

The Impact of Faculty Members' International Collaboration on the Centrality Measure of their Local Collaboration Network: The Case of Electrical and Computer Engineering in the Selected Iranian Universities

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ABSTRACT

The importance of scientific collaborations is mainly because of the professional learning obtained from the formation of research connections. Each researcher brings a feature and advantage to the research team, such as mastering a particular topic and its subdivisions or improving team thinking. The importance of collaboration is doubled when researchers collaborate at the international level, resulting in access to up-to-date resources and equipment, consequently increasing the quantity, quality, and impact of research activities. The primary purpose of this study is to investigate the effect of international collaboration of faculty members on the centrality of the university network collaborations, which measures how much a scientist is at the center of a local collaboration network. The data is taken from faculty members' publications in the electrical and computer engineering departments of the selected Iranian universities (the Isfahan University of Technology, Iran University of Science and Technology, Amirkabir University of Technology, University of Tehran, Ferdowsi University of Mashhad, and the Sharif University of Technology). Using multiple linear regression, the results show a twofold effect: The significant positive effect of having international collaboration on the centrality degree of scientists' network and the significant negative effect of the international collaborations over the total collaborations ratio on the centrality degree. This means that international collaborations of faculty members per se put them at the center of the university network. However, this positive effect turns negative if its weight is dominant compared to all publications. The finding highlights the importance of a balance between international and local collaborations.

Keywords: International research collaborations, Network analysis, Degree centrality, Betweenness centrality.

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INTRODUCTION

Scientists are generally interested in cooperation and collaboration because they acquire tacit knowledge, develop new skills, or access updated facilities. Scientific cooperation can lead to scientific production and the development of capability and competencies. Articles that two or more authors have co-authored may attract more attention than single-author papers.^[1] Hence it is possible to argue that scientific collaboration is an essential factor in the production of science. Sooryamoorthy^[2] shows that researchers who had more international collaboration have also published more single-author articles. Research collaboration also increases

scientists' visibility and consequently the likeliness of getting a citation.^[3]

Focusing on the increasing trend of joint scientific productions, quantitative analysis, and social network¹ indicators contribute to identifying a typical pattern in cooperation and collaboration. The social network analysis method is a sociological approach to analyze patterns of relationships and interactions between social entities to discover existing structures and know how content is transmitted between network actors.^[4-5] Co-authorship networks can illustrate changes in scientific interactions, knowledge sharing, and research communities.^[6] In recent years, using this approach

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1 It is worth mentioning that in this research, the social network does not mean web 2 networks such as Facebook, Twitter, etc., but networks that have existed for a long time and are based on various relationships and interactions in scientific collaborations.

in scientometric studies, the structure and features of the scientific network have been investigated.

This study aims to validate the effect of international cooperation on the centrality measures of faculty members' internal networks. The study is limited to the co-authorship network of researchers in the fields of electrical and computer engineering in selected Iranian universities that have a high rank in the number of published articles and the number of international collaboration (Isfahan University of Technology, Iran University of Science and Technology, Amirkabir University of Technology, University of Tehran, Ferdowsi University of Mashhad, and Sharif University of Technology). Using the results of this study, policymakers may understand the usefulness of international research collaboration to develop appropriate policies to expand this cooperation.

The remainder of the article is as follows: the theoretical framework is presented in Section 2; the data is described in Section 3; presenting econometric analysis and providing its empirical implications are done in Section 4; and finally, Section 5 provides a conclusion.

Theoretical Framework

In recent years, there have been a growing number of scientometric studies on collaboration and co-authorship patterns at the national and international levels. The studies provide evidence from different aspects like the trend of publication, collaboration pattern, and social network indicators analysis. It is possible to define the research collaboration and co-authorship as the participation of two or more authors in conducting research, leading to scientific production plausibly with a higher quantity or quality than when a scientist alone publishes a work.^[7] Co-authorship networks represent papers by nodes and then show co-authorships by connections between them. The study of such networks provides an insight into the social structure of research communities and shows which authors play a central role in the network communication process. In other words, instead of the features and characteristics of each person, social network analysis focuses on the relationships between people and their impact on each other.

One style to identify and analyze the position of influential writers is the holistic investigation, describing the characteristics of the entire network by indicators like graph diameter, mean node distance, number of components, cliquishness index, number of clusters, and local network structure. Another style is the approach of individual characteristics or micro-indices that examines the performance of each network node by looking into the position of actors, their distance, and position in the cluster.^[8]

One of the most important social network analysis measures that we consider in the present study is network centrality, which has different measures. The closeness centrality indicates how close one node is to other nodes in the network.^[8] The Closeness centrality of a node is equal to the inverse of the mean of the shortest path between the two nodes.^[9] Betweenness centrality represents the number of times that node is placed in the shortest path between the other two nodes in the network. High-betweenness nodes with a central location in the network play an important role in network connectivity and information flow.^[10] The betweenness centrality is calculated based on the position of each individual in the network. An individual has the most betweenness centrality, which is placed among groups of other nodes. The betweenness centrality in scientific maps indicates the value of the node. For example, if a node is a bridge between two unrelated clusters, that node has a very high betweenness centrality value. The rank or degree centrality is one of the simplest types of centrality indices that the value of each node is obtained by counting the number of its neighbors. This index is based on the edges and the weight of the edges that connect that node to other nodes.^[11]

The use of social network analysis indices to examine scientific collaboration networks was first used by Newman in computer science, physics, and biomedicine.^[4] After that, several studies provide social network analysis to describe the co-authorship network of authors in different fields and investigate the relationship with authors' performance in terms of scientific productivity and impact. The articles by Guns *et al.*, Hou *et al.*,^[12-13] and Yan *et al.*^[14] are just some examples.

In Iran, some studies on co-authorship networks have been conducted to identify the structure of scientific collaboration by different fields of knowledge.^[17] Notably, Hassanzadeh and Khodadoost (2012) analyzed the international co-authorship network of Iranian nanotechnology researchers and showed the centrality degrees. In another study, Zandian *et al.*^[18] concluded that there is a significant² network of scientific collaboration between Iranian medical researchers. In terms of country affiliation, Osareh *et al.*^[16] showed that Iranian scientists' most international research collaboration has been with researchers in the United Kingdom, the United States, and Canada. Looking into Iranian articles' impact, Tajedini *et al.*^[19] showed that the number of received citations increased by researchers' degree centrality and betweenness centrality. As the last example of Iran context, Soheili *et al.*^[17] showed that there is a significant relationship between the journal impact factor and all measures of centrality.

² In degree centrality, the network focus is equal to 0.573%, the betweenness centrality is 4.39% and the closeness centrality index or the mean node distance is equal to 40.382, which indicates that the network has a good condition.

A review of previous research shows that the linkages between international collaboration and characteristics of local co-authorship networks have not been studied yet. The present study aims to investigate these linkages. Electrical and computer engineering fields are selected as they have the most international collaboration.

Data

In terms of data, first, the names of the electrical and computer engineering faculty members in the mentioned universities were extracted. Using the Scopus database and its unique code of each author, a search based on the author's name was used to extract scientists' publication information. For 496 faculty members of electrical and computer engineering of selected universities, 33,103 articles were extracted with the desired organizational affiliations. We used VOSviewer software to cluster and visualize the data to draw the co-authorship network between the actors. The output sample of this software for all six universities is given in Figure 1. We also extracted the number of international research collaborations of faculty members. Finally, the output related to the network variables (degree centrality, closeness centrality, and betweenness centrality) will be extracted.

For this study, we run a regression analysis to understand the relationship between the output of the network analysis software and the number of international research collaborations. The left-hand side variable of the regression equation is the research collaboration network centrality measure. The primary explanatory variable is the number of international collaborations each scientist has. There are also some other control variables. The following formula describes our regression equation model:

$$CICent_i, BetCent_i, \text{ or } DegCent_i = f(NbIntColl_i, NbIntColl_i, IntallpropUniv_i)$$

The data list is provided in Table 1

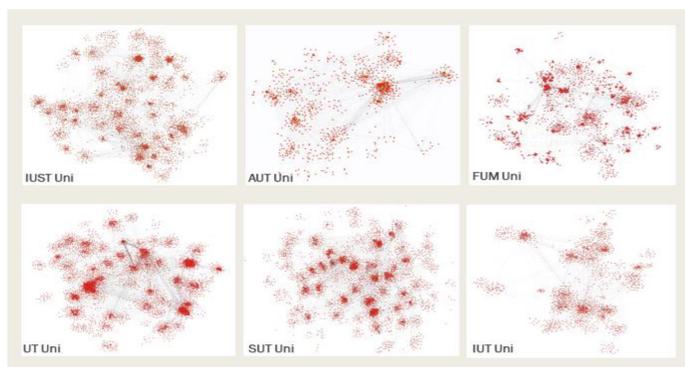


Figure 1: Collaboration network of six selected universities.

Table 1: Data list.

Data	Parameter
Total number of collaborations	NbIntColl _i
International collaborations	NbIntColl _i
The percentage of international collaborations	intallprop
Dummy variable of universities	dUniv _i
Closeness centrality	CICent _i
Betweenness centrality	BetCent _i
Degree centrality	DegCent _i

The index i represent the i^{th} researcher.¹

¹ Coll_i, for example, means the international collaboration of the i researcher.

Statistical Analysis

Previously, we argued that increasing the faculty members' number of international collaborations leads to capabilities such as forming new ideas, increasing the research quality, and access to equipment and resources of countries with advanced technologies. In addition to the expected higher research quality/quantity of scientists with international collaboration, other researchers may be interested in interacting with these scientists to achieve better research results. In other words, international collaboration is a competency index for faculty members that motivate other researchers to interact with them as local/internal collaboration. This would result in a more central position of faculty members with international collaboration in their university network. In the following, we examine the effect of international collaboration size on the formation of local research collaboration networks, measured by degree centrality and betweenness centrality. It should be noted that explanatory variables do not significantly explain closeness centrality.

Degree Centrality

The degree centrality helps analyze the overall structure of networks and the place of individuals in the network, which reflects an individual's reputation and relationship activity. In a graph, the degree centrality calculates the number of connections of a node with other people in the network. Table 2 shows the regression equation's estimation, which shows a positive and significant effect of international collaborations on degree centrality. This would imply the importance of faculty members with international collaboration in the internal network, increasing the motivation of other researchers to interact with them.

In addition to the number of international collaborations, the weight of these collaborations is also examined in this study. For faculty members to be at the center of the internal network, the number of international collaborations and

Table 2: Regression results of degree centrality.

Variable	Reg1	Reg2	Reg3
Constant	19.07143*** (14.61)	28.3194*** (19.79)	32.65922*** (13.36)
Number of international collaboration	1.253235*** (22.34)	1.456398*** (27.24)	1.432581*** (26.72)
intallprop		-55.20649*** (-11.15)	-50.43642*** (-9.94)
daut			.9258991 (0.29)
dferdowsi			-8.448858* (-2.42)
disfahan			-12.70366*** (-3.57)
dsharif			-8.571138*** (-2.77)
dtehran			-3.313692 (-0.99)
Number of obs	469	495	495
Prob>f	0.0000	0.0000	0.0000
R-squared	0.5026	0.6025	0.6222

*, **, and *** show the significance level at 0.05, 0.02, and 0.01 respectively.

the total number of collaborations must be high; this means that high international collaborations will have a positive effect when the total number of collaborations is also high. The coefficients of university dummy variables also show the university fixed effect.

Betweenness Centrality

The betweenness centrality for one specific node is the number of shortest paths between every two other nodes that include the specific node. Scientists with a high betweenness index can mediate communication between other nodes. Our regression results in Table 3 indicate that the effect of international collaborations on the betweenness centrality is positive and significant. This means that faculty members collaborating with scientists in other countries are generally placed in the shortest path between other researchers in the internal network. Similar to degree centrality, the portion of international collaborations in total collaboration is important in this effect. If this portion is low, the scientist moves away from the center of the network. In addition, the dummy variables of Amir Kabir University of Technology, Ferdowsi University of Mashhad, Isfahan University of Technology, Sharif University of Technology, and Tehran Universities are significant, indicating that there is university fixed effect.

DISCUSSION AND CONCLUSION

International collaborations of faculty members positively affect the degree centrality and betweenness centrality. However, the results indicate that if the number of international collaborations considers as a small portion of the total collaborations of faculty members, the international collaborations result in a lower betweenness and degree centrality. The findings of this study are consistent with the study of Erfan Manesh and Arshadi, Bashiri and Gilori, and Asadi *et al.*,^[20-22] who highlighted the importance of international co-authorship in the Iran context.

A recent review of the international collaborations of Iranian faculty members shows that the number of international collaborations is relatively lower than the number of domestic collaborations. Most of them are done at Tehran University and Sharif University of Technology. These collaborations have an increasing trend in other universities, as discussed in Riahi and Ghani Rad and Mardani *et al.*^[23] Their findings show that the trend of international co-authorship of faculty members and the willingness of researchers to collaborate in international research has been increased. Aytac^[24] also showed that international scientific collaborations grew significantly among the 50 under study countries. In terms of research output, the results of this study are consistent with findings by Hu *et al.* and Soheili *et al.*,^[17] who showed that there is a positive and significant correlation between researchers'

Table 3: regression results of betweenness centrality.

Variable	Reg1	Reg2	Reg3
Constant	10159.7*** (3.21)	17480.97*** (4.54)	49605.83*** (7.71)
Number of international collaboration	822.895*** (6.04)	984.3385*** (6.85)	919.607*** (6.52)
intallprop		-4378.27*** (-3.29)	-35174.29*** (-2.64)
daut			-35669.88*** (-4.24)
dferdowsi			-48092.4*** (-5.23)
disfahan			-49406.43*** (-5.28)
dsharif			-45637.42*** (-5.60)
dtehran			-22319.49*** (-2.54)
Number of obs	496	495	495
Prob>f	0.0000	0.0000	0.0000
R-squared	0.0689	0.0877	0.1715
Adj R-squared	0.0670	0.0850	0.01596

*, **, and *** show the significance level at 0.05, 0.02, and 0.01.

outputs (in terms of quality and quantity) and centrality measures.

Some of the policies related to the development of science in the country through international interactions are the following: (1) facilitating the presence of researchers in prestigious international conferences, (2) supporting sabbatical opportunities, and (3) offering courses with prestigious universities around the world. In addition, to strengthen the use of academic trips of university faculty members, they may be asked to supervise some theses and dissertations jointly with other researchers abroad.

However, according to the results of this study, domestic and international interactions are simultaneously effective on the position of scientists in the network. Hence, policymakers are advised not to only focus on strengthening international interactions. In the promotion process, policymakers are required to consider more research points for those researchers who simultaneously advance their collaborations with researchers from the world's top universities and domestic researchers.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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