Does the superior position of countries in co-authorship networks lead to their high citation performance in the field of nuclear science and technology?

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ABSTRACT

The objective of this research was to determine the macro-topological structure and the relationship between citation performance and centrality measures of co-authorship social networks of countries in the field of Nuclear Science and Technology from 2008 to 2010. The present study applied the network analysis method in order to visualize co-authorship networks. Hypothesized relationships were tested using the authors of 24,308 documents cited in the Web of Science. Data relevant to citation performance of a country was based on the articles published by the researchers of the country in a three-year period and the citation data of articles were collected two years after their publication. The investigation of co-authorship social network in the field of Nuclear Science and Technology revealed that the countries which are members of a Nuclear Club hold a prominent position in the network and their influence or power in the network is greater than other countries. Having characteristics like short mean path length, low network diameter (less than or equal to 6) and relatively high clustering coefficient, this network is regarded as a Small World Network. The results of testing the research hypotheses indicated that as the value of centrality of countries rise, the citation performance of researchers in that country is also improved. The analysis of variance confirmed the validity of stepwise regression analysis in predicting the citation performance of researchers (F=816.958 and p>0.000) and through three steps, three components including degree centrality, beta centrality and flow betweenness centrality were concluded to have multiple correlation with citation performance of researchers.

Keywords: Research impact; Citation performance; Centrality indicators; Nuclear Science and Technology; Co-authorship networks; Macro-topological structure; Social network analysis (SNA).

INTRODUCTION

One of the most important factors of a country's development is conducting worldwide collaborative research. International collaboration, as the most extensive form of scientific collaboration, is a method to enhance the scientific performance of developing countries. This does not only improve the research by more extensive researches, facilities and

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technologies, but also results in the dynamicity of researchers by letting them exchange experiences, skills and expertise (Gazni, Sugimoto and Didegah 2012). Moreover, investments in high-tech, particularly in nuclear science and technology, are required for scientific development since producing value-added services and products in this industry at the international level is greatly under the influence of these technologies. Manufacturing units based on the mentioned technologies can produce very expensive products with a limited number of skilled and experienced people, as they are highly knowledgeable and are consistent with knowledge and experience more than anything. According to the development of science and scientific fields, scientific cooperation seems to be able to open new insights for the researchers and scholars. Definitely the benefits of scientific collaboration and cooperation cannot be dismissed and since one person is not able to do research in all scientific fields to find the solution to all relevant issues, it is necessary to utilize the ideas of experts in those fields (Davarpanah and Aslekia 2008).

Co-authorship is the product of scientific cooperation (Kumar 2015). Whenever an author publishes a co-authored paper, he/she actually creates a co-authorship network. Co-authorship network is a class of social networks also known as scientific cooperation network (Inkpen and Tsang 2005; Ponomariov and Boardman 2016). The existing evidence reveals a significant relationship between team cooperation and quality of scientific works. In this regard, as team cooperation among researchers is increased, the quality of their scientific works will be improved (Dehdarirad and Nasini 2016). However, scientific cooperation is not an indicator of research quality; rather it is a means to achieve the quality (Li, Liao and Yen 2013).

Research impact is the recorded or auditable occasion of the influence of a research on actors of the society (Public Policy Group 2011). In an academic context, research impact usually refers to the number of citations a researcher receives (Bornmann, Mutz and Daniel 2008). Studies have indicated that scientific collaboration would result in a higher research impact for the collaborative authors (Sooryamoorthy 2009; Abbasi, Altmann and Hwang 2010; Liao 2010; Bordons et al. 2015; Wang and Shapira 2015). This is possibly since a single author is not able to provide sufficient resources to carry out his/her research (Kling and McKim 2000). A researcher can share resources such as tools and equipment, workload, expertise and knowledge with other researchers through research cooperation (Katz and Hicks 1997; Lee and Bozeman 2005; Abramo, D'Angelo and Solazzi 2011).

Counting the number of citations is an important factor of research impact provided by the global citation databases such as the Web of Science and Scopus (Abbasi, Altmann and Hossain 2011). This factor is widely used to evaluate papers, journals, institutions and people (Biscaro and Giupponi 2014; Brown and Gardner 1985). In co-authorship social networks, centrality is an important structural feature representing the official power or priority of one actor over other actors in the network (Badar, Hite and Badir 2012). There are several measures for centrality including degree centrality, closeness centrality, betweenness centrality, eigenvector/eigenvalue centrality, flow betweenness, beta centrality, information centrality and reach centrality (Yan and Ding 2009).

Degree centrality is defined as the number of direct connections a particular actor or node has with other actors irrespective of the strength of the connections. Each direct connection is regarded as a unique co-authorship. Therefore, being a central author with high degree centrality means that the researcher has collaborated with many colleagues (Koseoglu 2016; Otte and Rousseau 2002). *Closeness centrality* is the mean shortest distance of a particular actor from other nodes in the network. In a co-authorship network, a high closeness for a researcher means that he/she can have a better access to the required resources belonging to other people in the network. *Betweenness centrality* is the proportion of the shortest paths among all pairs of nodes that would pass through a given actor (Borgatti 2005). The betweenness centrality of an actor reveals his/her ability to control the flow of resources or information in the network enabling him/her to broker resources and information to other actors (Freeman 1979; Abbasi, Hossain and Leydesdorff 2012). Therefore, high betweenness centrality for an author means that he/she plays the role of middleman or bridge and can obtain various resources or information from different groups in co-authorship network (Lu and Feng 2009). *Flow betweenness* is a measure of the extent to which the flow between other pairs of actors in the network is reduced if a particular actor is removed, hence, measuring the contribution of an actor to the maximum flow possible in the network (Zemljic and Hlebec 2005). Flow betweenness develops the concept of betweenness in two aspects (Lulli et al. 2015; Freeman 1979). First, flow betweenness takes into consideration all relationships between actors not just the geodesic ones (the shortest path between two actors) since there might be lot of other longer paths. Second, while betweenness divides the nodes into two sections, flow betweenness takes into account valuable relationships with high values indicating stronger ties. The point with the highest eigenvector is the one with many central neighbors. In fact, higher eigenvector centrality would lead to more strength (Jain and Reddy 2015). *Information centrality* measure investigates the possibility of transferring information and knowledge through different paths. This measure is calculated based on the strength and degree of nodes and their distance. In other words, this measure assesses the transfer of information between two points in the network (Stephenson and Zelen 1989). *Reach centrality* provides the answer to the question that what extent or percentage of nodes in a network is able to reach a node in the network step-by-step through first, second, third and other steps (Soheili and Mansoori 2014). If an actor has a central position in the network, it has a great number of connections with other actors and occupies a significant strategic position in the overall structure of that network (Troshani and Doolin 2007).

In a co-authorship context, the country having many connections with other countries through scientific outputs of its researchers is able to receive more information, knowledge and resources. The works published by these researchers are expected to have higher quality and consequently, receive more citations from other researchers. Thus, it is predicted that the countries having an extensive connection with other countries in a co-authorship network can gain advantage and receive more citations. The main objective of this study is to determine the macro-topological structure of co-authorship social network of countries in the field of nuclear science and technology. A review of the previous research conducted on the topic by means of social network analysis shows that researchers have employed the micro-level for their analysis. The present study favors a macro-level analysis since the theory of social capital acquired from the social networks, including co-authorship networks, and measurement criteria can have compatibility with the analysis at the micro-level. The functions and analysis of social capital at the macro-level are compatible with the network analysis at the micro-level (Lin 2008). Thus, individual and collective social capital will have theoretical and methodological coherence at the levels of analysis though the network analysis at the collective level needs further details and elaboration. A group can be considered as a nod in a given social network with the members (nods) bringing sources as the social capital gained from this group will reflect itself in the sources provided by each member of the group (Rouxel et al. 2015). The field of Nuclear Science and Technology holds a different nature as opposed to other fields simply because this area has very strategic aspects in many countries. It might be also probable that the structure of co-authorship network and social capital obtained from this network might differ from other areas of science. There has been a dearth research into this topic in the area of basic sciences; thus, there exists an urgent need to investigate such issues.

OBJECTIVE AND METHOD

The present study uses bibliometrics and applies network analysis method in order to visualize co-authorship networks and answer the following research question: “What is the macro-topological structure of co-authorship social network of countries in the field of nuclear science and technology?” Lancaster describes bibliometrics as the study of relationship patterns of authors, publications and texts by means of different statistical analysis methods (Baker and Lancaster 1991). The research has the following two hypotheses:
Hypothesis 1: In the co-authorship social network structure, in the field of nuclear science and technology, there is a positive and significant relationship between centrality of a country and citation performance of researchers of that country.
Hypothesis 2: In the co-authorship social network structure, in the field of nuclear science and technology, there is a multiple relationship between centrality of a country and citation performance of researchers of that country.

Social network analysis is a set of developed analytic tools to analyze relational structure and its impacts on individual behaviors and systemic performance (Marin and Wellman 2011). It is a powerful diagnostic method to analyze the nature and pattern of relationships among the members of a particular group and includes a set of graph analysis methods developed to analyze the networks in social sciences, communication studies, economics, political sciences, computer networks and etc. The popularity of social network analysis is to a great extent is the result of the great capacity of modeling and real world analysis of complicated network systems like scientific cooperation networks (Albert, Jeong and Barabasi 1999; Scott 2012).

Generally, in network analysis method the attention is concentrated on the form and content of relationships and the way they are arranged. For instance, if the relations between government and people are considered, the researcher will pay attention to the form of these relations, their content, the strength or weakness of connections and if they are symmetrical or not based on the theoretical framework. Thus, in network analysis method, relational data are emphasized (D'Angelo and Ryan 2016). In network analysis, the form and content of the relationship between nodes is more important than the characteristics and attributes of the actors (Homolová 2014). A number of studies in social network analysis focus on morphological analysis of the network, the investigation of structural features of nodes and their relationships and how the network topology would influence the structures, the behavior of members of the network and the entire network (Albert and Barabasi 2002).

The statistical population of this research consists of those international scientific productions including article, meeting abstracts, proceedings papers, reviews and software reviews cited in Science Citation Index Expanded (Clarivate Analytics’ Web of Science) from 2008 to 2010. After deleting the Editorial, Letter and Correction from *document types* due to their single-authored nature, 24,308 documents form the population of this study.

Data collection was carried out through several stages. First, to collect data from Web of Science, the following formula was used in the *advanced search* option:
WC= (Nuclear Science & Technology) DocType=All document types; Language=All languages Indexes=SCI-EXPANDED Timespan=2008-2010

Next, document types including Article, Meeting Abstract, Proceedings Paper, Review, and Software Review, which are considered as scientific productions and are referred to as articles in this research, were saved as Plain Text (500-item records in full records). Data were saved as a single file. Thereafter, preprocessing was run on saved data to detect and correct repeated and wrong cases, as well as different spellings of the same items.

In the next stage, a design was proposed to create relation matrices in this study to be used as inputs for UCINET (Borgatti, Everett and Freeman 2014). Each cell of the relation matrix represents the number of cooperation between each two determined nodes (researcher/country/organization). The co-authorship of countries was obtained via Bibexcel Software (Persson 2017). Weighted matrix was utilized in this research since not only the relationship or lack of relationship between researchers and countries in the field of nuclear science and technology was investigated, but also the number of repetition of relationships between countries was required.

In order to measure citation performance of researchers of each country, the effect of a two-year delay after publishing an article was taken into account because the citations an article receives are usually few during the first years of publication. In citation studies, the period of two years is usually taken as an interval to receive citations. In Journal Citation Reports (Web of Science), also a two-year period is considered to investigate the number of citations given to articles.

Data related to citation performance of a country was collected from the articles published by the researchers of that country in a 3-year period and citation data of the article were collected two years after its publication. For instance, if an article was published in 2008, its citation data were collected from 2010 and later. The results of the previous studies revealed that a significant bibliometric research must at least take a three-year window as the citation period (van Raan 2006). Thus, a three-year citation period was set in the present research. Table 1 presents the citation period from 2008 to 2010.

Table 1: Citation Window for Articles in Nuclear Science and Technology

Time period	Year	Citation window (three years)
2008-2010	2008	2010-2012
	2009	2011-2013
	2010	2012-2014

The number of citations were collected from the Science Citation Index Expanded since it provides the experience of an author and his/her publications as well as all citations given to each of his/her publications. Nevertheless, the citation data in Science Citation Index Expanded also include self-citations leading to bias in estimating the influence of research impact of an article (Nederhof 2006). To prevent such biasness in this research, the citations given to each article in a three-year period were manually counted, excluding self-citations. Each citation from an author or his/her co-authors in an article was regarded as self-citation and was subtracted from the number of citations. Thus, the citation performance of a researcher was obtained by subtracting the number of self-citations from the total number of citations obtained by articles published by that author in the citation window.

RESULTS

The co-authorship network of countries in the field of Nuclear Science and Technology consists of 116 nodes and 3502 ties: nodes represent countries and ties connect countries in the form of co-authorships. The size of a node is proportional to the number of co-authorships of that country (Figure 1). The scientific output and citation performance of countries prominent in the field of nuclear science and technology are presented in Table 1. As depicted in Table 1, the United States of America, Germany and Japan had the highest number of documents with 4736, 2740 and 2693 documents, respectively. Moreover, the United States of America, Germany and France received the highest number of citations with 22015, 12003 and 10270 citations, respectively.

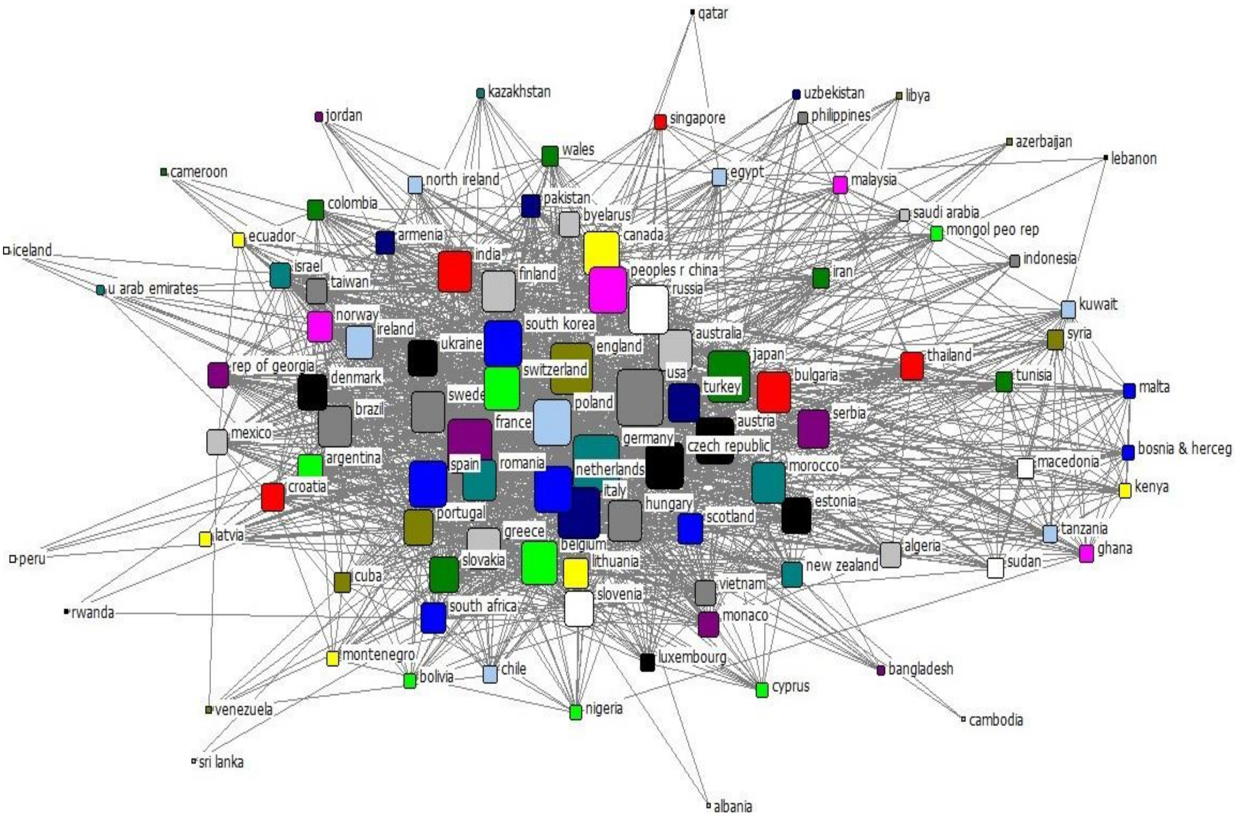

Figure 1: The Co-Authorship Network of Countries in Nuclear Science and Technology (main component)

Table 1: Scientific Output and Citation Performance of Countries

Country	Scientific output		Citation performance		Country	Scientific output		Citation performance	
	N	%	N	%		N	%	N	%
USA	4736	14.2184	22015	16.8294	**Turkey**	433	1.2999	1780	1.3607
Japan	2740	8.2260	8789	6.7188	**Iran**	369	1.1078	1118	0.8547
Germany	2693	8.0849	12003	9.1757	**Austria**	318	0.9547	1613	1.2331
France	2077	6.2356	10270	7.8509	**Hungary**	303	0.9097	1263	0.9655
Italy	1884	5.6561	6463	4.9406	**Finland**	298	0.8947	1127	0.8615
Peoples R China	1658	4.9776	5740	4.3879	**Taiwan**	290	0.8706	791	0.6047
Russia	1505	4.5183	3776	2.8866	**Australia**	266	0.7986	1563	1.1948
South Korea	1419	4.2601	3687	2.8185	**Egypt**	250	0.7505	692	0.5290
UK	1259	3.7798	5179	3.9591	**Portugal**	248	0.7445	1065	0.8141
India	1185	3.5576	4178	3.1939	**Romania**	244	0.7325	835	0.6383
Switzerland	890	2.6720	3953	3.0219	**Greece**	215	0.6455	749	0.5726
Ukraine	856	2.5699	924	0.7064	**Pakistan**	207	0.6215	545	0.4166
Spain	759	2.2787	3047	2.3293	**Mexico**	182	0.5464	659	0.5038
Canada	658	1.9754	2979	2.2773	**Slovenia**	156	0.4683	620	0.4740
Belgium	579	1.7383	2970	2.2704	**Serbia**	149	0.4473	474	0.3623
Czech Republic	494	1.4831	1932	1.4769	**Israel**	138	0.4143	601	0.4594
Poland	478	1.4350	2020	1.5442	**Argentina**	128	0.3843	505	0.3860
Sweden	468	1.4050	2264	1.7307	**Denmark**	110	0.3302	960	0.7339
Netherlands	468	1.4050	2930	2.2398	**South Africa**	107	0.3212	382	0.2920
Brazil	464	1.3930	1259	0.9624	**Turkey**	433	1.2999	1780	1.3607

The values of indicators in co-authorship network of countries in the field of nuclear science and technology are depicted in Table 2. As shown in Table 2, the co-authorship network of countries in the field of nuclear science and technology from 2008 to 2010 consisted of 116 nodes and 3502 ties. Network density was 0.263, number of components in the network was 5 and proportion of the largest component to total number was 0.966. Furthermore, mean path length of the network was 1.833. The value of separation measure was 0.068, network concentration was 0.450, network diameter or the distance between the furthest nodes in main component was 4, connection indicator was 0.932 and clustering coefficient was 0.380.

Table 2: The Topological Structure of Co-Authorship Network of Countries in the Field of Nuclear Science and Technology

Number of nodes	116
Number of ties	3502
Density of network	0.263
Number of components (parts)	5
Number of nodes in main component	112
Proportion of nodes in the largest component to the total number of nodes	0.966
Mean path length of the network	1.833
Network separation	0.068
Clustering coefficient	0.380
Network diameter	4
Network concentration	0.450
Network connection	0.932

Hypothesis 1: There is a positive and significant relationship between centrality of a country and citation performance of researchers of that country.

As presented in Table 3, the level of significance for all variables was lower than the statistical value determined in the present study ($p<0.05$). Therefore, the first hypothesis is confirmed, i.e. as the value of centrality of countries gets higher, the citation performance of the researchers of that country is also improved.

Table 3: Correlation between Centrality of Countries and Citation Performance of Researchers in the Field of Nuclear Science and Technology

Time period	Type of centrality	The citations received in countries		Relationship	Type of relationship
		Pearson correlation			
		Correlation (r)	P		
2008-2010	Reach	.477**	.000	Exists	Positive
	Betweenness	.730	.000	Exists	Positive
	Flow betweenness	.774**	.000	Exists	Positive
	Eigenvector	.774	.000	Exists	Positive
	Beta	.887**	.000	Exists	Positive
	Information	.243	.008	Exists	Positive
	Closeness	495**	.000	Exists	Positive
	Degree	761**	.000	Exists	Positive

Hypothesis 2: There is a multiple relationship between centrality of a country and citation performance of researchers of that country.

As shown in Table 4, based on stepwise regression analysis, through three steps, degree centrality, beta centrality and flow betweenness centrality were of multiple correlation with citation performance of researchers, while other variables had insignificant correlation and were removed from the equation. According to the importance of predictor variables in stepwise regression analysis, in the first step, the correlation coefficient between degree centrality variable and citation performance of researchers was 0.899. In the second step, by adding beta centrality variable, the multiple correlation coefficient became 0.973 and the value of correlation coefficient added by beta centrality was 0.074. In the third step, by adding flow betweenness centrality variable, multiple correlation coefficient became 0.979. The value of correlation coefficient added by degree centrality was 0.006.

Table 4: Correlation Coefficients, Squared Multiple Correlation Coefficient and Adjusted Correlation Coefficient between Centrality Measures and Citation Performance of Researchers

Predictor variables	**Correlation coefficient**	**Squared multiple correlation coefficient**	**Adjusted correlation coefficient**	**Estimated standard error**
Degree centrality	.899[a]	.808	.806	1247.54686
Beta centrality	.973[b]	.946	.945	663.37048
Flow betweenness centrality	.979[c]	.958	.957	590.64239

According to Table 5, the analysis of variance confirmed the validity of stepwise regression analysis in predicting the citation performance of researchers (F=816.958 and p>0.000). In other words, independent variables were appropriate variables to explain the changes in citation performance of researchers.

Table 5: Analysis of Variance for Multiple Stepwise Regression of Centrality Measures with Citation Performance of Researchers

Model	**Sum of squares**	**Degree of freedom**	**Mean of squares**	**F**	**Level of significance**
Regression	855008476.679	3	285002825.560	816.958	.000[c]
Residual	37676711.000	108	348858.435		
Total	892685187.679	111			

As depicted in Table 6, in the final stepwise regression analysis, three variables including flow betweenness centrality, beta centrality and degree centrality were entered into the regression equation to predict the citation performance of researchers. In this regard, beta centrality variable with standardized beta coefficient of 0.518, degree centrality with standardized beta coefficient of 0.400 and flow betweenness centrality with standardized beta coefficient of 0.179 had significant predictive power for citation performance of researchers (p>0.0001).

Table 6: Standardized and unstandardized regression coefficients of centrality measures with citation performance of researchers

Model	**Unstandardized beta coefficients**		**Standardized beta coefficient**	**t value**	**Level of significance**
	B	Std. Error	Beta		
Constant	-72.380	66.875		-1.082	.282
Degree centrality	1.958	.189	.400	10.367	.000
Beta centrality	.007	.000	.518	19.048	.000
Flow betweenness centrality	2.911	.536	.179	5.431	.000

DISCUSSION AND CONCLUSION

The density of co-authorship networks of countries in the field of nuclear science and technology revealed that from 2008 to 2010, 26.3% of all potential relationships among countries, whether strong or weak, were realized. In a co-authorship network, it is not unusual to observe a large co-authorship network with low density. In fact, based on the studies carried out by Baker (2000), network density has an inverse relationship with network size –calculated by the number of nodes and relationships among them. In other words, the network nodes not only increase the number of potential ties but also result in a low density in the network. However, the investigation of density indicator in co-authorship network of countries in the field of nuclear science and technology demonstrated that as the number of co-authored articles rises, the density of co-authorship network is also increased. In this time period, more than one-fourth of the whole potential relationships of the network were realized, which indicates the relations between different countries and high cohesion of co-authorship network of countries in the field of nuclear science and technology. The value of co-authorship network density of countries in the field of nuclear science and technology was higher than that of Latin American Countries in management; in the research by Ronda-Pupo (2015), the density of co-authorship network of these countries in the field of management was 10.8.

In co-authorship networks, low density might suggest network separation, which is resulted from the cooperation of researchers with a limited number of co-authors or the repetition of their cooperation with the same people. This interpretation of network density is at first shown by network separation indictor. This value was 0.068 in the time period of 2008 to 2010. It means that from 2008 to 2010, 6.8% of nodes (countries) in co-authorship social network in the field of nuclear science and technology were disjoint. Low value of network separation indicator reveals the variety of scientific relations among countries in the field of nuclear science and technology. It is proved by the small number of isolated countries in co-authorship network in this field; only four countries including Uruguay, Namibia, Madagascar and Ethiopia were isolated countries in this period.

Investigating the components of co-authorship network of countries in the field of nuclear science and technology indicates that this network, like many other social networks, consists of one main component and a number of small components. Small components of the network are usually created by the distance between countries with low degree centrality and countries with high degree centrality due to geographical isolation. In other words, since it is not possible for the researchers of some countries to co-author with the researchers of prominent countries with high production, they do intra-country cooperation and hence, will not be connected to the main component in co-authorship network. In this time period, the main component contains 97% of nodes of co-authorship network of countries in the field of nuclear science and technology. The results of this research were compatible with those of other fields like biology, physics and mathematics (Newman 2004) in which the largest component contained 82-92% of the nodes. The results of this research were, nevertheless, significantly different from the results of some other fields like education and training in which the largest component occupied 3% of the network (Wang et al. 2014). Kretschmer (2004) stated that the main component usually contained about 40% of the whole nodes of the network. The countries regarded as main component, which are supposed to encompass a high percentage of nodes of the network, usually play the pivotal role in productivity (the number of scientific outputs) in co-authorship network. Most countries, which hold a relatively great number of ties with others, are usually in the center of the main component of co-authorship network and most of these countries are members of nuclear club.

Co-authorship social network concentration indicator (0.450) reveals the growing reliance of network on one or more key countries in co-authorship network of countries i.e. countries with high degree centrality are of paramount importance in this network.

Mean path length in co-authorship network of countries in the field of nuclear science and technology was 1.8, which was less than six degrees of separation; number six was derived from mathematical calculations. Watts (2003) argued that rather than an arbitrary number, number 6 is a mean (Wang et al. 2014). Mean path length in co-authorship network in the field of nuclear science and technology was shorter than in Biology with 4.6 steps, Scientometrics with 5.8 steps, Physics with 5.9 steps and Mathematics with 7.6 steps (Newman 2004). Short path length would lead to fast information flow in the network since fewer resources (including fewer number of countries and less time) are used to share and exchange information. According to Ye, Li and Law (2013), although adding new nodes to the network and connecting them to the main component via one or more ties is inevitable, certain costs like the increase in average distance and network density are imposed to the network resulting in reduction of network density and cohesion as time goes by. Therefore, it is crucial to strengthen the connections among new, old and key nodes (countries) so as to optimize the network.

According to what was said above, the co-authorship network of countries in the field of nuclear science and technology is a kind of Small World Network with characteristics like short mean path length, low network diameter (less than or equal to 6) and relatively high clustering coefficient. Small World Network is a social network in which most nodes are not directly connected to each other but are accessible through a chain of co-authorship connections and by passing a short path (Watts and Strogatz 1998). In other words, in Small World Networks, despite the expansion of the network and entrance of new nodes, the connections among nodes are still strong and their distance remains short.

The investigation of co-authorship social network in the field of nuclear science and technology indicated that the position of countries which are members of nuclear club is a prominent one and their influence or power in the network is greater than other countries. The influence or power in the network is regarded as an indicator of the control of one actor over other actors and is a concept which is increased or decreased as per the position and connections of each node in the network as well as restrictions or opportunities provided for the node. As the node is encountered with fewer restrictions, its opportunities are increased and it occupies a more desirable position in the network and becomes stronger and more powerful (Brandes and Erlebach 2005).

The results of testing research hypothesis showed that as the value of centrality of countries rises, the citation performance of researchers in that country is also improved. The results of this research were compatible with those of the research by Ronda-Pupo (2015), revealing that there was a significant and positive relationship between centrality of Latin American Countries and their citation performance. The theoretical explanation for this behavior is found in absorptive capacity theory. Tsai (2001) demonstrated that high centrality in the network would lead to a high absorptive capacity. In co-authorship network of countries in the field of nuclear science and technology, the countries which were members of the network would benefit from the research capacity of countries with high centrality. Thus, countries that are more central are considered as a bridge to let other countries into research cycle in the field of nuclear science and technology and devise a penetration strategy to develop their social capital. Li, Liao and Yen (2013) revealed the importance of using social networks to develop social capital of researchers and the positive reaction of network to their citation performance.

In order to analyze multiple relationship between different kinds of centrality measures and citation performance of researchers of countries, stepwise regression was adopted. Through three steps, degree centrality, beta centrality and flow betweenness centrality were of multiple correlation with citation performance of researchers of countries in the field of nuclear science and technology. In the first step, the correlation coefficient between degree centrality variable and citation performance of researchers was 0.899. In the second step, by adding beta centrality variable, the multiple correlation coefficient became 0.973 and the value of correlation coefficient added by beta centrality was 0.074. In the third step, by adding flow betweenness centrality variable, multiple correlation coefficient became 0.979. The value of correlation coefficient added by degree centrality was 0.006. The analysis of variance confirmed the validity of stepwise regression analysis in predicting the citation performance of researchers ($F=816.958$ and $p>0.000$). Beta centrality variable with standardized beta coefficient of 0.518, degree centrality with standardized beta coefficient of 0.400 and flow betweenness centrality with standardized beta coefficient of 0.179 had significant predictive power for citation performance of researchers ($p>0.0001$). The observed beta value indicates that the three variables of beta centrality, degree centrality, and betweeness centrality are as the predictive flow of the criterion variable (citation performance), and each of the three variables explains the changes of the criterion variable. This means that with a unit of change in the value of the three variables, the citation performance increases and changes as much as 0.979. Moreover, the calculated "T value" of these three steps is greater than the critical value, and this value is significant at the level of One percent.

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REFERENCES

Abbasi, A., Altmann, J. and Hwang, J. 2010. Evaluating scholars based on their academic collaboration activities: Two indices, the Rc-index and the Cc-index, for quantifying collaboration activities of researchers and scientific communities. *Scientometrics,* Vol. 83, no. 1: 1-13.

Abbasi, A., Altmann, J. and Hossain, L. 2011. Identifying the effects of co-authorship networks on the performance of scholars: A correlation and regression analysis of performance measures and social network analysis measures. *Journal of Informetrics,* Vol. 5, no. 4: 594-607.

Abbasi, A., Hossain, L. and Leydesdorff, L. 2012. Betweenness centrality as a driver of preferential attachment in the evolution of research collaboration networks. *Journal of Informetrics,* Vol. 6, no. 3: 403-412.

Abramo, G., D'Angelo, C.A. and Solazzi, M. 2011. Are researchers that collaborate more at the international level top performers? An investigation on the Italian university system. *Journal of Informetrics,* Vol. 5, no. 1: 204-213.

Albert, R., and Barabasi, A. L. . 2002. Statistical mechanics of complex networks. *Review of Modern Physics,* Vol. 74, no. 1: 47-97.

Albert, R., H. and Barabasi, A. 1999. Internet: The diameter of the world wide web. *Nature,* Vol. 401: 130-131.

Badar, K., Hite, J. and Badir, Y. 2012. Examining the relationship of co-authorship network centrality and gender on academic research performance: The case of chemistry researchers in Pakistan. *Scientometrics,* Vol. 94, no. 2: 755-775.

Baker, S. L., and Lancaster, F.W. 1991. *Measurement and evaluation of library services.* Arlington, VA.: Information Resources Press.

Baker, W.E. 2000. *Achieving success through social capital: Tapping the hidden resources in your personal and business networks*. Vol. 9: Jossey-Bass San Francisco, CA.

Biscaro, C. and Giupponi, C. 2014. Co-authorship and bibliographic coupling network effects on citations. *PloS one,* Vol. 9, no. 6: e99502.

Bordons, M., Aparicio, J., González-Albo, B. and Díaz-Faes, A.A. 2015. The relationship between the research performance of scientists and their position in co-authorship networks in three fields. *Journal of Informetrics,* Vol. 9, no. 1: 135-144.

Borgatti, S., Everett, M.G. and Freeman, L.C. 2014. Ucinet. In *Encyclopedia of Social Network Analysis and Mining*. Springer.

Bornmann, L., Mutz, R. and Daniel, H.D. 2008. Are there better indices for evaluation purposes than the h index? A comparison of nine different variants of the h index using data from biomedicine. *Journal of the American Society for Information Science and Technology,* Vol. 59, no. 5: 830-837.

Brandes, U. and Erlebach, T. 2005. *Network analysis: methodological foundations*. Vol. 3418: Springer Science & Business Media.

Brown, L.D, and Gardner, J.C. 1985. Using citation analysis to assess the impact of journals and articles on contemporary accounting research (CAR). *Journal of Accounting Research,* Vol. 23, no. 1: 84-109.

D'Angelo, A. and Ryan, L. 2016. *Social network analysis: a mixed method approach*. In: An End to the Crisis of Empirical Sociology? Routledge.

Davarpanah, M.R. and Aslekia, S. 2008. A scientometric analysis of international LIS journals: Productivity and characteristics. *Scientometrics,* Vol. 77, no. 1: 21-39.

Dehdarirad, T. and Nasini, S. 2016. Research impact in co-authorship structures: a two-mode analysis. Available at: https://www.researchgate.net/publication/306353453_Research_impact_in_co-authorship_structures_a_two-mode_analysis.

Freeman, L. C. 1979. Centrality in social networks: Conceptual clarification. *Social Networks,* Vol. 1, no. 3: 215-239.

Gazni, A., Sugimoto, C.R. and Didegah, F. 2012. Mapping world scientific collaboration: Authors, institutions, and countries. *Journal of the American Society for Information Science and Technology,* Vol. 63, no. 2: 323-335.

Homolová, A. 2014. *Social network analysis as a method in the data journalistic toolkit*, Master Thesis. Tilburg University.

Inkpen, A.C, and Tsang, E.W.K 2005. Social capital, networks, and knowledge transfer. *Academy of Management Review,* Vol. 30, no. 1: 146-165.

Jain, A. and Reddy, B.V.R. 2015. Eigenvector centrality based cluster size control in randomly deployed wireless sensor networks. *Expert Systems with Applications,* Vol. 42, no. 5: 2657-2669.

Katz, J.S. and Hicks, D. 1997. How much is a collaboration worth? A calibrated bibliometric model. *Scientometrics,* Vol. 40, no. 3: 541-554.

Kling, R. and McKim, G. 2000. Not just a matter of time: Field differences and the shaping of electronic media in supporting scientific communication. *Journal of the American Society for Information Science,* Vol. 51, no. 14: 1306-1320.

Koseoglu, M.A. 2016. Growth and structure of authorship and co-authorship network in the strategic management realm: Evidence from the Strategic Management Journal. *BRQ Business Research Quarterly,* Vol. 19, no. 3: 153-170.

Kretschmer, H. 2004. Author productivity and geodesic distance in bibliographic co-authorship networks, and visibility on the Web. *Scientometrics,* Vol. 60, no. 3: 409-420.

Kumar, S. 2015. Co-authorship networks: a review of the literature. *Aslib Journal of Information Management,* Vol. 67, no. 1: 55-73.

Lee, S., and Bozeman, B. 2005. The impact of research collaboration on scientific productivity. *Social Studies of Sciences,* Vol. 35, no. 5: 673-702.

Li, E.Y, Liao, C.H. and Yen, H.R. 2013. Co-authorship networks and research impact: A social capital perspective. *Research Policy,* Vol. 42, no. 9: 1515-1530.

Liao, C.H. 2010. How to improve research quality? Examining the impacts of collaboration intensity and member diversity in collaboration networks. *Scientometrics,* Vol. 86, no. 3: 747-761.

Lin, N. 2008. A network theory of social capital. In D. Castiglione, J. W. v. Deth and G. Wolleb (eds). *Handbook on social capital.* New York: Oxford University Press.

Lu, H., and Feng, Y. 2009. A measure of authors centrality in co-authorship networksbased on the distribution of collaborative relationships. *Scientometrics,* Vol. 81, no. 2: 499-511.

Lulli, A., Ricci, L., Carlini, E. and Dazzi, P. 2015. *Distributed current flow betweenness centrality*. Paper presented at 2015 *IEEE 9th International Conference on Self-Adaptive and Self-Organizing Systems.* Cambridge, MA, USA, September 20-25, 2015.

Marin, A., and Wellman, B. 2011. *Social network analysis: An introduction*. In *The Sage handbook of social network analysis*, edited by J. Scott and P. J. Carrington. Thousand Oaks, CA: SAGE Publications Inc.

Nederhof, A. J. 2006. Bibliometric monitoring of research performance in the socialsciences and the humanities: a review. *Scientometrics,* Vol. 66, no. 1: 81-100.

Newman, M.E.J. 2004. Coauthorship networks and patterns of scientific collaboration. *PNAS,* Vol. 101, Suppl. 1: 5200–5205.

Newman, M.E.J. 2004. *Who is the best connected scientist? A study of scientific coauthorship networks*. In *Complex networks*: Springer.

Otte, E., and Rousseau, R. 2002. Social network analysis: a powerful strategy, also for the information sciences. *Journal of Information Science,* Vol. 28, no. 6: 441-453.

Persson, O. 2017. Bibexcel. A tool-box programme for bibliometric analysis.

Ponomariov, B. and Boardman, C. 2016. What is co-authorship?. *Scientometrics,* Vol. 109, no. 3: 1939–1963.

Public Policy Group, LSE. 2011. *Maximizing the impacts of your research: a handbook for social scientists. Consultation draft 3* London, UK: LSE Public Policy Group, London School of Economics and Political Science.

Ronda-Pupo, G. A. 2015. Does the Centrality Degree of Latin American Countries Predict their Citation Based Performance on Management Research? *International Journal of Information Science and Management (IJISM),* Vol. 13, no. 2: 957-983.

Rouxel, P.L., Anja Heilmann, A., Aida, J. and Watt, R.G. 2015. Social capital: theory, evidence, and implications for oral health. *Community dentistry and Oral Epidemiology,* Vol. 43, no. 2: 97-105.

Scott, J. 2012. *Social network analysis*. London: Sage.

Soheili, F. and Mansoori, A. 2014. The Analysis of the Iranian Chemistry co-Authorship Network using Centrality Measure. *Journal of Library and Information Science Studies*, Vol. 6, no. 13: 89-106.

Sooryamoorthy, R. 2009. Do types of collaboration change citation? Collaboration and citation patterns of South African science publications. *Scientometrics*, Vol. 81, no. 1: 177-193.

Stephenson, K. and Zelen, M. 1989. Rethinking centrality: Methods and examples. *Social Networks*, Vol. 11, no. 1: 1-37.

Troshani, I. and Doolin, B. 2007. Innovation diffusion: a stakeholder and social network view. *European Journal of Innovation Management,* Vol. 10, no. 2: 176-200.

Tsai, W. 2001. Knowledge transfer in intraorganizational networks: Effects of network position and absorptive capacity on business unit innovation and performance. *Academy of Management Journal*, Vol. 44, no. 5: 996-1004.

van Raan, A. F. J. 2006. Comparison of the Hirsch-index with standard bibliometricindicators and with peer judgment for 147 chemistry research groups. *Scientometrics*, Vol. 67, no. 3: 491-502.

Wang, J. and Shapira, P. 2015. Is there a relationship between research sponsorship and publication impact? An analysis of funding acknowledgments in nanotechnology papers. *PloS one*, Vol. 10, no. 2: e0117727.

Wang, T., Wang, X., Tang, S., Lin, Y., Liu, W., Liu, Z., Xiu, B., Shen, D., Zhao, X. and Gao, Y. 2014. Collaborations patterns and productivity analysis for IEEE T-ITS between 2010 and 2013. *Intelligent Transportation Systems, IEEE Transactions on*, Vol. 15, no. 6: 2360-2367.

Watts, D.J. 2003. *Small worlds: The dynamics of networks between order and randomness.* Princeton, NJ: Princeton University Press.

Watts, D.J. and Strogatz, S.H.. 1998. Collective dynamics of ‘small-world’networks. *Nature*, Vol. 393, no. 6684: 440-442.

Yan, E. and Ding, Y. 2009. Applying centrality measures to impact analysis: A coauthorship network analysis. *Journal of the American Society for Information Science and Technology*, Vol. 60, no. 10: 2107-2118.

Ye, Q., Li, T. and Law, R. 2013. A coauthorship network analysis of tourism and hospitality research collaboration. *Journal of Hospitality & Tourism Research*, Vol. 37, no. 1: 51-76.

Zemljic, B. and Hlebec, V. 2005. Reliability of measures of centrality and prominence. *Social Networks*, Vol. 27, no. 1: 73–88.