly productivity indicators—the number of books/book chapters and journal articles written by faculty in the previous 3 years, the number of citations of faculty members' scholarly publications, the number and dollar amount of grants received by faculty members, and the awards/honors received by the faculty members—were collected by AA from independent databases, web sources, and government agency reports. Second, AA's scholarly productivity metric, called the Faculty Scholarly Research Index (FSRI), was used to quantify scholars' relative impact in their respective disciplines. FSRI is a standardized score that is derived based on a set of statistical algorithms developed by AA, which assign differential weights on the four aforementioned indicators in one's respective field. Third, the h-index extracted from Scopus quantifies both productivity and impact of the published work of a scholar. Specifically, the h-index means that h documents from the author's set of published studies have been cited at least h times (i.e. 10 papers have been cited at least 10 times, resulting in an h-index of 10), but others have been cited fewer than h times. Lastly, the number of extramural grant proposals submitted by the faculty member as a principal investigator (PI) or a Co-PI was used to quantify the extent to which a faculty member is active in seeking extramural grants.

Attitudes Toward Interdisciplinary Research

Attitudes toward interdisciplinary research were measured using 10 researcher-developed survey items. Examples of survey items measuring attitudes toward interdisciplinary research include "Interdisciplinary research imposes a significant time burden", and "I rarely interact with researchers from other departments". Responses were measured on the 5-point Likert scale, ranging from 1 for Strongly Disagree to 5 for Strongly Agree. A factor score was computed after performing exploratory factor analysis of 10 survey items using the principal axis factoring method, with a higher score indicating more positive attitudes toward interdisciplinary research. Cronbach's alpha for the current sample (n = 161) was 0.75.

Perceived Support for Interdisciplinary Research

Perceived support from the institution for interdisciplinary research was measured using 4 survey researcher-developed items. Examples of items include "institution provides incentives for interdisciplinary research", and "institution recognizes and rewards interdisciplinary researchers". Responses were measured on the 5-point Likert scale, ranging from 1 for Strongly Disagree to 5 for Strongly Agree. A factor score was computed after performing exploratory factor analysis of four items using the principal axis factoring method, with a higher score indicating more perceived support from the institution toward interdisciplinary research. Cronbach's alpha for the current sample (n = 171) was 0.87.

Analytic Strategies

We first summarized and compared the academic backgrounds of awardees of an interdisciplinary pilot research funding program, faculty who have received other forms of internal funding, and faculty who have not received either of these internal grants. Then, propensity score matching (PSM, Guo & Fraser, 2014) were performed to evaluate whether awardees of an interdisciplinary pilot research funding program have demonstrated different levels of scholarly productivity, when compared to faculty who have received other forms of internal funding, and faculty who have not received any internal funding. The MatchIt package (Ho et al., 2007a; 2007b) available in R (R Development Core Team, 2008) was used to perform PSM in order to examine whether interdisciplinary pilot research funding awardees were more likely to submit grants, be awarded external funding, publish more books or scholarly articles, or have publications with higher impact. Specifically, PSM is used to create matched subgroups that adjust for faculty academic ranks, years of experience post terminal degree, and faculty members' disciplines, and then to compare scholarly productivity measures between balanced subgroups (i.e., interdisciplinary pilot research funding awardees; institution's internal funding recipients; other faculty members who have received neither). The major advantage of this approach is that the potential selection bias that would threaten the validity of statistical results using the observational data (without random assignment) would be reduced by equating comparison groups based on the potential confounding covariates, when estimating the effectiveness of a program.

Results

Interdisciplinary Pilot Research Funding Awardees

Of a total of 63 interdisciplinary pilot research funding awardees, 49% are tenured or tenure-track faculty members. These include 3 Assistant (4.8%), 15 Associate (23.8%), and 13 Full (20.6%) professors. Those interdisciplinary pilot research funding awardees have a mean of 20.1 years since highest degree earned (SD = 9.1, min = 3, max = 45) from diverse fields of study: awardees in the 2019 funding cycle were affiliated with physical and life sciences (19%), engineering (15%), computer science (12%), education (12%), social and behavioral sciences (11%), medical and health sciences (11%), business (4%), arts and humanities (8%), communication (4%), and law (4%).

Interdisciplinary pilot research funding awardees had a mean of 17.9 h-index (SD = 16.7, min = 0, max = 85); a mean of 204.9 citations compiled by Scopus in 2017 (SD = 363.7, min = 0, max = 1763); a mean of 215.3 citations compiled by Scopus in 2018 (SD = 360.8, min = 0, max = 1941); a mean of 41.0 citations compiled by Scopus in 2019 (SD = 360.8, min = 0, max = 1941); and a mean of .28 of the Faculty Scholarly Research Index reported by Academic Analytics (SD = 71.1, min = 0, max = 665). On average, interdisciplinary pilot research funding awardees submitted approximately 2.5 external grant proposals through the institution's ORA from FY15 to FY18. Total grant proposals being submitted through the institution's ORA between FY15 and FY18 by these awardees ranged from 1 to 34 (M = 9.7, SD = 8.4). According to AA, which provides a four-year snapshot of grant awards, interdisciplinary pilot research funding awardees have received a mean amount of $286,016 (SD = $350,107, min = 0, max = $1,435,118) from their extramural grant agents.

Academic Characteristics of Interdisciplinary Pilot Research Funding Awardees

When compared to other internal funding recipients, interdisciplinary pilot research funding awardees tend to be: (1) higher-ranked professors in the institution, indicating that assistant professors were less likely to join interdisciplinary pilot research teams, and (2) more experienced (i.e., 22.1 years since terminal degree award for interdisciplinary pilot research funding awardees vs. 12.1 for other internal funding recipients, $t(62.42) = 4.8$, $p < .05$). In addition, interdisciplinary pilot research funding awardees were less likely to be from humanities, engineering, and business, while they were more likely to be from biological sciences, natural resources and conservation, or health-related disciplines. When compared to all other faculty members in the institution, interdisciplinary pilot research funding awardees tend to be less experienced (21.8 years for interdisciplinary pilot research funding awardees vs. 26.1 years for other faculty members; $t(131.83) = -3.29$, $p = .001$).

Scholarly Productivity of Interdisciplinary Pilot Research Funding Awardees

Grant Submissions

After adjusting for faculty academic rank, years of experience in the field and broader discipline, results from propensity score analysis (PSA) indicate that there was a significant difference in the average number of external grant proposals submitted through ORA between interdisciplinary pilot research funding awardees and other internal funding recipients. As shown in Figure 1, interdisciplinary pilot research funding awardees submitted significantly more grant proposals (n = 11.6) through ORA than other internal funding recipients (n = 5.2), $t(37.84) = -3.42$, $p = .002$, 95% CI: -10.09 to -2.58. This suggests that interdisciplinary pilot research funding awardees are more experienced with the process of applying for extramural grant funding when they enter the pilot interdisciplinary research funding program.

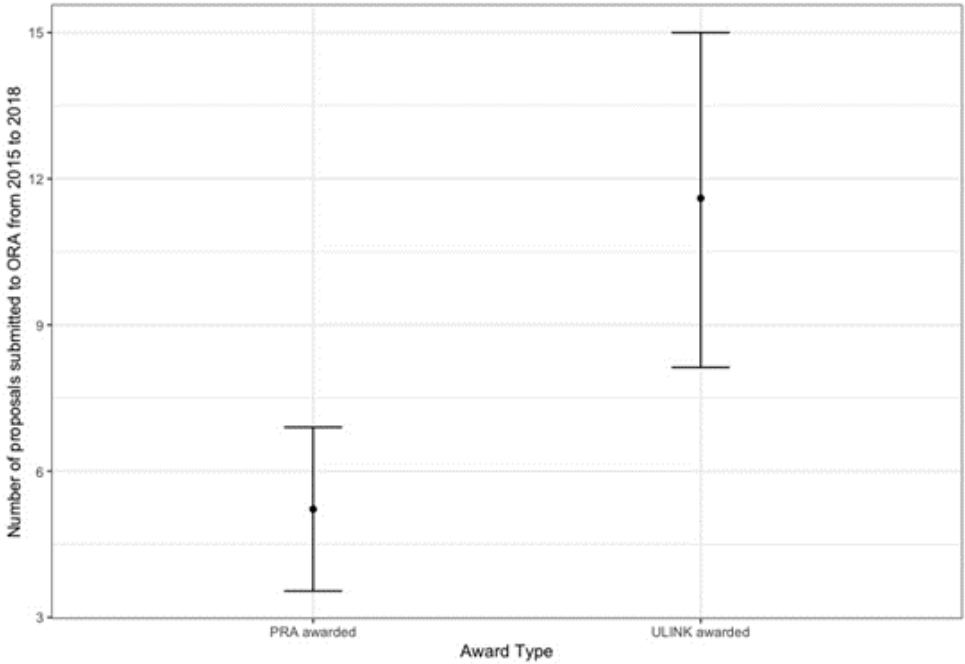

Figure 1. Comparison of External Grant Proposals Submitted by Internal Award Type
Click here for larger image

Scholarly Productivity

After adjusting for faculty rank, years of experience and discipline, results from propensity score analysis suggest that no significant difference exists between interdisciplinary pilot research funding awardees and other internal funding recipients on any other indicators of faculty scholarly productivity. The indicators of faculty productivity that we examined include faculty h-index (compiled by Scopus), number of scholarly citations (compiled by Scopus) in 2017, 2018, and 2019, overall Faculty Scholarly Research Index (compiled by Academic Analytics), as well as numbers of published books, articles, and citations (as compiled by Academic Analytics), number and dollar amount of grants (Academic Analytics), and faculty members' rankings within their own disciplines (Academic Analytics). Similarly, after controlling for all pre-existing confounding variables including faculty rank, experience, and disciplines, we found no statistically significant differences in any indicators of faculty productivity between interdisciplinary pilot research funding awardees and other faculty members in the institution.

Attitudes Toward Interdisciplinary Research

We were interested in whether attitudes toward interdisciplinary research among faculty based on their award status. Results from Analysis of Variance (ANOVA) indicated that no significant differences were found in faculty members' overall willingness to collaborate between faculty

who had applied to a pilot interdisciplinary funding opportunity (M = 4.16, SD = .46, n = 34) and those who had not applied (M = 3.99, SD = .50, n = 95) or those who did not know about it (M = 3.97, SD = .60, n = 32), F (2, 158) = 1.57, p = .21. (Please see Figure 2.)

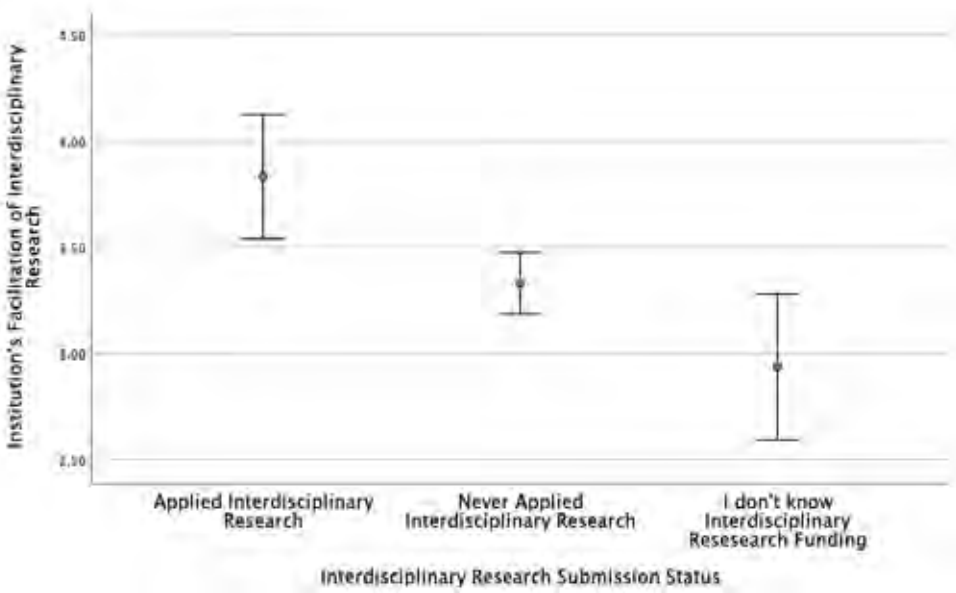

Figure 2. Perceived Support for Interdisciplinary Research by Faculty Members by Internal Grant Application Status

Click here for larger image

There were also no significant differences in willingness to collaborate between faculty who had been awarded a pilot interdisciplinary funding grant (M = 4.10, SD = .44, n = 26) and those who had not (M = 4.35, SD = .51, n = 8), F (1, 32) = 1.76, p = .19; this is presented in Figure 3. This indicates that faculty members who are not currently involved with a pilot interdisciplinary funding grant are nonetheless willing to engage in interdisciplinary collaborations.

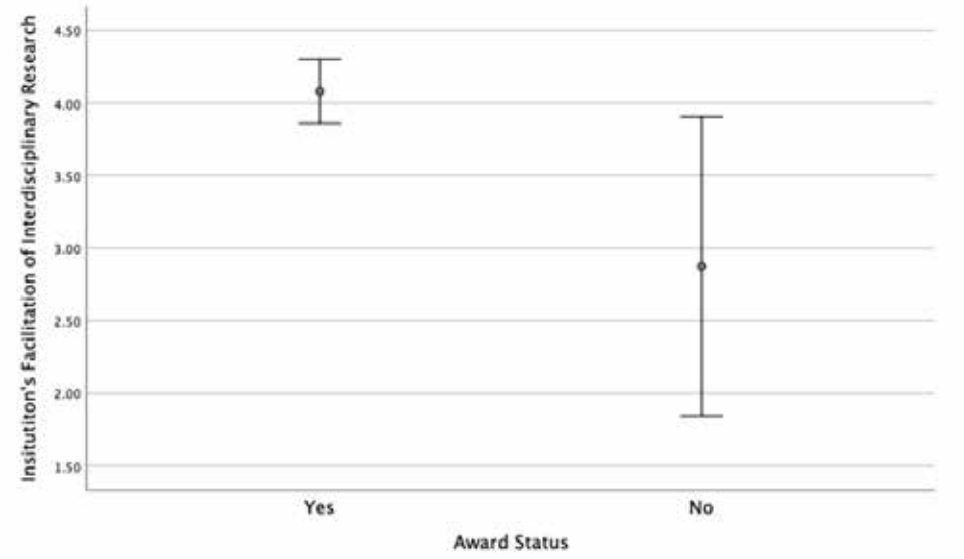

Figure 3. Perceived Support for Interdisciplinary Research by U-LINK Award Status

Click here for larger image

Discussion

A common criteria for evaluating applications for internal or external funding is the level of prior accomplishment of applicants. Additionally, funding programs designed to foster interdisciplinary team research through pilot funding involve the evaluation of proposals based on the likelihood that a team will succeed, which is often thought to be linked to the productivity of individual team members. Further, it stands to reason that any empirical evaluation of the effectiveness of an interdisciplinary funding program in producing greater research productivity should account for the possibility that the researchers who decide to join scientific teams are fundamentally different in some ways from other faculty members, i.e. that they are already more productive. Faculty "pushback" to internal funding programs sometimes takes the form of sentiments that such programs favor individuals who are less in need of scarce internal resources because they would be successful in applying for external funding without it.

To address these questions, we examined whether members of interdisciplinary teams are similar to faculty who were on teams that applied but were not awarded funding, or alternatively, faculty who have successfully competed for other internal funding without a specific interdisciplinary focus. In essence, these analyses are designed not only to provide insights into the attributes of faculty willing to engage in interdisciplinary collaborations, but also to investigate whether the future success of a pilot funding program might owe more to the characteristics of participating faculty members than to the features of the program itself.

Our analyses of multiple quantitative measures of faculty productivity indicate that with one exception, the faculty involved in a pilot interdisciplinary research program are no more (nor less)

likely to be highly productive. However, we found that faculty submitting applications for internal funding (both for the support of individual research and for interdisciplinary team projects) were more likely to have submitted external grant proposals, though they were not more likely to have been awarded external grant funding. These findings are important because in order to assert that faculty involvement in interdisciplinary research activities leads to greater faculty productivity and success, it is critical to establish a clear baseline for researcher activities and outcomes. While our analyses of items on a Research Climate Survey regarding attitudes toward interdisciplinary work indicate that most faculty are willing to engage in interdisciplinary research, it is also worth noting that open-ended responses indicate that some faculty have misgivings about the effects of such work on tenure and promotion decisions. If institutions are committed to interdisciplinary collaboration, such misgivings must be addressed by administrators and by faculty governing bodies (such as the Faculty Senate).

Our results are consistent with the work of researchers who have discovered that high levels of individual productivity are not predictive of interdisciplinary team success (Hara et al., 2003; Lungeanu et al., 2014; Pentland, 2012; Woolley et al., 2010, 2015). This finding indicates that interdisciplinary pilot funding programs can serve as a means to motivate mid- and late-career faculty members who may be searching for new sources of inspiration. A focus on broad challenges to society virtually demands the participation of faculty from diverse disciplinary backgrounds, including those in the humanities and social sciences, where insights into the human condition and human behaviors can lead to outcomes that are more easily translatable and implementable by key stakeholders. Similarly, faculty at smaller or mid-sized universities may find that they have fewer potential collaborators within their own disciplines. A well-run interdisciplinary research program that incentivizes the formation of new collaborations (without regard to current levels of research productivity) may be the spark needed to create innovative, fundable work.

There are, of course, limitations to this study. First and foremost, it provides insights into the patterns of productivity at just one university; unfortunately, the use of diverse sources of confidential data makes it difficult to perform these analyses across multiple universities. At the same time, this study provides a useful blueprint for conducting similar analyses at other institutions. Second, measures of productivity are controversial at best; it is difficult to distinguish between quality and quantity of research, for example. We have tried to mitigate the impact of this issue by incorporating multiple indicators of productivity and both internal and external sources of data.

There are several areas that warrant further exploration by researchers. First, because this study focuses on just one university, we would suggest that a consortium of research administrators across multiple universities follow the data collection procedures detailed here to create an expanded data set that can yield more generalizable findings. Second, we believe that universities interested in research productivity look to new and less traditional metrics (such as Altmetrics) to assess the impact of pilot research funding on private industry practice or public discourse about issues of importance via the media (Biancani et al., 2018).

Our findings have, of course, practical implications for research administrators. Perhaps most obviously, we believe that while measures of productivity and impact are important to consider

as accountability measures, they should be applied to individuals and teams who have already received funding rather than those who are applying for funding. Because past productivity appears not to be associated with long-term outcomes associated with the award of pilot funding, using an applicant's past scholarly productivity as a criteria is not only unwarranted, it may actually be counterproductive. Faculty who need the opportunity to pursue a more fruitful line of research or who need to restart a program of research after a period of inactivity would not be competitive for awards that could otherwise support their ability to join the ranks of productive and innovative researchers whose work advances the strategic objectives of the institution. This is particularly true for less-productive faculty who seek to engage in interdisciplinary team research, which offers unique opportunities to generate novel discoveries and successfully compete for external funding support (Lungeanu et al., 2014).

Conclusion

This study provides good news for universities that seek to promote interdisciplinary research and who hope for a significant return on investment. Although "superstar" faculty members may find it easy to hand-pick teams that include other highly productive faculty members, this is not a prerequisite for success. Our well-triangulated analyses demonstrate that interdisciplinary teams that secure funding in a highly competitive process have individual members who are no more or less productive than the average faculty member. This suggests that application review criteria should focus on the innovation represented in the proposal more than the prior achievements of faculty members on the team.

These findings also have significant implications for university recruitment of new faculty. Depending on university goals, investing in the hiring of a "big ticket" faculty superstar may not be as wise as investing funds in faculty development to teach faculty how to collaborate effectively across disciplinary boundaries in the quest to create meaningful and potentially transformative innovation. Such productive collaborations require that researchers know how to exhibit social sensitivity and to communicate effectively. These are skills that can and should be taught; greater collective productivity and innovation are likely to follow.

Authors' Notes

Soyeon Ahn, Ph.D., Professor and Chair, Educational and Psychological Studies, School of Education and Human Development, University of Miami (s.ahn@miami.edu).

Susan E. Morgan, Ph.D. Vice Dean for Research and Creative Activity and Professor, Communication Studies, School of Communication, University of Miami (semorgan@miami.edu)

Ali Mosser, Ph.D., Senior Research Manager, Vital Research, Los Angeles, CA

John L. Bixby, Ph.D., Professor, Molecular and Cellular Pharmacology and Neurological Surgery, University of Miami (jbixby@med.miami.edu)

Correspondence concerning this article should be addressed to Soyeon Ahn, Ph.D., Chair of Educational and Psychological Studies, School of Education and Human Development, University of Miami, Coral Gables, FL 33124 (s.ahn@miami.edu) or Susan E. Morgan, Vice Dean for Research and Creative Activity (semorgan@miami.edu), School of Communication, University of Miami, Coral Gables, FL 33124.

References

Association of Public and Land-Grant Universities. (2014). https://www.aplu.org/

Baldwin, R., & Chang, D. (2007). Collaborating to learn, learning to collaborate. *Peer Review, 9*(4), 26–30. https://www.aacu.org/publications-research/periodicals/collaborating-learn-learning-collaborate

Belkhoujaa, M., & Yoon, H. (2018). How does openness influence the impact of a scholar's research? An analysis of business scholars' citations over their careers. *Research Policy, 47*(10), 2037–2047. https://doi.org/10.1016/j.respol.2018.07.012

Bennett, H., Gadlin, M., & Levine-Finley, S. (2010). Collaboration & team science: A field guide. National Institutes of Health. http://teamscience.nih.gov

Biancani, S., Dahlander, L., McFarland, D. A., & Smith, S. (2018). Superstars in the making? The broad effects of interdisciplinary centers. *Research Policy, 47*(3), 543–557. https://doi.org/10.1016/j.respol.2018.01.014

Blue Ridge Institute for Medical Research. (2018). Ranking tables of NIH funding to US medical schools in 2018. http://www.brimr.org/NIH_Awards/2018/NIH_Awards_2018.htm

Boardman, P., & Corley, E. (2008). University research centers and the composition of research collaborators. *Research Policy, 37*(5), 900–913. https://doi.org/10.1016/j.respol.2008.01.012

Falk-Krzesinski, H., Contractor, N., Fiore, S., Hall, K. L., Kane, C., Keyton, J., Klein, J. T., Spring, B., Stokols, D., & Trochim, W. (2011). Mapping a research agenda for the science of team science. *Research Evaluation, 20*(2), 145–158. https://doi.org/10.3152/095820211X12941371876580

Frenken, K., Holzl, W., & Vor, F. (2005). The citation impact of research collaborations: The case of European biotechnology and applied microbiology (1988–2002). *Journal of Engineering and Technology Management, 22*(1-2), 9–30. https://doi.org/10.1016/j.jengtecman.2004.11.002

Guo, S., & Fraser, W. M. (2014). *Propensity score analysis: Statistical methods and applications* (2nd ed.). Sage Publications.

Hall, K. L., Vogel, A. L., Huang, G. C., Serrano, K. J., Rice, E. L., Tsakraklides, S. P., & Fiore, S. M. (2018). The science of team science: A review of the empirical evidence and research gaps on collaboration in science. *American Psychologist, 73*(4), 532–548. https://doi.org/10.1037/amp0000319

Hara, N., Solomon, S., Kim, S. L., & Sonnenwald, D. H. (2003). An emerging view of scientific collaboration: Scientists' perspectives on collaboration and factors that impact collaboration. *Journal of the American Society for Information Science and Technology, 54*(10), 952–965. https://doi.org/10.1002/asi.10291

Ho, D., Imai, K., King, G., & Stuart, E. (2007a). Matching as nonparametric preprocessing for reducing model dependence in parametric causal inference. *Political Analysis, 15*(3), 199–236. http://gking.harvard.edu/files/abs/matchp-abs.shtml

Ho, D., Imai, K., King, G., & Stuart, E. (2007b). Matchit: Nonparametric preprocessing for parametric causal inference. *Journal of Statistical Software*. http://gking.harvard.edu/matchit/

Iglič, H., Doreian, P., Kronegger, L., & Ferligoj, A. (2017). With whom do researchers collaborate and why? *Scientometrics, 112*(1), 153–174. https://doi.org/10.1007/s11192-017-2386-y

Jeong, S., & Choi, J. Y. (2014). Collaborative research for academic knowledge creation: How team characteristics, motivation, and processes influence research impact. *Science and Public Policy, 42*(4), 460–473. https://doi.org/10.1093/scipol/scu067

Klein, J. T. (2008). Evaluation of interdisciplinary and transdisciplinary research: A literature review. *American Journal of Preventive Medicine, 35*(2 Suppl.), S116–S123. https://doi.org/10.1016/j.amepre.2008.05.010

Lotrecchiano, G. R., Mallinson, T. R., Leblanc-Beaudoin, T., Schwartz, L. S., Lazar, D., & Falk-Krzesinski, H. J. (2016). Individual motivation and threat indicators of collaboration readiness in scientific knowledge producing teams: A scoping review and domain analysis. *Heliyon, 2*(5), e00105. https://doi.org/10.1016/j.heliyon.2016.e00105

Lungeanu, A., Huang, Y., & Contractor, N. S. (2014). Understanding the assembly of interdisciplinary teams and its impact on performance. *Journal of Informetrics, 8*(1), 59–70. https://doi.org/10.1016/j.joi.2013.10.006

Mo, G. Y., Hayat, Z., & Wellman, B. (2015). How far can scholarly networks go? Examining the relationships between distance, disciplines, motivations, and clusters. In *Communication and Information Technologies Annual* (pp. 107–133). *Studies in Media and Communications*: Vol. 9. Emerald Group Publishing Limited. https://doi.org/10.1108/S2050-206020150000009005

Morgan, S. E., Ahn, S., Bixby, J. L., Mosser, A., Harrison, T., & Wang, J. (2020). *Measuring program and interdisciplinary team success: Metrics, measures, and impacts* [Conference presentation]. Annual meeting of the International Network for the Science of Team Science, Durham, NC (online conference). https://www.youtube.com/atch?v=XJ4f9z8rjgc&list=PL66EPbm4ojiAFgVZBuNOtQct6orXWozaB&index=5&t=0s

Morgan, S. E., Bixby, J. L., Mosser, A., de Velasco, J., Isom, D., Agarwal, A., Clement, A., Miller, K., Celik, N., Ferriss-Hill, J., Sawicki, A., & Timpano, K. (2020). *U-LINK: An innovative pilot funding program that operationalizes empirical findings in SciTS* [Conference presentation]. Annual meeting of the International Network for the Science of Team Science, Durham, NC (online conference). https://www.youtube.com/watch?v=-eWfej2H-Rs&list=PL66EPbm4ojiAFgVZBuNOtQct6orXWozaB&index=3&t=0s

Morgan, S. E., Mosser, A., Ahn, S., Harrison, T. R., Wang, J., Reynolds, A., Huang, Q., Mao, B., & Bixby, J. L. (2019). T*he University of Miami's Laboratory for INtegrative Knowledge: An evaluation of a team science workshop* [Conference presentation]. Annual Meeting on the Science of Team Science, Lansing, MI.

National Center for Science and Engineering Statistics, National Science Foundation. (2018). Higher Education Research and Development Survey, fiscal year 2018. http://ncsesdata.nsf.gov/herd/

Pentland, A. S. (2012). The new science of building great teams. *Harvard Business Review, 90*(4), 61–70.

R Core Team. (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Stipelman, B. A., Feng, A., Hall, K., Moser, R., Stokols, D., Nebeling, L., Berger, N., Goran, M., Jeffery, R., McTiernan, A., & Thornquist, M. (2010). The relationship between collaborative readiness and scientific productivity in the transdisciplinary research on energetics and cancer (TREC) centers. *Annals of Behavioral Medicine, 39*(1 Suppl.), S143.

Stipelman, B. A., Huang, G., Hall, K. L., Wagner, R., Shuptrine, S. R., Pearson, K., et al. (2014, August 6–8). *An analysis of NIH funding of team-based research grant mechanisms* [Poster presentation]. Fifth Annual International Science of Team Science Conference, Austin, TX.

Welch, E. W., & Jha, Y. (2016). Network and perceptual determinants of satisfaction among science and engineering faculty in US research universities. *Journal of Technology Transfer, 41*(2), 290–328. http://dx.doi.org/10.1007/s10961-015-9393-z

Woolley, A. W., Aggarwal, I., & Malone, T. W. (2015). Collective intelligence and group performance. *Current Directions in Psychological Science, 24*(6), 420–424. https://doi.org/10.1177%2F0963721415599543

Woolley, A. W., Chabris, C. F., Pentland, A., Hashmi, N., & Malone, T. W. (2010). Evidence for a collective intelligence factor in the performance of human groups. *Science, 330*, 686–688. https://www.jstor.org/stable/40931726

Appendix A

Attitudes Toward Interdisciplinary Research survey items

Interdisciplinary research imposes a significant time burden.

I rarely interact with researchers from other departments.

Interdisciplinary research improves research productivity.

Interdisciplinary research improves research quality.

Interdisciplinary research questions do not interest me.

Interdisciplinary collaboration is difficult because of differences in research methodology.

It is difficult to find a journal to publish interdisciplinary research.

Interdisciplinary research results in more publications than single-disciplinary research.

Interdisciplinary research threatens my autonomy as a researcher.

Interdisciplinary research increases the potential for scientific innovation.