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# Influence of Scientific Collaboration Network on Academic Performance

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**Abstract**

Collaboration in science is a complex phenomenon that affects scientific performance in various ways. Thus, understanding the influences of the research collaboration network is important for researchers. This paper explores the relationship between research collaboration network structural and scientific research performance and conducts an empirical test with data from 416 scholars. Findings revealed that network stability reduces the scholars' research performance, and network centrality promotes research performance. The network structural holes that the scholar spans, moderate the detrimental effects of network stability. This research provides suggestions for scholars to build a reasonable scientific research collaboration network to improve their research performance.

**Keywords:** academic performance, collaboration network, network centrality, network stability, scientific collaboration

## 1. Introduction

The academic study about the scholars' research performance is a time-honored topic. Through a series of relevant indicators to evaluate scholars' performance, we can identify defects and problems, and then promote the development and progress of individuals and their institutions (Abbasi et al., 2011). On the other hand, scientific research collaboration is considered a key factor in scientific progress, as researchers in collaboration networks can share their knowledge and ideas, use similar methods and techniques, and interact with each other. Scientific research collaboration is a very complex phenomenon that affects scientific research productivity and the dissemination of knowledge within and between disciplines in various ways (Lee & Bozeman, 2005).

Figg and other researchers found that the number of citations and cooperative personnel and the number of collaboration institutions is significantly related (Figg et al., 2006), which through the statistical analysis of literature data in six high-impact factor journals. The results of a study specifically on the association between the R and h index by Parish and others showed that researchers with more collaborators tended to have a higher h index (Parish et al., 2018). Analysis of scientific collaboration data by Wang Wei shows that establishing stable and close cooperative relations with a small number of authors can help improve the level of scientific research output of researchers (Wei et al., 2013). The results of scholars Shi Yanqing and Sun Jianjun also show that there is a positive correlation between the degree of international cooperation of scholars and their scientific research performance, which has a positive effect on the quality of their scientific research output and output results (Shi et al., 2017).

However, with the deepening of research work, some different views and research conclusions are gradually revealed, mainly in the relationship between some specific indicators and influence. Because of this, this study measures the scholars' various scientific collaboration network and attribute indicators based on the method of social network analysis, and uses the methods of Spearman rank correlation analysis and multi-regression model (MVRM) analysis. The relationship and influence between the stability of the researchers' cooperative network and academic performance are explored and analyzed in depth.

## 2. Theory and Hypotheses

### *2.1 Collaboration Network Centrality and Academic Performance*

Burt's researches support a link between the researcher's performance and both the number of ties and centrality in networks, with higher-performing researchers holding more ties and having more network centrality (Burt, 2009; Cross & Cummings, 2004). Additionally, researchers also believe that researchers with greater centrality will have access to more information, have more power, and have greater influence (Chen & Guan, 2010).

The network centrality describes the power that the individual has in the network. Most researchers believe that the more the actor is in the center of the network, the greater its comprehensive influence in the network. Therefore, compared with other scholars, scholars in the center of the network It is easier to establish cooperative relations with other subjects, to obtain more heterogeneous resources, which helps to improve its innovation performance. Therefore, the following hypotheses are accordingly proposed:

H1: The researcher's collaboration network centrality positively correlates with his/her research performance.

### *2.2 Collaboration Network Stability and Academic Performance*

Phelps finds that technological diversity, coupled with network closure, enhances innovation (Phelps, 2010). Rodan and Galunic summarize, "while network structure matters, access to heterogeneous knowledge is…of greater importance for innovation performance" (Rodan & Galunic, 2004). From the perspective of social resources, whether the weak tie or the bridging will not bring network advantages, but whether the researchers' partners have the resources needed to meet their research needs, and whether the researchers can obtain these resources.

Therefore, we believe that in the case of a stable collaboration network, the beneficial effect of communication between researchers and the subsequent improvement of knowledge transfer efficiency in the collaborative network can successfully reduce the negative impact of stability to a certain extent, but it may not provide enough traction to construct the impact of network stability on innovation, whether upward tilt or quadratic curve. In other words, the relationship between the stability of scientific research collaboration networks and academic performance is likely to be monotonous and decreasing. Therefore, we assume that:

H2: Collaboration network stability of the researcher is associated with reduced academic performance for the researcher.

### *2.3 Moderating role of Collaboration Network Structure Holes*

In the above hypothesis, we hypothesized that the stability of the collaboration network has a negative impact on the researcher's academic performance. However, if researchers cross the structural holes in collaboration networks, previous theories and studies suggest that researchers can obtain both more information sources and more diverse information than researchers who cross fewer structural vulnerabilities (Burt, 2004). The network structure full of structural vulnerabilities improves the quality of information available to researchers because it can compare and compare the accuracy of information provided by different researchers. Therefore, researchers who cross structural loopholes can take advantage of greater arbitrage ability. In summary, crossing structural holes allows researchers to mitigate the negative effects of stability described in the previous section (Burt, 2004).

Therefore, we argue that when the researcher spans more structural holes, the negative effects of collaboration network stability on academic performance are mitigated. Thus,

H3: The greater the spanning of structural holes by the researcher, the less negative the relationship between collaboration network stability and the researcher's academic performance.

Based on the above theories and hypotheses, we propose the following conceptual framework:

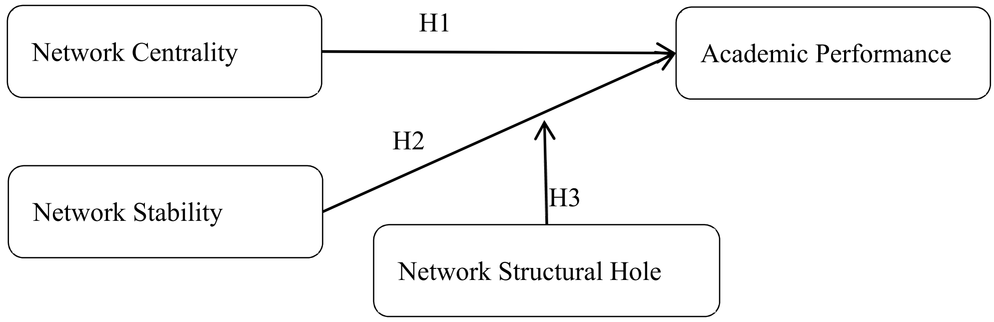


Figure 1. The conceptual model

## 3. Data and Methodology

### 3.1 Data and Sample

We choose Chinese university scholars engaged in "leadership behavior" as the sample for the empirical analysis and collect the papers of these scholars from CAJD and build a scientific research collaboration network based on the collaboration between papers. There are several reasons for this.

First, the Academic journal paper is one of the main forms of scholars' scientific research output (Hongzhen et al., 2005). In the scholars' academic performance research, the co-authored papers can record the academic innovation activities of scholars at different time points more completely and objectively. By observing and analyzing the above information, the author studies the academic performance of the scholars' academic papers and builds a scientific collaboration network by the scholars' collaboration in academic papers. Second, the "Leadership Behavior" research field is a relatively mature subject area, and there is extensive academic collaboration, and eliminate the influence of differences between the different subjects. Third, China Academic Journal Network Publishing Database (CAJD) is the largest and most valuable Chinese academic database in the world. It follows the law of Bibliometrics and uses a combination of quantitative and qualitative evaluation to select source journals, which have been recognized by many researchers and institutions.

Our sample consisted of scholars who published at least one paper that was published in journals between 2009 and 2018, and who published papers during the observation period 2009-2013 and 2014-2018. 416 scholars have been published papers in these two periods. The data of these 416 scholars become our sample data.

### 3.2 Variables Measurement

1) Dependent Variable

We evaluated the academic performance of scholars based on the citation of the paper. Since the papers in this study are co-authored papers, this paper gives different co-authors different proportions. The first author of the paper accounted for 50%, and the other authors divided the remaining 50%. We call this the contribution value and record it as A.

And m indicates that the author's signature rank order in the paper is *m* (*m=1, 2...*). $A_{ijm}$ indicates that the author *i* in paper j author order is *m*. If $C_j$ is the number of citations of the paper j, then we can calculate $A_{ijm}$ like this: $A_{ijm}=C_j/2$ (if m=1) or $A_{ijm}=C_j/2(aj-1)$ (if $m>1$), and $a_j$ indicates the number of the author in paper *j* is $a_j$.

At the same time, in order to eliminate the influence of the number of citations due to the publication time, this study considers the factors of the number of years of publication of the paper when calculating the number of citations, and uses the average number of times of citations to calculate. If the citations of paper *i* is $C_i$, the years of the papers is *yi*, then the number of citations is $C_i/Y_i$.

Therefore, we can compute the academic performance as the following formula:

$$AP_i = \sum_j^n \left(\frac{C_i}{Y_j} \times A_{ijm}\right) = \begin{cases} \sum\limits_i^n \frac{C_i}{Y_i} \times \frac{1}{2} & m = 1 \\ \frac{C_i}{Y_i} \times \left(\frac{1}{2\times(a_j-1)}\right) & m > 1 \end{cases}$$

Where, in this formula, *APi* is the academic performance of author *i*, *Cj* is the total number of citations of paper *j*, *Yj* is the number of years of the paper *j*, *aj* is the number of author of paper *j*,and *Aijm* is the contribution value of author *i* in paper *j*.

2) Independent Variables

Collaboration network stability refers to the situation in which scholars added or lost collaborators at different times in their scientific collaboration network. The formula for the network stability measure is as follows:

$$C_i = \frac{\sum_i^n (C_{max} = C_i)}{n-1}$$

Where, in this formula, $AT_i$ is number of added ties from period 1to period 2, $LT_i$ is the number of lost ties from period 1 to period 2, and $T_{it}$ is the total number of ties in periods *1* and *2*.

The network centrality is mainly calculated by the centrality of each body. This study using Bunderson's Network Centrality Formula to calculate the centrality of connections between members of the scientific collaboration network.

$$S_{it} = 1 - Churn_{it} = 1 - \frac{AT_i + LT_i}{T_{it}}$$

Where n is the number of network members, $C_{max}$ is the maximum centrality in the network, and $C_i$ is the degree of centrality of the network members *i*.

We choose Burt's structural holes index as the representation variable of the scientific collaboration network structure hole, which is mainly because Burt believes that Limitation is the most important indicator when measuring structural holes. This measure is mainly used to measure the limited situation of individuals in the network when measuring structural holes. We calculate the value of network structural holes using Burt’s formula as following:

$$H_{iqt} = (p_{iqt} + \sum_i^n p_{ikt} \times p_{kqt}, k \neq i, q)^2$$

3) Control Variables

According to previous studies, gender, age, education level, etc. have an impact on scholars' performance (Ohly et al., 2006). Therefore, this study selects the gender, age, degree, and professional title of the scholars as control variables that can greatly reduce the potential risk of the research model.

Hirsch proposed using the h-index to evaluate scientists' academic achievements (Hirsch, 2005). We focus on the “Leadership Behavior” research field, all the scholars are in the same field. Therefore, using the h-index to measure scholars' past academic achievements is appropriate.

## 4. Analyses and Results

Table 1 reports descriptive statistics and correlations among the variables. Though some variables exhibit moderate-to-high correlation, this is not an issue because the variance inflation factor (VIF) doesn’t exceed 10, with the mean VIF being 5.43. Thus, the col-linearity problem is not a serious threat in this study.

Table 1. Descriptive statistics and correlations (N = 416).

| | Mean | S.D. | Min | Max | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. AGE | 3.16 | 2.02 | 1 | 5 | 1 | | | | | | | | | | |
| 2. Gen | 1.35 | 0.61 | 1 | 2 | 0.11 | 1 | | | | | | | | | |
| 3. PT | 2.46 | 0.89 | 1 | 5 | .38** | .545** | 1 | | | | | | | | |
| 4. AD | 2.26 | 0.81 | 1 | 3 | 0.028 | -0.05 | .244* | 1 | | | | | | | |
| 5. AA | 3.34 | 1.71 | 1 | 5 | .35** | .492** | .636** | 0.072 | 1 | | | | | | |
| 6. UL | 2.22 | 0.63 | 1 | 3 | 0.066 | 0.08 | -0.001 | -0.041 | 0.081 | 1 | | | | | |
| 7. US | 3.77 | 1.40 | 1 | 6 | .57** | 0.084 | 0.042 | -0.174 | .259** | 0.081 | 1 | | | | |
| 8. PA | 15.83 | 13.69 | 0 | 65 | 0.097 | .206* | .226* | -0.003 | .287** | 0.176 | 0.032 | 1 | | | |
| 9. NS | 0.46 | 0.18 | 0 | 0.78 | -0.13 | 0.009 | 0.078 | -0.055 | -0.019 | 0.075 | 0.142 | 0.062 | 1 | | |
| 10. NC | 0.08 | 0.046 | 0.03 | 0.25 | 0.112 | 0.094 | 0.185 | 0.119 | 0.163 | -0.027 | 0.151 | 0.052 | 0.057 | 1 | |
| 11. NSH | 3.30 | 4.40 | 0 | 18 | .42** | .396** | .457** | 0.073 | .569** | 0.002 | .379** | 0.122 | -0.02 | .546** | 1 |
| 12. AP | 9.551 | 11.09 | 0.32 | 79.53 | .44** | .423** | .489** | 0.08 | .580** | 0.005 | .389** | 0.117 | -0.07* | .545** | .971** |

Table 2 presents the results of the regression analysis using the multiple linear regression analysis used to test the hypotheses. Model 1 in Table 2 is a control-variables-only baseline model. The independent variables, including Collaboration Network Stability and Network Centrality, are added to model 2 and model 3 respectively. We add the interaction between Network Stability and Structural holes in model 4 and this is our fully specified model with all variables and interaction terms.

Table 2. Regression analysis results

| Variables | Model-1 | Model-2 | Model-3 | Model-4 |
|---|---|---|---|---|
| AGE | 0.138 | 1.104 | 2.087 | -0.275 |
| Gender | 0.186 | 4.829 | 5.394 | 0.917 |
| Professional Title | 0.115 | 3.38 | 0.985 | 1.129 |
| Academic Degree | 0.071 | 2.037 | 0.704 | 0.531 |
| Academic Age | 0.322 | 5.104 | 5.207 | 0.004 |
| University Level | -0.052 | -1.175 | -0.955 | 0.319 |
| University Size | 0.225 | 2.68 | 1.37 | 0.468 |
| Past Achievement | -0.047 | -0.045 | -0.059 | -0.007 |
| Network Stability | | -7.464** | | -0.534* |
| Network Centrality | | | 1.257** | -0.014* |
| Network Structural Holes | | | | 0.461** |
| Network Stability ×Network Structural Holes | | | | -0.208** |
| $R^2$ | | 0.576 | 0.638 | 0.955 |
| □$R^2$ | | 0.422 | 0.601 | 0.949 |
| F-value | | 8.878 | 41.372 | 66.497 |
| p-value | | 0 | 0 | 0.009 |

Model 2 adds Network Stability on the basic model 1, the change of F Value show significant ($p<0.01$), which means that Network Stability (NS) has an explanatory meaning for the models. In addition, the increase of R squared value from 0.468 to 0.576 means that Network Stability can produce 23.1% explanatory power for academic performance. And we also can know there is no multicollinearity between the independent variables (VIF<2.792). Specifically, the regression coefficient of network stability is -7.464 and shows a significant ($p=0.009<0.01$), which means that Network Stability has a significant negative impact on performance. H1 states that network stability negatively affects scholars' academic performance. Stability has negative and significant ($P<0.01$) coefficient estimates in Model 2. The bottom panel shows that Stability has a negative, but diminishing, and significant ($p<0.01$) impact on the predicted mean counts. These findings are consistent with H1. That means the Scientific Collaboration Network Stability has a negative impact (H1) on scholars' academic performance is supported.

From Table 2, Model 3 adds Network Centrality (NC) on the basic model 1, the change of F Value shows significant ($p<0.01$), which means that Network Centrality has an explanatory meaning for the models. In addition, the increase of R squared value from 0.468 to 0.638 means that Network Centrality can produce 36.3% explanatory power for academic performance. And we also can know there is no multicollinearity between the independent variables (VIF<2.581). Specifically, the regression coefficient of network centrality is 1.257 and shows a significant ($p<0.01$), which means that Network Centrality has a significant positive impact on performance. H2 states that Network Centrality affects scholars' academic performance. Centrality has positive and significant ($P<0.01$) coefficient estimates in Model 3. The bottom panel shows that Centrality has a positive and significant ($p<0.01$) impact on the predicted mean counts. These findings are consistent with H2. That means the Scientific Collaboration Network Centrality has a positive impact (H2) on scholars' academic performance is accepted.

We add the interaction between NS and SH in Model 4. And we can know the change of F value show significant ($p<0.01$), which means that the interaction of NS and SH has an explanatory meaning for the model. Specifically, the interaction term's coefficient with network stability is -0.208 ($p<0.01$), achieving a significant level effect. This result shows that the Network Structure Hole (SH) has a negative moderating effect on network stability and academic performance, which is to confirm hypothesis H3 proposed in this study. H3 proposes a positive moderating effect of structural holes on the relationship between Stability and academic performance. The coefficient of interaction between Stability and Structural holes is negative and significant($p<0.01$) in model 4. The result shows the negative effect of stability on the predicted academic performance is more detrimental to a scholar with low levels of structural holes in its network than for a scholar with high levels of structural holes. The result largely supports H3 in this study.

## 5. Conclusion and Discussions

How does network stability affect academic performance? Consistent with much extant work, our baseline findings indicate that a scholar that spans structural holes reaps greater academic performance. However, in addition to the academic performance benefit provided by network structure configuration perse, we empirically disentangle the negative innovation implication of network stability and show how these effects are contingently influenced by network configuration, specifically, structural holes.

The results from this study found significant relationships between scientific collaboration networks and academic performance. It means the academic performance could come from scientific collaboration networks. If the scholar is successful in the collaboration network, they can promote academic performance.

### *5.1 Network Stability has a Negative Effect on Academic Performance*

In this research, we can know that in the case of a stable collaboration network, the beneficial effect of communication between researchers and the subsequent improvement of knowledge transfer efficiency in the collaborative network can successfully reduce the negative impact of stability to a certain extent, but it may not provide enough traction to construct the impact of network stability on innovation. In other words, the relationship between network stability and scholars' academic performance is most likely monotonically decreasing. That means Greater network stability of scholars is associated with reduced academic performance for the scholar.

### *5.2 Network Centrality has a Positive Impact on Academic Performance*

In this research, the empirical studies show that the higher the concentration index of scholars' scientific collaboration network, the more power the scholars' scientific collaboration network publishes information on specific members. However, social network research has found that the concept of knowledge innovation usually comes from the edge of the network, not the center or the upper level, that is, the organization is in an informal relationship, and the core of the network has the power to publish and share information. Because of the high degree of concentration, the network is more dispersed, and the transmission and exchange of information are concentrated on a small number of members. Therefore, the types of distributions of network marginal scholars will be wider, which will result in higher heterogeneity among network edge scholars. The empirical results show that the concentration of scientific collaboration network can significantly affect academic performance, that is, the positive relationship between scientific collaboration network concentration and academic performance, which is also the benefit that scholars can integrate into the more concentrated scientific collaboration network.

### *5.3 Network Structural Holes Reduces the Negative Impact of Stability on Academic Performance*

The empirical study shows that network stability has a detrimental effect on scholars' academic performance. The effect, taken together with the mitigating influence of structural holes spanned by the scholar, highlights the potentially opposing forces at play in assessing the value of networks. Bringing stability into the picture attenuates the academic performance of scholars in the scientific collaboration networks because of knowledge relational lock-in, and knowledge availability from the scientific collaboration network resources. However, when the scholar spans structural holes, it can limit the negative effects of stability.

## 6. Limitations

Any research has inexhaustible points or faces. This study is also true. Only by understanding the defects can we make up for these shortcomings in the future, make the research more perfect, and the conclusions are more reliable. The study has the following limitations:

First, this study only studies scholars in the field of "Leadership Behavior" in Chinese universities, which may affect the degree of universalization of the results of this study. Future research can be analyzed by other industries and for each sub-industry. Data are compared and analyzed to understand their differences;

Secondly, the performance of the research scholars is measured by the number of scholars' academic papers, the number of downloads, and the number of citations. Future research can be analyzed with more diverse subjective and objective indicators, and the conclusions obtained will be more reliable.

Thirdly, in this study, the scientific collaboration network between academic papers published by scholars is used to construct a scientific collaboration network, ignoring other forms of scientific research cooperation (such as patent cooperation, project collaboration, etc.), so the scientific collaboration network constructed is not comprehensive. In future research, we can build a scientific collaboration network from more levels and perspectives to further study its impact on academic performance.

Another interesting area for future research would be to examine how network stability, or the stability of a basic network building block, affects the stability of network structures and properties such as overall connectivity, and centrality. In other words, examining the link between local and global network stability may produce important insights if the effects are super-additive or substitutive.

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