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The Effects of Diversity and Network Ties on Innovations: The Emergence of a New Scientific Field

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Abstract

This study examines the influence of different types of diversity, both observable and unobservable, on the creation of innovative ideas. Our framework draws on theory and research on information processing, social categorization, coordination, and homophily to posit the influence of cognitive, gender, and country diversity on innovation. Our longitudinal model is based on a unique data set of 1,354 researchers who helped create the new scientific field of *oncofertility*, by collaborating on 469 publications over a 4-year period. We capture the differences among researchers along cognitive, country, and gender dimensions, as well as examine how the resulting diversity or homophily influences the formation of collaborative innovation networks. We find that innovation, operationalized as publishing in a new scientific discipline, benefits from both homophily and diversity. Homophily in country of residence and working with prior collaborators help reduce uncertainty in the interactions associated with innovation, while diversity in knowledge enables the recombinant knowledge required for innovation.

Keywords

innovation, coauthorship, networked work, diversity

Networked work is an increasingly prevalent mode to organize work within and between organizations (Chen, Rainie, & Wellman, 2012). Recent advances in information and communication technologies (ICTs) enable individuals to engage in networked work by connecting and collaborating much more efficiently and

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effectively with their colleagues and customers. Hence networked work has the potential to facilitate innovation. Networked workers can communicate easily and frequently across space and time using different types of ICTs, allowing organizations to be more flexible, team based, and displaying a flatter, decentralized structure (Gladwell, 2003). Such networks hold the promise for better use of people's knowledge and can therefore be more effective in accomplishing creative tasks (Burt, 2010; Monge & Contractor, 2003; Wu, Lin, Aral, & Brynjolfsson, 2009). This characteristic of networked work is particularly important, since innovation is critical to achieving competitive advantages in areas as diverse as scientific research, entrepreneurial ventures, and Broadway shows (Reagans & Zuckerman, 2001; Taylor & Greve, 2006; Uzzi & Spiro, 2005; Wuchty, Jones, & Uzzi, 2007).

Although networked work has the potential to facilitate innovation, it can also impede its progress. ICTs may increase miscommunications among networked workers (Cramton, 2001), which is especially problematic in knowledge-intensive collaborations that are created for the purpose of producing innovation.

The researcher represents a specific type of networked worker (Dimitrova et al., 2013) who collaborates explicitly and exclusively with the intent of creating innovation. Current trends in scientific research reflect the emergence of networked research, characterized by a focus on creative content rather than managing coordination challenges that are more generally prevalent in networked work. This study focuses on the dilemma of diversity for fostering innovation in networked research. On the one hand, generating innovative ideas requires the ability for recombinant searches (Fleming & Sorenson, 2001) across diverse areas of the knowledge possessed within the team (West, 2002). On the other hand, it requires team members who are comfortable working with each other (e.g., Guimera, Uzzi, Spiro, & Amaral, 2005; Taylor & Greve, 2006). We seek to address this dilemma by parsing the effects of different dimensions of diversity and network ties on innovation in networked research. More specifically, we examine the influence of cognitive, gender, and country diversity (or its opposite, homophily), as well as prior network ties on the emergence of collaborative networks of innovation over time.

Theoretical Background and Hypotheses

Understanding the determinants of innovation has been an object of study for decades (Burns & Stalker, 1961). Historically, scholars assumed that the creation of an innovation was the output of a single individual and investigated individual-level, sociocognitive factors influencing creativity (e.g., Amabile, 1983; Gupta, Tesluk, & Taylor, 2007). However, the ascendance of networked research has been accompanied by an increasing amount of innovation emerging from teams, leading some to signal the demise, or at least the attenuation, of the age of the solo hero researcher (Saporito, 2013) or lone inventor (Singh & Fleming, 2010).

Prior research on teams has pointed out that the creative process leading to innovation presents unique challenges because team members differ from each other on many dimensions and are oftentimes dispersed in time and space (Cummings & Kiesler, 2007). For instance, prior research has shown that diversity positively influences creative and innovative outcomes in teams, but it has also noted that diversity lowers the level of team cohesion (Milliken, Bartel, & Kurtzberg, 2003). These mixed findings are supported by a recent review by Joshi and Roh (2009) that revealed how some dimensions of diversity positively affect team output (e.g., Ancona & Caldwell, 1992), while other dimensions have a negative effect (e.g., Leonard, Levine, & Joshi, 2004; Tyran & Gibson, 2008).

Hypotheses

Research on teams has investigated several dimensions of diversity that affect creativity and innovation (Cady & Valentine, 1999; Joshi & Roh, 2009). These dimensions have been broadly considered in two categories: whether they are relatively unobservable (such as cognitive or expertise diversity) or observable (such as gender and country diversity). In this section, we offer a set of three hypotheses concentrating on different dimensions of diversity in each of these two broad categories. We focus on cognitive diversity as a relatively unobservable, task-based, diversity attribute of the team that has usually been associated with skill-based and informational differences among members of the work group (Jackson, May, & Whitney, 1995). We focus on gender and country as two readily observable diversity attributes of team members that have usually been associated with social categorization processes and have been found to impede the development of a shared identity within the team (Van Knippenberg, De Dreu, & Homan, 2004). Unlike most prior studies, we examine these effects in teams where researchers have the discretion of whom to collaborate with on innovative tasks.

Cognitive diversity. In their literature review on the topic of diversity, Williams and O'Reilly (1998) noted that diversity of knowledge is useful for idea generation and performance in teams. Information and decision-making perspectives also suggest that greater cognitive diversity leads to higher performance (Milliken et al., 2003; Taylor & Greve, 2006; Tziner & Eden, 1985). When individual team members have different backgrounds, skills, abilities, information, and knowledge, they are more likely to search for solutions that recombine heretofore disconnected ideas and thereby generate innovation (Guimera et al., 2005).

> **Hypothesis 1:** Individuals that possess disparate knowledge are more likely to produce innovative ideas through collaboration.

Gender homophily. Self-categorization theory suggests that individuals characterize themselves using categories such as age, gender, and race (e.g., Turner, Hogg, Oakes, Reicher, & Wetherell, 1987). Individuals then select similar others in order to reduce the potential conflict in their relations (Byrne, 1971), or to reduce the psychological discomfort that may arise from cognitive or emotional differences (Heider, 1958). This process is known as the similarity-attraction hypothesis.

Gender homophily represents one dimension of homophily that affects the formation of ties in many different settings, ranging from friendship networks to professional ties in advertising firms (Ibarra, 1992; Leenders, 1996). In the case of scientific collaborations, researchers have investigated the effect of gender homogeneity on the outcomes of team work (Stvilia et al., 2011). Gender homophily leads to an increased ease of communication (Ibarra, 1992) and decreased levels of emotional conflict (Pelled, Eisenhardt, & Xin, 1999). Therefore, we propose that collaboration based on gender homophily is more likely to achieve innovation (Cady & Valentine, 1999; Gilson, Mathieu, Shalley, & Ruddy, 2005):

> **Hypothesis 2:** Individuals of the same gender are more likely to produce innovative ideas through collaboration.

Country homophily. Research collaborations often span organizational, functional, or cultural boundaries. Such collaborations may be affected by processes of social categorization, in which individuals from different groups make in-group/out-group distinctions purely on the basis of social characteristics such as country especially when they have inadequate information about others (Whitener, Brodt, Korsgaard, & Werner, 1998). These distinctions are more common in distributed collaborations where members tend to rely more on collocated partners, attaching socially negative perceptions to remote collaborators, thereby undermining group cohesion (Cramton, 2001). Given that social cohesion is an important predictor of one's motivation to transfer knowledge (Reagans & McEvily, 2003), we expect that knowledge transfer is less likely to occur in distributed collaborations, which will in turn negatively affect innovation (Gibson & Gibbs, 2006) and the desire to collaborate.

In addition, geographically dispersed research collaborations impose search and coordination costs for bridging geographic distance and institutional differences (Cummings & Kiesler, 2007). Furthermore, property rights issues, university regulations, research assessment criteria, and—more generally—shared norms and values all render research projects easier to coordinate at national levels than at the international level (Hoekman, Frenken, & Tijssen, 2010).

> **Hypothesis 3:** Individuals located within the same country are more likely to produce innovative ideas through collaboration.

Methodology

Data and Sample

We tested these hypotheses using archival and bibliographic data about teams that collaborated to publish scientific articles in the recently emerging field of Oncofertility. The term *oncofertility*, coined in 2007, refers to research on fertility preservation for cancer patients.

We identified all scientific articles that were published in the field of Oncofertility using the keywords *oncofertility*, or *cancer* and *ovarian tissue cryopreservation*, or *cancer* and *fertility preservation*. We used the *Web of Science* (*WoS*) database to construct researchers' coauthorship relations among publications related to Oncofertility. Since there were some articles that were not indexed in the *WoS* database, we supplemented the data set with articles indexed in the *PubMed* database. The data set for this study utilized all publications between 2007 and 2010, and comprised 469 publications from 1,354 researchers. Additional bibliometric information, such as prior non-Oncofertility coauthorship and citation, was extracted from the *WoS* database. Author name disambiguation is a recognized issue when constructing bibliometric measures (Torvik, Weeber, Swanson, & Smalheiser, 2005). To address this limitation, we took a conservative approach in identifying an author's non-Oncofertility publications, considering only those publications with identical author names, e-mail addresses, and Digital Author Identification system numbers, a unique internal ID used by *WoS* database to disambiguate authors.

Demographic information and country affiliation were manually coded by the lead author and three research assistants. Gender information was obtained using text (e.g., text references such as "her work") and image searches on researchers' institutional Web pages. Gender information could not be coded for 49 out of 1,354 researchers. Country affiliation was extracted from researchers' vitae and publication information.

Variables

Our dependent variable is the collaboration network that resulted in innovation, operationalized in this study as publishing in the emerging field of Oncofertility. Coauthorship of a journal publication is an important measure of researchers' collaborative relationship (Guimera et al., 2005). Thus, based on publication information, we defined a coauthorship relation between two researchers if they published a scientific article together in the field of Oncofertility. This procedure generated four undirected 1,354 by 1,354 coauthorship relation matrices, one for each year of observation (2007, 2008, 2009, and 2010). Each cell within a matrix represents the coauthorship relation between two researchers: *1* if two researchers collaborated on at least one article and *0* if not. Our analysis was confined to a binary, rather than a weighted coauthorship network, because stochastic actor-oriented models, used for our analysis, are currently only developed for binary dependent network relations: an existing (*1*) or nonexisting (*0*) coauthorship tie between any pair of Oncofertility researchers.

Control variables. Given the interdependence that exists in network ties, it is important to isolate the impact of diversity and homophily on innovation evidenced by the coauthorship network. Therefore, we control for the potentially confounding effects associated with network structures and individual researchers' attributes. In terms of the former, we control for the endogenous and exogenous effects of network structures on coauthorship relations. *Endogenous network effects* control for the tendency of creating new coauthorship ties based exclusively on prior ties of the same kind, such as previous coauthorship in the area of Oncofertility. *Exogenous network effects* control for the tendency to explain the creation of new ties based on the existence of prior ties of a different kind, such as prior coauthorship on non-Oncofertility publications. Additionally, we also controlled for country and gender as these two attributes may affect a researcher's proclivity to coauthor Oncofertility publications.

We used three network structures to control for the endogenous network effects of prior Oncofertility coauthorships relation to future coauthorship of related publications: density, transitive triads, and the number of actor pairs at Distance 2. Here density controls for the overall "baseline" propensity of any two researchers in the field to coauthor a publication. Like the intercept term in a regression or a grand mean in ANOVA, this measure reflects the probability of two researchers coauthoring a publication in the area of Oncofertility if nothing is known about their prior Oncofertility or non-Oncofertility coauthorship patterns, their country or their gender. Additionally, transitive triads control for researchers' proclivities to coauthor Oncofertility publications with their prior coauthors' prior coauthors and focuses on the formation of new coauthorship ties, while the number of actor pairs at Distance 2 controls for the inverse tendency of researchers to keep their coauthors' prior coauthors at two degrees of separation by not coauthoring with them and focuses on the dissolution of ties in order to create a distance of 2.

We used *prior coauthorship of non-Oncofertility* publications by researchers as an exogenous network control for future coauthorship of publications in the area of Oncofertility. Unlike the previously discussed endogenous networks effects, this exogenous effect regards a different relationship, the coauthorship of non-Oncofertility publications at a prior time. As mentioned previously, in addition the Oncofertility publications we extracted each scientific article published by the 1,345 researchers in the data set prior to the start of their Oncofertility collaborations. We assigned a prior non-Oncofertility collaboration score of *1* between two participants if they both coauthored such a publication. This score was weighted by the total number of scientific articles that these two researchers' published together. We used the natural logarithm of the number of publications coauthored by the researchers in the data sample because this procedure generated three undirected 1,354 by 1,354 coauthorship relation matrices (prior to 2008, prior to 2009, and prior to 2010).

Hypothesized variables. Our three hypothesized independent variables are cognitive similarity, gender similarity, and country similarity. *Cognitive similarity* was measured as citation similarity between two researchers using the Jaccard similarity coefficient. Here, two researchers who cite the same literature are found to be more likely to come from the same research area and to possess similar knowledge. This procedure generated three undirected 1,354 by 1,354 coauthorship relation matrices (prior to 2008, prior to 2009, and prior to 2010). Next, we coded the researcher's *gender* as *1* for female and *0* for male and we identified a total of 34 unique *countries*, with the United States of America being the most represented (35.59%, see the appendix). As gender and country are categorical variables, *gender similarity and country similarity* were calculated as *1* or *0*, with *1* indicating a pair of actors having the same gender, or being from the same country.

Analysis

The diversity and homophily hypotheses were tested using SIENA, stochastic actor-oriented models for network dynamics (Snijders, Van de Bunt, & Steglich, 2010). This statistical model simulates the evolution of the network, using discrete observations over time, and estimates parameters for the underlying mechanisms of network dynamics between these discrete, incremental observations by combining random utility models, Markov processes, and simulation. The SIENA model is appropriate, as the dependent variable innovation is operationalized as a network tie, consisting of coauthorship among two individuals publishing in the field of Oncofertility. In addition, an examination of the emergence of coauthorship ties requires a longitudinal approach which is offered by this model. In this model, positive and significant estimations of coefficients indicate that the corresponding structures are more likely to occur than by random chance alone, whereas negative and significant coefficients indicate that these structures are less likely to occur than by random chance (for more details, see Snijders et al., 2010; Van de Bunt & Groenewegen, 2007).

Results

Oncofertility Network Evolution and Descriptive Statistics

Prior research has shown that innovation is often the result of work done in teams (Uzzi & Spiro, 2005), and that for almost all scientific fields, research is increasingly done in a collaborative manner (Jones, Wuchty, & Uzzi, 2008; Wuchty et al., 2007). Our results show that this is also true in the field of Oncofertility as 87% of the publications reviewed were the result of multiauthor collaborations. Our results also show that 21% of researchers were involved in more than one team, a significant number given that we only observed teams whose work was published over a 4-year period. These results reinforce the idea that investigating tie formation, which explains how teams are assembled in new scientific fields, is a process relevant for understanding networked research (Börner et al., 2010; Contractor, 2013).

Each year new researchers joined the scientific field of Oncofertility and new collaboration ties were created. Table 1 reports the changes within the Oncofertility collaboration network over time, with the number of ties changing from 0 (*no collaboration*) to 1 (*collaboration*). Here we find that changes from $0 \rightarrow 1$ are greater than the number of ties changing from $1 \rightarrow 0$ between subsequent years. Thus, each year, more ties were created than dissolved. These results indicate that the network grew over the duration of our study, a result evident in Figure 1 (Hansen, Shneiderman, & Smith, 2010; Smith et al., 2010) which presents the evolution of the Oncofertility network from 2007 until 2010.

Table 1. Oncofertility Collaboration Tie Changes.

	Tie change			
	0 → 0	0 → 1	1 → 0	1 → 1
From Time 1 = 2007 to Time 2 = 2008	914,319	1,038	520	104
From Time 2 = 2008 to Time 3 = 2009	913,595	1,244	1,042	100
From Time 3 = 2009 to Time 4 = 2010	913,068	1,569	1,236	108

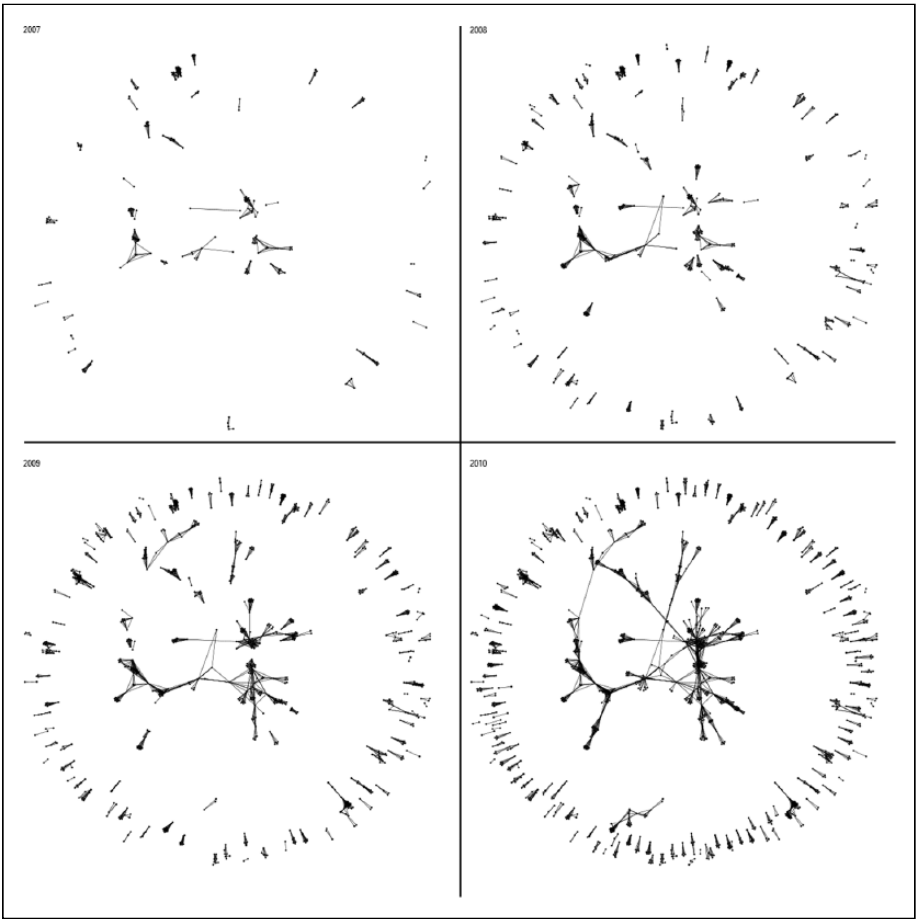

Figure 1. Oncofertility network evolution.

As demonstrated in Figure 1 and Table 2, the density of the Oncofertility coauthorship relation is very low in all 4 years. This suggests that while new researchers joined the field, there were only limited interactions. This is not surprising given that this is a

Table 2. Oncofertility Structural Network Characteristics.

Observation time	Time 1 = 2007	Time 2 = 2008	Time 3 = 2009	Time 4 = 2010	Whole network
Actors	238	412	439	576	1,354
Ties	624	1,142	1,344	1,677	4,772
Density	0.02	0.01	0.02	0.01	0.01
Main component size	19	27	39	71	474
Main component %	7.98	6.55	8.88	12.33	35.01

Table 3. Correlation Matrix.

	N	1	2	3	4	5	6	7	8	9	10	11	12
1. Rate of change, Time 1 to Time 2	1,354	—											
2. Rate of change, Time 2 to Time 3	1,354	−0.01	—										
3. Rate of change, Time 3 to Time 4	1,354	−0.03	0.89	—									
4. Density	1,354	−0.03	0.95	0.87	—								
5. Transitive triads	1,354	0.22	−0.61	−0.51	−0.67	—							
6. Number of actor pairs at Distance 2	1,354	0.06	−0.95	−0.91	−0.97	0.65	—						
7. Gender—Male	1,354	−0.11	0.52	0.46	0.48	−0.42	−0.47	—					
8. Country—United States	1,354	0.06	−0.83	−0.76	−0.81	0.54	0.81	−0.82	—				
9. Prior collaboration (coauthorship log)	1,354	0.00	−0.21	−0.17	−0.25	0.32	0.23	0.18	−0.01	—			
10. Cognitive similarity (citation similarity)	1,354	0.00	−0.69	−0.66	−0.75	0.32	0.64	−0.48	0.61	−0.19	—		
11. Gender homophily	1,354	−0.05	0.63	0.72	0.65	−0.37	−0.67	0.40	−0.69	0.00	−0.53	—	
12. Country homophily	1,354	0.01	0.77	0.67	0.76	−0.35	−0.68	0.55	−0.67	0.01	−0.81	0.48	—

new scientific field and researchers are just starting to publish and collaborate. Furthermore, similar to the evolution of other scientific fields, the size of the giant component, the largest number of researchers who are connected to other researchers via direct or indirect coauthorship ties, increases each year (Bettencourt, Kaiser, & Kaur, 2009). This suggests that new researchers are entering the field by coauthoring with existing researchers.

Hypotheses Testing

Table 3 reports the correlation matrix and Table 4 the results of the coevolution model based on stochastic actor-based models.

Hypothesis 1 predicted that individuals possessing expertise in different knowledge or research areas are more likely to produce innovative ideas through collaboration. The results of the model indicate a negative and significant effect for cognitive similarity (−0.04, $p < .05$). A negative effect indicates dissimilarity in knowledge and hence such a result supports Hypothesis 1. To publish in a new interdisciplinary scientific field, researchers are creating collaboration ties with others who possess different

Table 4. Parameter Estimates and Standard Errors for the Coevolution of the Oncofertility Collaboration Network.

	Estimate	*SE*
Rate of change, Time 1 to Time 2	75.564	65.044
Rate of change, Time 2 to Time 3	127.393	22.081
Rate of change, Time 3 to Time 4	191.912	16.077
Network structures		
Endogenous effects of the Oncofertitlity collaboration relation		
Density	−2.560*	0.086
Transitive triads	0.644*	0.020
Number of actor pairs at Distance 2	−0.137*	0.044
Exogenous effects of the non-Oncofertility prior collaboration relation		
Prior collaboration (coauthorship log)	0.471*	0.046
Attributes effects		
Gender—Male	−0.011	0.043
Country—United States	−0.560*	0.063
Similarity effects		
Hypothesis 1: Cognitive similarity (citation similarity)	−0.041*	0.016
Hypothesis 2: Gender homophily	−0.022	0.023
Hypothesis 3: Country homophily	0.913*	0.041

*$p < .05$.

knowledge sets. Creating ties across such disciplinary boundaries facilitates knowledge transfer and innovation. This result is consistent with the suggested potential benefits of networked research in forging ties between different areas of expertise and agrees that "the scope and complexity of research issues today often benefit from multi-disciplinary solutions" (Dimitrova et al., 2013, p. 291).

Hypothesis 2 predicted that individuals are more likely to achieve innovation with others of the same gender, drawing on arguments about attraction and ease of communication among similar people. However, we did not find support for this hypothesis (−0.02, $p > .05$), suggesting that diversity based on gender in not necessarily beneficial to collaboration.

Finally, Hypothesis 3 predicted that individuals are more likely to achieve innovation when collaborating with others within the same country. This hypothesis was supported (0.91, $p < .05$), revealing that despite the advance of ICTs and researchers' familiarity with technology, distance continues to inhibit the creation of scientific innovation by teams (Cummings & Kiesler, 2005). This is also consistent with prior work on networked research which found that researchers are more likely to collaborate locally (Dimitrova et al., 2013).

Next, we consider the control variables used in our model to account for prior endogenous and exogenous network effects on innovation. In our model, we controlled for the endogenous network effects of prior Oncofertility coauthorship using three structural tendencies: density, transitive triads, and the number of actor pairs at Distance 2. We found density to be significant and negative (−2.56, $p < .05$), suggesting that the costs of collaboration preempt researchers from creating coauthorship ties with random others. The transitive triad parameter on the other hand was found to be positive and significant (0.64, $p < .05$), suggesting that there is indeed a tendency for researchers to collaborate with "friends of their friends," or more accurately prior coauthors' of their prior coauthors. Consistent with this finding, estimates for the number of actor pairs at Distance 2 is negative and significant, signaling a tendency toward network closure. Individuals are likely to forge new collaboration ties with their collaborators' collaborators and not dissolve old ties.

We also controlled for the exogenous network effects of prior coauthorship on non-Oncofertility publications. The results show that researchers are more likely to engage in new collaborations in this field with those whom they have previously collaborated with on non-Oncofertility collaborations (0.47, $p < .05$). This reflects a tendency for individuals to engage in innovation with familiar others.

Finally, we controlled for two attribute variables, country of origin and gender. With regard to country, researchers from the United States demonstrated a lower likelihood to collaborate with other researchers compared with those from other countries (−0.56, $p < .05$). There was no such systematic proclivity for a gender effect as being male or female was not associated with a significantly higher tendency to coauthor an Oncofertility publication.

Discussion

The emergence of a new scientific discipline represents a unique environment to study the formation of collaborative innovative ties. A high level of creativity and uncertainty is characteristic of new scientific disciplines in particular, and networked research more generally. Recently, scholars have started to focus on understanding the factors that influence collaboration in networked work, and more specifically the collaboration of researchers in teams established for the purpose of achieving innovation (Lungeanu, Huang, & Contractor, 2014). The diversity of teams in innovative networks has been theoretically argued as an important factor influencing the likelihood, magnitude, and quality of collaborations and their achievements. However, most prior theoretical and empirical research has considered the formation of teams by focusing on only a limited number of dimensions of diversity. Furthermore, they focus on attributes of individuals rather than also considering relational ties. Finally, they consider collaborations as isolated, one-off events, without evaluating prior collaborations between team members or others. Our study addresses these limitations.

We found that individuals who draw knowledge from multiple varied sources and have access to diverse knowledge areas (Lee, 2010) are more likely to collaborate on innovative tasks. This reinforces our understanding that assembling teams with diverse cognitive resources is more likely to yield innovation. While researchers rarely team up with individuals who possess different knowledge sets, in other research we discovered that when this does occur, such teams are more likely to accomplish innovative outcomes, in this case the funding of a research proposal (Lungeanu et al., 2014). Unfortunately, we are unable to replicate those findings here because we do not have access to collaborations that did not result in publications. Furthermore, it is well known that some of the most innovative articles undergo a gestation period before the scholarly community embraces their true merit. Given the recentness of this field, we are unable to confidently assess variance in the innovativeness of the publications based on citation indices.

We also found that individuals from the same country are more likely to achieve innovation. This speaks to the level of comfort that accompanies being in the same country. We assume that country homophily reflects geographic proximity. However, this is certainly not always the case, especially in large countries where, for instance, a researcher in Toronto, Canada, is geographically closer to a researcher in Chicago, United States, than a fellow Canadian in Vancouver. In addition, individuals collaborate with others in the same country for several reasons: they may share common cultural and educational backgrounds, a common language, and potential constraints from national funding agencies that encourage, or even require, collaborations with others within the country by controlling the amount of funding allowed to leave the country.

It is worth noting that we observed this preference for proximity within the past decade, despite the surge of technological affordances pointing to networked research (Cairncross, 1997). Indeed, *The Economist*, which heralded the death of distance in Cairncross' cover story in 1995, and in a book in 1997, has since heralded the "Death of the death of distance" in a 2008 blog post and, more recently, reinforced this view in the print edition (Lane, 2012). While the affordances technologies provide to bridge distance are intuitive, the affordances they offer to facilitate coordination among proximate others may be less so, regardless of their prevalence. As a result, even technologically savvy scholars often use the tools of networked research to facilitate proximate collaborations.

Finally, conventional wisdom based on the literature concerning innovation and structural holes suggests that novel ideas come from nonredundant ties (Ahuja, 2000; Burt, 2004). However, this study reveals that while researchers who collaborate on innovative tasks come from different research areas, they share a history of prior collaborations with each other, as well as their coauthors' coauthors. This reliance on closure distinguishes our research from other empirical studies of network research. One possible explanation for this difference may be that, during the new, emerging stages of a field, such network closure can help build an intellectual coherence that is critical in gaining legitimacy within the larger scholarly community, as well as with funding agencies. It is also known that individuals who share many common network partners are more likely to trust each other given the cost of being exposed to their common connections (Burt & Knez, 1995). Furthermore, we also know that trust plays an important role in enabling the discussion of unformed creative ideas, a hallmark of the innovation enterprise (Abrams, Cross, Lesser, & Levin, 2003). Taken together with net findings about cognitive dissimilarity, this study suggests that innovation in networked research is most likely when teams draw on individuals with diverse knowledge resources, but who also have prior collaborations with each other or with common others. The key to sustaining innovation in such teams is to reduce the possibility that close collaboration results in a reduction of the diversity in their knowledge expertise (Lungeanu et al., 2014).

Although we recognize that multidisciplinary and global collaborations are needed to solve the grand societal challenges we face today, networked research continues to reflect individuals' natural proclivities to collaborate with others within their own discipline and local unit (Dimitrova et al., 2013). However, our study shows that when researchers do collaborate across disciplines they can be innovative and help launch a new scientific field. In summary, we found that innovation, exemplified as publishing in a new scientific discipline, benefits from both homophily and diversity. Homophily in country of origin and working with prior collaborators helps reduce the uncertainty in interactions associated with innovation, while diversity in knowledge enables the recombinant knowledge required for innovation.

Appendix

Country List

Country	Number of researchers	Country	Number of researchers
United States	482	Sweden	14
France	109	Australia	11
Israel	101	Turkey	11
Italy	95	Taiwan	10
Germany	89	Czech Republic	8
Canada	58	Denmark	7
United Kingdom	51	India	3
Belgium	47	Serbia	3
Spain	41	Poland	2
Austria	29	Argentina	1
China	27	Egypt	1
Japan	27	Malaysia	1
Brazil	26	Malta	1
Greece	26	Portugal	1
Netherlands	26	Russia	1
South Korea	22	Singapore	1
Switzerland	21	South Africa	1

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