**Research Performance and Degree Centrality in Co-authorship Networks: The Moderating Role of Homophily**

* Purpose

This paper explores the nature of the relationship between a scholar's research performance (using weighted journal-impact factor average) and their degree centrality; the impact of author-homophily (in terms of gender, institutional sector, academic age, academic ranks, province and city) on this relationship is investigated as well.

* Design/methodology/approach

Using scientific publishing data and journal impact factors from Thomson Reuters' ISI Web of Science (SCI) and Journal Citation Reports (JCR), respectively, the domestic co-authorship network of Chemistry researchers in Pakistan during 2002-2009 was constructed and then modeled via Ordinary Least Squares regression.

* Findings

Results show that the personal characteristics of a researcher do not necessarily lead to high degree centrality, i.e., attributes may not be causal to co-author relationships. Instead, high degree centrality is more a function of the forerunning research performance of the researcher: Those who publish more in terms of impact factor, attract more co-authors (high degree centrality). Moreover, the relationship between research performance and degree centrality is positively moderated by age and province homophily and negatively moderated by city homophily.

Research limitations/implications

Data is sourced wholly from the Pakistani Chemistry research community; results many not be generalizable to other sub-populations or the wider research community.

Practical implications

The findings provide insights to performance-seeking authors: Knowing that their research performance enhances their centrality, which in turn may lead to increased research performance and various other desirable professional outcomes. In addition, researchers can look towards establishing similar (homophilous) or dissimilar (heterophilous) ties knowing that the relationship between research performance and centrality will likely be stronger when similarity or dissimilarity exists.

Social implications

This study supports the idea that high research performance attracts more potential co-authors, which in-turn may lead to ever greater research performance, which suggests that the research

community will be fragmented between high- and low-performing researchers. Also researcher will have similar or dissimilar ties in terms of various characteristics which in turn moderate the research performance centrality relationship.

* Originality/value

This paper counteracts the belief that researchers are attractive as potential co-authors according to their personal and professional characteristics. It is actually their research performance and homophily or heterophily of their ties which matters.

Key words: research performance, co-author network, homophily, network centrality, degree centrality, Pakistan, bibliometrics



## Introduction

Research performance is the quintessential metric for research faculty. Whether one is motivated by career advancement or personal fulfillment, publishing research is a rigorous condition for membership in the scientific community and employment at research-oriented universities. Moreover, while some faculty consider research their defining characteristic (Crittenden, 1997), some maintain that teaching-oriented faculty also benefit from conducting research (Webster, 1986), as research and teaching activities are considered complementary (Marsh and Hattie 2002).

While some researchers choose to single-author, depending on the field, the vast majority of academic research is published jointly with co-authors (Abramo *et al.*, 2009). Research conducted collaboratively with others can be full of tension, strife and inefficiencies (Hackett, 2005), but from the perspective of an individual's published-research yield, teaming up with others is indispensible (Lee and Bozeman, 2005). Lately, multiple-author research has become a necessity as cutting-edge research becomes increasingly complex and interdisciplinary (Cummings and Kiesler, 2005).

Collectively, scholars co-authoring research publications form an expressive social network, namely a *co-authorship network* (Katz and Martin, 1997; Kumar, 2015a; Newman, 2004a), though there is debate whether such relationships are an indicator for meaningful scientific collaboration (Katz and Martin, 1997). Along with the rise of computing technology and increasing volumes of scientific publishing output, co-authorship networks have become extensively studied, specifically by applying the lens and tools of social network analysis (Newman, 2004b).

The construct of *centrality* is an indication of the advantageous position of an actor in a social network according to the actor's relationships and the structure of the network (Badar *et al.*, 2015). An actor in a co-authorship network can benefit from the knowledge flowing within the network to derive enhanced research performance outcomes; a *highly* central actor is structurally positioned to benefit more so than others *less* central. Previous studies have

investigated and identified the positive influence of network centrality on research performance outcomes in co-authorship networks in various contexts (Badar *et al.*, 2013, 2014; Bordons *et al.*, 2015; Eaton *et al.*, 1999; Fischbach *et al.*, 2011; Gonzalez-Brambila *et al.*, 2013; Gonzalez-Brambila, 2014; Lee *et al.*, 2012; Li *et al.*, 2013; Liao, 2011). In addition, a few studies have also reported diminishing returns of network centrality for authors in the co-authorship network (Badar *et al.*, 2015; McFayden and Cannella, 2004; Rotolo and Petruzzelli, 2013). While the aforementioned studies have rigorously tested the network centrality leading to performance hypotheses, the direction of causality or the presence of reverse causality has largely been ignored. It can equally be argued that high research performance causes authors to be central (Perry-Smith and Shalley, 2003). Moreover, the notion of homophily or similarity in co-authorship ties has largely been ignored. We believe that homophily might moderate the relationship between research performance and network centrality (Perry-Smith and Shalley, 2003).

This article extends previous research of co-authorship networks by focusing on a co-authorship network of faculty members from Pakistan publishing in Chemistry and its sub-fields. We propose and test whether high research performance in an earlier time period (aggregate impact factor) causes authors to be central in a later time period (degree centrality), and whether homophily in ties —in terms of gender (Sax, Hagedorn, Arredondo, and Dicrisi III, 2002; Xie and Shauman, 1998), institutional sector (Lawler, and Yoon, 1998), academic age (Levin, and Stephan, 1991), academic rank, province and city)— moderates the aforementioned relationship. Therefore our research questions are as follows:

> *RQ1*. Does higher research performance lead to authors being central in the co-authorship network?
>
> RQ2. How does homophily moderate the relation between research performance and network centrality?

The remaining part of the paper is as follows: The section on theory and hypothesis presents a review of the relevant literature and the development of hypotheses, the methodology section presents a description of the data and the method adopted to test the hypotheses, and also presents the measurement of relevant variables. The results section presents the empirical results. Then, the results are discussed and the implications, limitations and recommendations conclude this article.

## Theory and hypotheses

### *Network Centrality*

Network centrality is an indication of the relative importance of a node in the network according to position within that network. It measures the prominent position of nodes in the network (Burkhardt and Brass, 1990) and reflects on the importance of the nodes in the network in terms

of power, status and/or influence (Guan and Chen, 2012). Various dimensions of network centrality have been proposed in the social network literature. Freeman (1979) pioneered three classical and most commonly used dimensions of network centrality, namely, degree centrality, closeness centrality and betweenness centrality. Degree centrality measures the number of direct ties a nodes has with other nodes, closeness centrality measures the direct as well as the indirect ties of a node (Scott, 1991) in terms of having a low average distance of a given node to all other nodes in the network, and betweenness centrality measures the proposition of shortest paths in the network that pass through a given node. For the purpose of this study, the measure of degree centrality is most relevant as is the extent to which a node is connected to other nodes in the social network (Wasserman and Faust, 1994). In essence, degree centrality is the number of unique co-authors a given author has published with. In practice, to facilitate comparison across networks of differing sizes, degree centrality is normalized by dividing the count by the number of possible other nodes in the network.

### *Research performance*

Various measures of a scholar's research performance are utilized in bibliometrics and scientometrics, such as: the count of papers, in whole terms or fractional counting (Lee and Bozeman, 2005); the number of papers weighted by ISI impact factor (Badar *et al.*, 2013, 2014; Mcfadyen and Cannella 2004; McFadyen *et al.*, 2009); the number of citations, the h-index and its variants (Batista *et al.*, 2006; Hirsch, 2005; Kelly and Jennions, 2006; Sidiropoulos *et al.*, 2007); and the g-index and its variants (Egghe, 2006; Van-Raan 2006; Costas and Bordons, 2007).

In Pakistan, the ISI impact factor is the official measure of research performance used by universities. The ISI impact factor is mandated by the Higher Education Commission (HEC)—the premier funding, overseer, regulator, and accrediting body of Pakistani higher education institutes—for use in appointments, promotions, awards and grants. Therefore, for the purpose of this study, the indicator to denote research performance is the number of published papers weighted by their ISI impact factor.

### *Homophily*

Homophily is the tendency of individuals creating ties with similar other (McPherson *et al.*, 2001). In the context of co-authorship networks, homophily means that a researcher might have ties with similar others in terms of specific sociodemographic, behavioral, or interpersonal characteristics (Pepe and Rodriguez, 2010).

We look at homophily of faculty members in the co-authorship network in terms of gender, institutional sector, academic age, academic ranks, province and city. Our argument on homophily is based on the idea that initiating new ties might be easier when some sort of similarity exists between the faculty members in the network (Perry-Smith and Shalley, 2003). Therefore, we expect homophily of faculty members in the network to moderate the relationship between research performance and network centrality.

## *Hypotheses*

### *Research performance and network centrality*

Evidence from prior research identifies some antecedents of network centrality: Rogers (1983**)** found that early adopters of innovations tend to be sought out for their advice and opinions, particularly in fields where norms favor innovative behavior, and Burkhardt and Brass (1990) found that early adopters of a technological innovation increased their power and centrality. Similarly, Perry-Smith and Shalley (2003) proposed the centrality-creativity spiral hypothesizing that creativity at the work place might lead an individual occupying a central network position.

Having high research performance in terms of cumulative ISI impact factor, authors can gain all the prestige and status needed in the field. Publishing more and more in impact factor journals will be seen as interesting, intriguing, motivational and inspirational by the peers. They likely will put work of high performing authors as a benchmark for their own work. The work of high performing authors likely will act as a catalyst for their own work. The peers thus will want to be around and have exposure to the high performing author and he/she will be sought out for advice, feedback and research collaboration. Therefore it is expected that high performing authors (in terms of cumulative impact factor) in an earlier time period will have more co-authors in a later time period (higher degree centrality). This leads to the first hypothesis:

*H1. Authors having higher research performance in an earlier time period will continue to have higher degree centrality in a later time period.*

### *Homophily as a moderator*

Mehra *et al.* (1998) found that centrality is less likely when an individual is part of a group that is rare in the network. Perry-Smith and Shalley (2003) argued that when an individual shows high performance at work, but is somehow different relative to the rest of the people in the network, that individual's performance will less likely lead to increment in centrality, because the formation of new ties will be hindered by the individual's diversity. On the other hand, formation of new ties will most likely be easier, if some sort of similarity or homophily exists between individuals of the network. When similarity or homophily exists, communication is easier and behavior is more predictable (Byrne, 1971). Natural group formations in organizations commonly tend to form based on similarity, familiarity, and proximity (e.g., Ancona and Caldwell, 1992; Jehn *et al.*, 1999). Therefore we expect the relationship between high performance and centrality to be stronger when some sort of similarity or homophily exists.

Along similar lines, the relationship between research performance and centrality is expected to be stronger for authors with high proportion of homophilous ties (in terms of gender, institutional sector, academic age, academic rank, province and city) with potential others. This leads to the second hypothesis:

*H2. Homophily positively moderates the relationship between research performance and degree centrality, such that this relationship is strong for authors with high proportion of homophilous ties as compared to authors with low proportion of homophilous ties.*

## Methodology

*Data collection*

Bibliometric data was obtained from ISI Web of Science (SCI) from years 2002–2009 following the similar collection and post-processing procedure, e.g., name disambiguation, as described in Badar *et al.* (2013, 2014, 2015). The selected articles (n=1,699) were those published in journals relating to Chemistry and its sub-fields and were each was authored or co-authored by at least one faculty member of a Pakistan-based university. The process resulted in a co-author network consisting of 1,782 distinct authors, including 203 that are unambiguously Pakistani-faculty members. Using the publicly available (online) CV's of the Pakistani authors, personal attribute data (gender, institutional sector, academic age, province and city) was appended to the Pakistani-author data records. Based on Badar *et al.* (2015), we extracted the co-authorship network existing only among the faculty members. This process was achieved using UCINET VI's filter/extract command and the extract sub-matrix subcommand, including only the identified faculty members.

The cleaned article data was then split into two distinct datasets according to each article's publication year ($t_0$: 2002–2005 and $t_1$2006–2009). Using impact factor data from ISI'S JCR , research performance for each author was calculated for time window $t_0$. Degree centrality and homophily measures were calculated for each author according to time window $t_1$.

*Research performance*

Research performance for each author is computed by weighing each publication of the author by the ISI impact factor of the journal in which it was published (see, e.g., Badar *et al.*, 2013).

*Degree centrality*

The network measure *degree centrality* is an extensively used node-level value which indicates the degree to which a specific node has relationship ties with other nodes in the same network.

Degree centrality of a node $n_i$ is mathematically computed as follows (Scott 1991):

$$C_D(n_i) = \sum_{j=1}^{g} a(n_i, n_j)\ a(n_i, n_j) = 1 \text{ if and only if } n_i \text{ and } n_j \text{ are connected} \quad (1)$$

$$a(n_i, n_j) = 0 \text{ if } n_i \text{ and } n_j \text{ are not connected}$$

where g is the total number of authors in the network and $a(n_i, n_j)$ is a function which is equal to 1 if and only if author $n_i$ and $n_j$ are connected and zero otherwise. A normalized version of degree centrality has been proposed (Freeman, 1979) which can be defined as the proportion of authors co-authoring with $n_i$:

$$C'_D(n_i) = \frac{\sum_{j=1}^{g} a(ni,nj)}{g-1} \quad (2)$$

The value of the normalized index $C'_D(n_i)$ ranges from 0 to 1. In the case of $C'_D(n_i) = 0$, the author $n_i$ is isolated from all others in the network, while when $C'_D(n_i) = 1.0$ node $n_i$ is tied to all

other authors in the network. Procedurally, UCINET VI (Borgatti *et al.*, 2002) was used to determine the $t_0$ and $t_1$ degree centrality values for each author.

### *Author characteristics*

The attributes for each author are recorded as nominal variables and coded as per:

- Gender: Male = 1, Female = 0.
- Institutional sector: Public = 1, Private = 0.
- Academic rank: Assistant professor = 1, Associate Professor = 2, Professor = 3.
- Province: Balochistan = 1, Sindh = 2, Punjab = 3, KPK = 4, Capital territory = 5, Azad Kashmir = 6.
- City: Quetta = 1, Jamshoro = 2, Karachi = 3, Lahore = 4, Peshawar = 5, Multan = 6, Kohat = 7, Malakand = 8, Manshera = 9, Islamabad = 10, D.I. Khan= 11, Faisalabad = 12, Bannu = 13, Bahawalpur = 14, Sargodha = 15, Gujrat = 16, Khairpur = 17, Abbottabad = 18, Muzafarabad = 19, Mardan = 20, Rawalpindi = 21.
- Academic age: Senior = 1, Junior = 0.

Academic age is originally a continuous variable indicating the number of years since a faculty member earned his Ph.D., through to 2002 (at the time the studied co-authorship network had been identified). The Academic age was re-coded as a dichotomous variable: authors of academic age below six years are assigned as juniors and those six years and above as seniors.

### *Control variables*

The OLS regression model controls for some of the relevant author attribute variables. Prior research shows that gender, institutional sector, academic age and academic rank have a strong impact on the development of co-authorship networks (Badar *et al.*, 2013, 2014, 2015; Lee and Bozeman, 2005; Oh *et al.*, 2005; James and Benjamin, 1988; Wilkinson and Yussof, 2005). Therefore, the control variables are gender, institutional sector, academic age and academic rank.

### *Homophily*

To measure the level of homophily for an individual author, PctHomoph (Crossley *et al.*, 2015) is employed. PctHomoph is defined as the proportion/percentage of an author's co-authors that have the same attribute. PctHomoph is calculated as follows (Hanneman and Riddle, 2005):

*PctHomoph = Number of ties between ego and an alter in the same attribute category / ego's total number of ties*

where ego is defined as the individual *focal node* and alters as all *other* nodes in the network (Hanneman and Riddle, 2005).

The value of the PctHomoph ($n_i$) ranges from 0 to 1. The measure returns values ranging from 0 to 1 (0 to 100 if expressed in percentage) with 1 (100%) expressing perfect homophily (similarity) and 0 expressing perfect hetrophily (dissimilarity). Procedurally, PctHomoph determined using the Network > Ego Networks > Egonet Homophiliy command. The 203 X 203 co-authorship network matrix was input as a network dataset along with each attribute dataset..

### *Analysis methods*

Traditional statistical procedures are followed to report the descriptive statistics and correlations for the all variables, to construct a model, and to test the hypotheses. Spearman Correlation is applied to determine the association amongst the variables. Ordinary Least Squares (OLS) procedures will be followed to construct the models consisting of the explanatory and control variables and potential interactions between the dependent and explanatory variables. The interaction terms are used to test the moderating role of homophily (variables were z-transformed prior to calculation of interaction terms). Variance inflation factor (VIF) values are used for a test of multicollinearity. The models' residual distribution is checked for normality assumptions (using histogram, skewness and kurtosis values, and normal P–P and Q–Q plots). The distribution of the dependent variable, degree centrality, is skewed, so it is log-transformed. From the best model the hypotheses will be tested.

## Results

Table 1 presents the means/percentages, standard deviations and Spearman correlations for all variables in the analysis. Findings indicate 77.80% faculty members are males, 73.40% are employed in public sector universities/research institutes, 62.60% are juniors and 40.60% assistant professors, 17.30% are associate professors and 42% are professors. Moreover, 32.50% of the faculty members in the co-authorship network are from Punjab province, followed by 27.60% from KPK, 19.70% from Sindh, 15.30% from capital territory, 3.40% from Balochistan and 1.50% from Azad Kashmir. Coming to city affiliation, 14.80% of the faculty members are from Islamabad, followed by 13.30% from Karachi, 12.80% from Peshawar, 10.30% from Lahore and Faisalabad respectively.

Coming to the scores of homophily, means of homophily measures specify whether the ties among faculty members on average have high homophily, moderate or low homophily. Means for gender homophily, affiliation homophily and province homophily is 0.72, 0.64 and 0.62 respectively, which specifies high levels of homophily. Means for academic age homophily, city homophily and rank homophily are 0.46, 0.43 and 0.42 respectively, specifying moderate levels of homophily.

Correlation among variables is generally low/insignificant with few exceptions. Research performance was significantly correlated with degree centrality. Institutional sector was

significantly correlated with research performance and academic age was significantly correlated with both degree centrality and research performance.

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Insert Table 1 about here
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Table 2 presents the results of OLS regression analysis used to test the hypotheses. We present three models with main focus on the full model (i.e., model 3). Model 1 is the base model containing only control variables. Model 2 contains the homophily variables and the independent variable, research performance. Model 3 contains all the variables and interaction terms (…homophily X research performance). The VIF values, shown for final model or model 3, mostly are below 5 and all below 10 indicating no real problem of multicollinearity. The residual distribution is normally distributed (histogram looks normal and normal P–P plot was almost a straight line).

Model 1 reveals insignificant findings except for the coefficient for institutional sector which was positive and significant ($\beta$=0.16, $p<0.01$) implying that faculty members employed in public sector universities/research institutes have higher degree centrality in a later time period. All other control variables namely gender, academic age, and rank have insignificant coefficients

In model 2, coefficient for research performance is positive and significant ($\beta$=0.04, $P<0.01$). This finding provides support to Hypothesis 1. The coefficient for rank homophily is negative and significant ($\beta$=-0.14, $p<0.05$) implying that faculty members having high level of homophilous ties in terms of rank (faculty members with same rank having authorship ties with each other) are less central in terms of degree centrality. The coefficients for other homophily measures and control variables are all insignificant.

In model 3, coefficient for research performance is positive and significant ($\beta$=0.08, $p<0.01$). Therefore we find ample support for Hypothesis 1. The coefficient for interaction term of research performance with academic age homophily and province homophily is positive and significant ($\beta$=0.27, $p<0.10$; $\beta$=0.33, $p<0.10$ respectively) implying that the relationship between research performance and degree centrality is positively moderated by homophilous ties of faculty in terms of age (juniors having authorship ties with juniors and seniors having authorship ties with seniors) and province (faculty members belonging to the same province having ties with each other). The coefficient for interaction term of research performance with city homophily is negative and insignificant ($\beta$=-0.60, $p<0.01$) which implies that relationship between research performance and degree centrality is negatively moderated by homophilous ties of faculty in terms of city (faculty members from the same city having authorship ties with each other). Coefficients for interaction term of research performance with other measures of homophily

(gender, institutional sector and rank) are insignificant. Therefore we find only weak support for Hypothesis 2.

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Insert Table 2 about here
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Figures 1, 2 and 3 present the interactions plots to visually represent the moderating impact of age, province and city homophily on the relationship between degree centrality and research performance.

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Insert Figures 1, 2 and 3 about here
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## Discussion

This study investigates the relationship between research performance and degree centrality in a domestic co-authorship network of Pakistani faculty members in Chemistry. Moreover, the moderating role of homophily on the aforementioned relationship is tested. The study first established that prior research performance *does* precede the degree centrality of an author in the co-authorship network. Results show that regard to co-author networks, the personal characteristics of a researcher do not necessarily precede having high degree centrality, i.e. attributes may not be causal to co-author relationships. Instead, high degree centrality is more so a function of the forerunning publishing output of the researcher. As provided above, the findings according to Model 2 and Model 3 provide indication and strong support for *Hypothesis 1: Authors having higher research performance in an earlier time period will have higher degree centrality in a later time period*. This phenomenon may seem counter intuitive, as it is likely affected by the context of the relationship. The highly-specialized nature of scholars in a co-author network, may explain this. Such scholars are acutely aware of their research environment and relevant high producers. Moreover, scholars are keenly aware of the research performance expected of them. It is, therefore, plausible that such scholars would not patently look at the personal attributes of others; instead, they look to the past performance of prospective co-authors. This particular finding of insignificance of control variables provides some strength to our first hypothesis. That is, it is actually high research performance which makes authors

attracted towards other authors which eventually might lead to establishment of an actual co-author relationship.

Coming to the finding related to hypothesis 2, we found only weak support, but still ample to get some valuable insights. Homophily in terms of academic age positively moderated the relationship between research performance and degree centrality. This finding is understandable in Pakistani organizational context. In Pakistani universities/research institutes, there exists a widened *generation gap*. Although senior faculty members are perceived as gurus of research (Badar *et al.*, 2014), due to a wide generation gap, most often they are also perceived as hard-to-work with and hard-to-communicate with by most junior faculty members. Similarly senior faculty members perceive juniors as their sub-ordinates and think that they as seniors always know better. But that doesn't, by any stretch of imagination, mean that senior and juniors do not collaborate. Actually the average homophily score for academic age was 0.46, which shows that there was a tendency of heterophilous ties (junior faculty having ties with senior faculty). The results related to academic age homophily implied that the relationship between research performance and centrality was stronger when academic age homophily existed (junior faculty having ties with junior faculty and senior faculty having ties with senior faculty) perhaps due to the reasons aforementioned. Homophily in terms of province also positively moderated the relationship between research performance and degree centrality. This finding yet again is understandable in Pakistani context. The country Pakistan consists of provinces based on ethnicity with each province having distinct languages and distinct cultures (see for e.g. Hurst, 2008). These deep-rooted ethnic divides make it understandable that faculty members from each distinct province will be at ease to communicate and collaborate with faculty from the same province. The average homophily score for province was 0.62, which shows that there is a tendency of more homophilous ties (faculty members from the same province having ties with faculty members from the same province) and less heterophilous ties (faculty members from different provinces having ties with each other). The results related to province homophily showed that the relationship between research performance and centrality was stronger when province homophily existed (faculty members form same province having ties with each other), perhaps due to the reasons aforementioned. Homophily in terms of city negatively moderated the relationship between research performance and degree centrality. The finding can be interpreted in terms of Pakistani context and the field understudy (Chemistry and its sub-fields) context. Talking about research in Chemistry and its sub-fields, labs are a necessity. But not all Universities/research institutes have satisfactory lab facilities. Therefore it is understandable that the faculty from universities/research institutes in smaller cities (with-in or out-side provinces) will look to collaborate with faculty from universities/research institutes in bigger cities where lab facilities are available. The average score for city homophily was 0.43, which shows there was a tendency of heterophilous ties (faculty members from different cities having ties with each other). The results related to city homophily showed that the relationship between research performance and centrality was stronger when city heterophily existed perhaps due to the reasons discussed. This particular finding opposed hypothesis 2 but still unveils some useful insights.

*Implications and limitations*

This study offers important implications for researchers. In opposition to prior research, this study contests the conjecture that centrality leads to researcher performance (Kumar, 2015b); instead, this study explored researcher's performance as an *antecedent* of network centrality (degree centrality). The finding related can be insightful for researchers as they can work towards achieving high performance, knowing that the research performance would ultimately enhance their centrality, which can in turn lead to various other desirable professional outcomes. Moreover, the findings related to homophily (in terms of gender, institutional sector, academic age, academic rank, province and city) as a moderator revealed important insights for practicing researchers. Researchers can look towards establishing homophilous or heterophilous ties knowing that these similar or dissimilar ties can lead to enhanced exploitation of the research performance and centrality relationship.

Methodological limitations of this study open several avenues for further research. First, similar hypotheses should be tested in other contexts (such as different country and different fields) to ascertain generalizability. Second, other latent antecedents of co-authorship network centrality such as extraversion and agreeableness should be tested; accomplished by bounding the network and administering social surveys to authors in network (Klein *et al.*, 2004). Third, other contextual moderators should be introduced, specifically between the research performance-co-authorship network centrality relationship such as cultural norms of the organizations and tightness of the symbolic structure of the field understudy (Perry-Smith and Shalley, 2003). Fourth, from a methodological point of view, to test the antecedents of network centrality, Exponential Random Graph Models (ERGMs) (also called p* models) could be used effectively. ERMG-based research can explore the probabilistic nature of the formation of ties as a function of antecedents (for e.g. mentioned earlier) of the network relationships.

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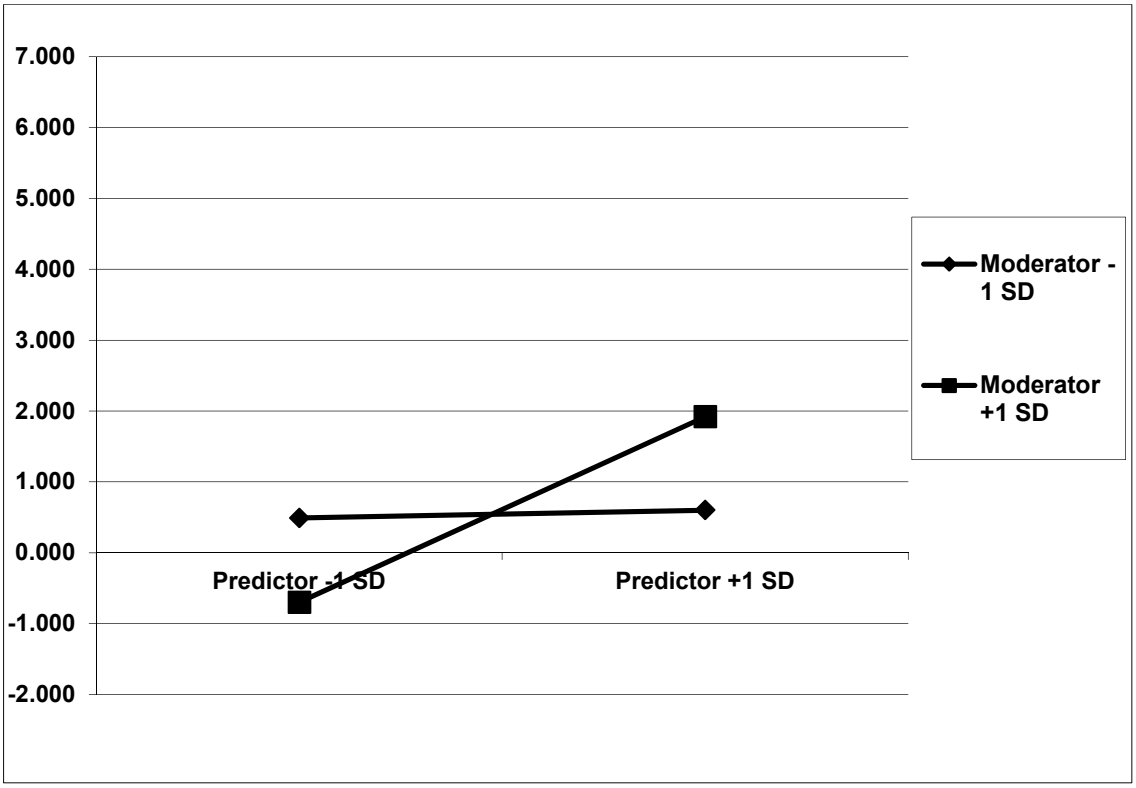


Figure 1. Interaction plot for moderating impact of age homophily

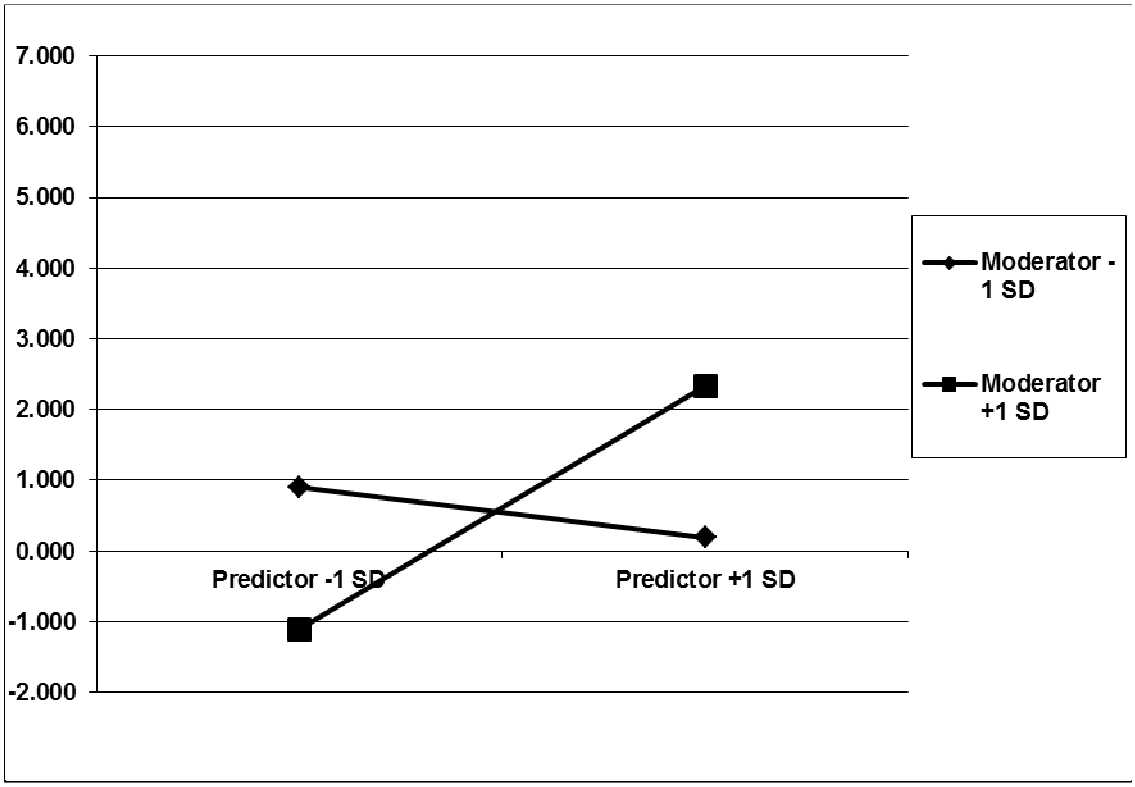


Figure 2. Interaction plot for moderating impact of province homophily

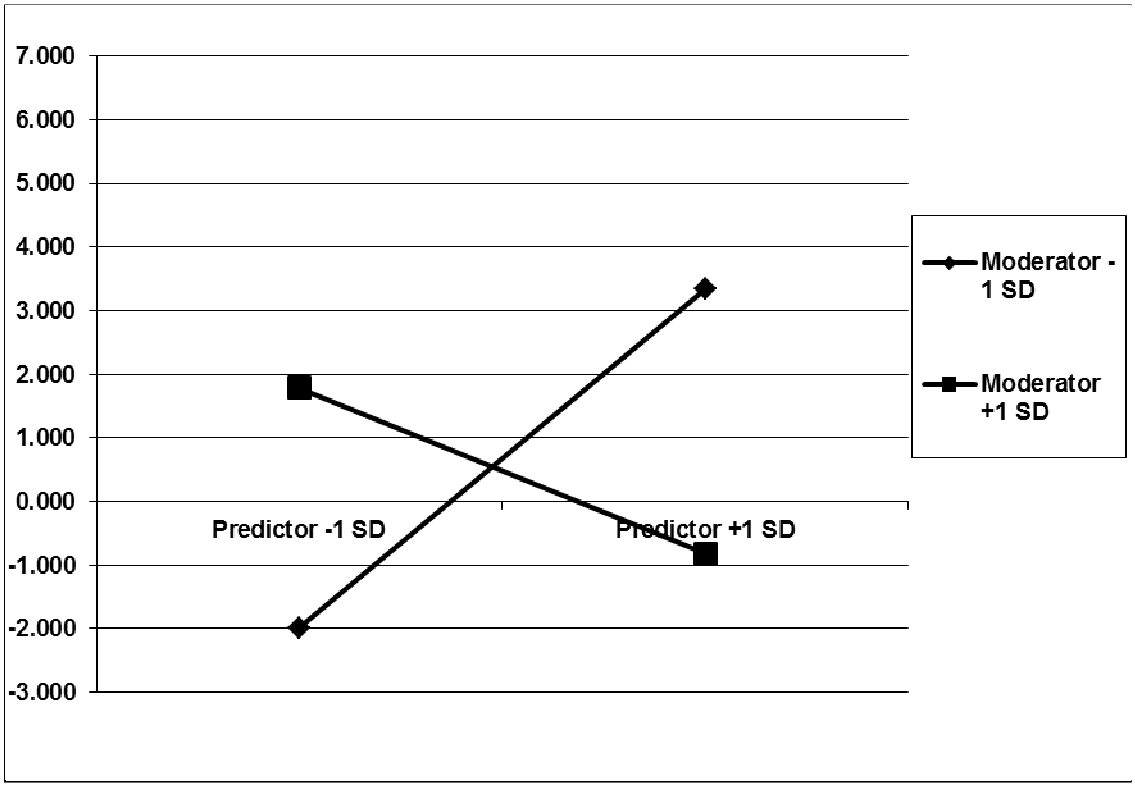


Figure 3. Interaction plot for moderating impact of city homophily

**TABLE 1**
**Means, Standard Deviations and Spearm**

| | Variable | Mean | S.D | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Degree centrality | 3.20 | 3.31 | | | | | | | | |
| 2 | Research performance | 4.16 | 8.86 | 0.54 ** | | | | | | | |
| 3 | Gender (1=male) | 0.78 | 0.42 | 0.06 | -0.04 | | | | | | |
| 4 | Institutional sector (1=public) | 0.73 | 0.44 | 0.13 | 0.21 ** | 0.05 | | | | | |
| 5 | Academic age (1=senior) | 0.37 | 0.49 | 0.18 * | 0.28 ** | 0.07 | 0.24 ** | | | | |
| 6 | Assistant Professor | 0.41 | 0.50 | 0.04 | -0.02 | 0.16 * | -0.03 | 0.04 | | | |
| 7 | Associate Professor | 0.17 | 0.37 | -0.08 | 0.02 | -0.13 | 0.02 | 0.02 | -0.37 ** | | |
| 8 | Professor | 0.42 | 0.50 | 0.02 | 0.01 | -0.06 | 0.02 | -0.05 | -0.71 ** | -0.39 ** | |
| 9 | Gender homophily | 0.73 | 0.32 | -0.11 | -0.03 | 0.61 ** | 0.06 | 0.01 | 0.19 ** | -0.18 * | -0.06 |
| 10 | Sector homophily | 0.64 | 0.35 | -0.03 | 0.11 | -0.06 | 0.71 ** | 0.12 | -0.08 | -0.29 | 0.10 |
| 11 | Age homophily | 0.46 | 0.26 | 0.00 | 0.04 | -0.03 | 0.04 | 0.15 * | -0.05 | 0.12 | -0.04 |
| 12 | Rank homophily | 0.42 | 0.30 | -0.04 | 0.00 | 0.04 | 0.05 | 0.24 ** | -0.04 | 0.11 | -0.04 |
| 13 | Province homophily | 0.61 | 0.36 | -0.31 ** | -0.29 ** | -0.07 | -0.03 | -0.01 | -0.03 | 0.07 | -0.02 |
| 14 | City homophily | 0.43 | 0.37 | -0.14 | -0.08 | -0.19 ** | 0.07 | 0.11 | -0.04 | 0.07 | -0.02 |

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

**an Correlations**

| 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| 0.01 | | | | |
| -0.15 * | 0.00 | | | |
| -0.11 | 0.10 | 0.47 ** | | |
| -0.06 | -0.04 | 0.07 | -0.02 | |
| -0.17 * | 0.12 | 0.11 | 0.03 | 0.62 |

**Table 2**
**Results of OLS Regression for degree centrality**

| Variable | Model 1 | Model 2 | Model 3 | VIF |
|---|---|---|---|---|
| **Explanatory variables** | | | | |
| Research Performance | | 0.04 *** | 0.08 *** | 5.98 |
| Gender homophily | | -0.08 | -0.10 | 2.25 |
| Insitutional Sector homophily | | 0.06 | 0.03 | 3.50 |
| Academic age homophily | | 0.07 | 0.13 | 2.55 |
| Academic rank homophily | | -0.14 ** | -0.08 | 2.27 |
| Province homophily | | -0.07 | 0.10 | 3.94 |
| City homophily | | -0.10 | -0.26 | 4.22 |
| Research Performance x Gender homophily | | | -0.12 | 2.06 |
| Research Performance x Sector homophily | | | -0.17 | 4.21 |
| Research Performance x Age homophily | | | 0.27 * | 3.17 |
| Research Performance x Rank homophily | | | 0.11 | 2.98 |
| Research Performance x Province homophily | | | 0.33 * | 7.93 |
| Research Performance x City homophily | | | -0.60 *** | 6.54 |
| **Control Variables** | | | | |
| Gender | 0.01 | 0.07 | 0.09 | 2.07 |
| Academic Age | 0.08 | -0.01 | -0.01 | 2.62 |
| Institutional Sector | 0.16 *** | 0.07 | 0.01 | 1.23 |
| Associate Professor | -0.06 | -0.05 | -0.05 | 1.28 |
| Professor | -0.02 | -0.08 | -0.05 | 1.23 |
| Intercept | 0.83 | 0.65 | 0.58 | |
| $R^2$(adjusted) | 0.03 | 0.31 | 0.39 | |
| F-test | 2.34 ** | 8.14 *** | 7.87 *** | |

*** p<0.01 **p<0.05 *p<0.10